BOARD MEETING AGENDA
SPECIAL MEETING OF THE BOARD OF DIRECTORS OF
CITRUS HEIGHTS WATER DISTRICT (CHWD)
SEPTEMBER 28, 2022 beginning at 6:00 PM

DISTRICT ADMINISTRATIVE OFFICE
6230 SYLVAN ROAD, CITRUS HEIGHTS, CA

PHONE CALL IN: (253) 215-8782
PHONE MEETING ID: 864 2984 1645
COMPUTER AUDIO/LIVE MEETING PRESENTATIONS: https://us06web.zoom.us/j/86429841645

In compliance with the Americans with Disabilities Act, if you have a disability and need a disability-related modification or accommodation to participate in this meeting, please contact the General Manager at (916) 725-6873. Requests must be made as early as possible, and at least one full business day before the start of the meeting.

CALL TO ORDER:

Upon request, agenda items may be moved to accommodate those in attendance wishing to address that item. Please inform the General Manager.

ROLL CALL OF DIRECTORS:

PUBLIC COMMENT:

CLOSED SESSION:

CL-1. CONFERENCE WITH REAL PROPERTY NEGOTIATORS

a. Pursuant to Section 54956.8:
Property: Parcel Number 257-0040-024-0000
Agency Negotiators: Brian Hensley, Rebecca Scott, Josh Nelson, Melissa Pieri, Hilary Straus, Steve Anderson, Brittney Moore, Lea Park-Kim, Alberto Preciado
Negotiating Parties: San Juan Unified School District
Under Negotiation: Price and Terms of Payment

FUTURE CHWD BOARD OF DIRECTORS MEETING DATES:

September 28, 2022	6:30 PM	Regular Meeting
October 19, 2022	6:30 PM	Regular Meeting
November 16, 2022	6:30 PM	Regular Meeting
December 21, 2022	6:30 PM	Regular Meeting

ADJOURNMENT:

CERTIFICATION:

I do hereby declare and certify that this agenda for this Special Meeting of the Board of Directors of the Citrus Heights Water District was posted in a location accessible to the public at the District Administrative Office Building, 6230 Sylvan Road, Citrus Heights, CA 95610 at least 24 hours prior to the special meeting in accordance with Government Code Section 54956.

Brittney Moore

Brittney Moore, Chief Board Clerk

Dated: September 22, 2022

BOARD MEETING AGENDA
REGULAR MEETING OF THE BOARD OF DIRECTORS OF
CITRUS HEIGHTS WATER DISTRICT (CHWD)
SEPTEMBER 28, 2022 beginning at 6:30 PM

CITRUS HEIGHTS WATER DISTRICT

DISTRICT ADMINISTRATIVE OFFICE
6230 SYLVAN ROAD, CITRUS HEIGHTS, CA

PHONE CALL IN: (253) 215-8782
PHONE MEETING ID: 864 2984 1645
COMPUTER AUDIO/LIVE MEETING PRESENTATIONS: https://us06web.zoom.us/j/86429841645

In compliance with the Americans with Disabilities Act, if you have a disability and need a disability-related modification or accommodation to participate in this meeting, please contact the General Manager at (916) 725-6873. Requests must be made as early as possible, and at least one full business day before the start of the meeting.

Members of the public may attend the meeting in person at the District headquarters or remotely through the phone number and link above.

CALL TO ORDER:

Upon request, agenda items may be moved to accommodate those in attendance wishing to address that item. Please inform the General Manager.

ROLL CALL OF DIRECTORS:

PLEDGE OF ALLEGIANCE:

VISITORS:

PUBLIC COMMENT:

The Public shall have the opportunity to directly address the Board on any item of interest to the public before or during the Board's consideration of that item pursuant to Government Code Section 54954.3. Public comment on items of interest within the jurisdiction of the Board is welcome. The Presiding Officer will limit comments to three (3) minutes per speaker.

(A) Action Item (D) Discussion Item (I) Information Item

CONSENT CALENDAR: (I/A)

All items under the Consent Calendar are considered to be routine and will be approved by one motion. There will be no separate discussion of these items unless a member of the Board, Audience, or Staff request a specific item be removed for separate discussion/action before the motion to approve the Consent Calendar.

CC-1a. Minutes of the Regular Meeting – August 17, 2022 (A)
CC-1b. Minutes of the Special Meeting – September 6, 2022 (A)
CC-1c. Minutes of the Special Meeting – September 19, 2022 (A)

Recommendation:

Approve the minutes of the August 17, 2022 Regular Meeting, minutes of the September 6, 2022 Special Meeting, and the minutes of the September 19, 2022 Special Meeting.

CC-2. Revenue Analysis Report for August 2022 (I)
CC-3. Assessor/Collector's Roll Adjustment for August 2022 (I)
CC-4. Treasurer's Report for August 2022 (I)
CC-5. Treasurer's Report of Fund Balances for August 2022 (I)
CC-6. Operating Budget Analysis for August 2022 (I)
CC-7. Capital Projects Summary for August 2022 (I)
CC-8. Warrants for August (I)
CC-9. Purchase Card Distributions for August (I)
CC-10. Employee Recognitions (I)
CC-11. Long-Range Agenda (I)
CC-12. Engineering Department Report (I)
CC-13. Operations Department Report (I)
CC-14. 2022 Water Supply (I)
CC-15. Water Supply Reliability (I)
CC-16. Water Efficiency and Safety Program Update (I)
CC-17. Discussion and Possible Action to Extend Resolution 07-2021 Authorizing Remote Public Meetings (A)

Recommendation:

Extend Resolution 07-2021 to permit future hybrid remote public meetings by the Board of Directors.

CC-18. Discussion and Possible Action to Approve Agreement with TAK Communications Ca, Inc. for the 6700 Madison Avenue at Dewey Drive Water Main Project (A)

Recommendation:

Accept the bid of TAK Communications Ca, Inc. in the amount of $57,930.00 and establish a contingency fund in the amount of $5,793.00 (10%), for a total amount of $63,723.00. Authorize the General Manager to execute an agreement with TAK Communications Ca, Inc.

PRESENTATIONS:

None.

PUBLIC HEARINGS:

None.

STUDY SESSION:

None.

BUSINESS:

B-1. Advanced Water Meter Replacement Planning Study Update (A)

Recommendations:

1. Receive and file the Study's Technical Memos.
2. Provide direction to Staff to return to the Board in Q2 of 2023 with an update on CHWD's meter program and the Regional Program.

MANAGEMENT SERVICES REPORTS (I):

None.

CONSULTANTS' AND LEGAL COUNSEL'S REPORTS (I):

None.

DIRECTOR'S AND REPRESENTATIVE'S REPORTS (I):

D-1. Regional Water Authority (Sheehan/Straus).
D-2. Sacramento Groundwater Authority (Sheehan).
D-3. San Juan Water District (All).
D-4. Association of California Water Agencies (Wheaton).
D-5. ACWA Joint Powers Insurance Authority (Wheaton/Moore).
D-6. City of Citrus Heights (Pieri).
D-7. Chamber of Commerce Update (Park-Kim).
D-8. RWA Legislative and Regulatory Affairs Update (Park-Kim).
D-9. Customer Advisory Committee (Riehle/Park-Kim).
D-10. Other Reports.

CLOSED SESSION:

None.

FUTURE CHWD BOARD OF DIRECTORS MEETING DATES:

October 19, 2022	6:30 PM	Regular Meeting
November 16, 2022	6:30 PM	Regular Meeting
December 21, 2022	6:30 PM	Regular Meeting

ADJOURNMENT:

CERTIFICATION:

I do hereby declare and certify that this agenda for this Regular Meeting of the Board of Directors of the Citrus Heights Water District was posted in a location accessible to the public at the District Administrative Office Building, 6230 Sylvan Road, Citrus Heights, CA 95610 at least 72 hours prior to the Regular meeting in accordance with Government Code Section 54954.2.

Brittney Moore

Brittney Moore, Chief Board Clerk

Dated: September 22, 2022

CITRUS HEIGHTS WATER DISTRICT
BOARD OF DIRECTORS REGULAR MEETING MINUTES
August 17, 2022

The Regular Meeting of the Board of Directors was called to order at 6:30 p.m. by President Sheehan and role was called. Present were:

Caryl F. Sheehan, President
Raymond A. Riehle, Vice President
David C. Wheaton, Director

Staff:

Bryan Abaya, Principal Information Technology Analyst
Timothy Cutler, Water Distribution Supervisor
Brian Hensley, Water Resources Supervisor
Brittney Moore, Administrative Services Manager/ Chief Board Clerk
Lea Park-Kim, Communications & Public Engagement Manager
Alberto Preciado, Interim Director of Finance and Administrative Services
Missy Pieri, Director of Engineering
Rebecca Scott, Director of Operations
Hilary Straus, General Manager

Shellie Anderson, Bryce Consulting

PLEDGE OF ALLEGIANCE:

President Sheehan led the Pledge of Allegiance.

PUBLIC COMMENT:

None.

CONSENT CALENDAR:

Vice President Riehle requested CC-18 be pulled from Consent Calendar.
After discussion, Vice President Riehle added CC-18 back to the Consent Calendar

President Sheehan asked for consideration and/or approval of the Consent Calendar.

CC-1a. Minutes of the Special Meeting – June 15, 2022 (A)
CC-1b. Minutes of the Regular Meeting – June 15, 2022 (A)
CC-1c. Minutes of the Special Meeting – June 28, 2022 (A)
CC-1d. Minutes of the Special Meeting – August 8, 2022 (A)

Recommendation:

Approve the minutes of the June 15, 2022 Special and Regular Meetings, minutes of the June 28, 2022 Special Meeting, and the minutes of the August 8, 2022

Special Meeting.

CC-2. Revenue Analysis Report for June and July 2022 (I)
CC-3. Assessor/Collector's Roll Adjustment for June and July 2022 (I)
CC-4. Treasurer's Report for June and July 2022 (I)
CC-5. Treasurer's Report of Fund Balances for June and July 2022 (I)
CC-6. Operating Budget Analysis for June and July 2022 (I)
CC-7. Capital Projects Summary for June and July 2022 (I)
CC-8. Warrants for June and July 2022 (I)
CC-9. Purchase Card Distributions for June and July 2022 (I)
CC-10. Employee Recognitions (I)
CC-11. Long-Range Agenda (I)
CC-12. Engineering Department Report (I)
CC-13. Operations Department Report for June and July 2022 (I)
CC-14. 2022 Water Supply (I)
CC-15a. Water Supply Reliability for July (I)
CC-15b. Water Supply Reliability for August (I)
CC-16. Water Efficiency and Safety Program Update (I)
CC-17. Discussion and Possible Action to Extend Resolution 07-2021 Authorizing Remote Public Meetings (A)

Recommendation:

Extend Resolution 07-2021 to permit future hybrid remote public meetings by the Board of Directors.

CC-18. Discussion and Possible Action to Approve Amendments to the Citrus Heights Water District Conflict of Interest Code Pursuant to the Political Reform Act of 1974 (A)

Recommendation:

1. Adopt Resolution 11-2022 and Updated Policy 1035 Appendix A and Appendix B to amend the Conflict of Interest Code pursuant to the Political Reform Act of 1974
2. Authorize the General Manager to Execute the CEO Declaration

CC-19. 2022 Compensation (A)

Recommendation:

Receive and file the 2022 Total Compensation Study

CC-20. Discussion and Possible Action to Adopt Information Technology Policy 10101.00 (A)

Recommendation:

Adopt the Information Technology policy (Exhibit A) accompanying the Board report.

CC-21. 2022 Strategic Plan Update and 2023 Strategic Plan Approval (A)

Recommendation:

1. Receive and file an update of the 2022 Strategic Plan.
2. Approve the 2023 Strategic Plan, and direct that Strategic Planning Objectives be included in the 2023 proposed budget, which will be considered by the Board of Directors for adoption later in 2022 for the 2023 budget year.

ACTION:
Director Wheaton moved and Vice President Riehle seconded a motion to approve the consent calendar.

The motion carried 3-0 with all Directors voting yes.

PRESENTATIONS:

P-1. Capital Improvement Program (CIP) Update (I/D)

PUBLIC HEARINGS:

None.

STUDY SESSION:

None.

BUSINESS:

B-1. Agreement with Stonehouse Drilling and Construction, LLC. For Test Hole Drilling (A)

ACTION:
Director Wheaton moved and Vice President Riehle seconded a motion to 1. Approve the agreement with Stonehouse Drilling & Construction, LLC in the Base amount of $221,900 and establish a change order contingency fund in the amount of $22,190 (10%).
2. Authorize total expenditure of not-to-exceed $244,090.
3. Authorize the General Manager to execute the agreement and issue a Notice to Proceed.

The motion carried 3-0 with all Directors voting yes.

MANAGEMENT SERVICES REPORTS (I):

None.

CONSULTANTS' AND LEGAL COUNSEL'S REPORTS (I):

None.

DIRECTOR'S AND REPRESENTATIVE'S REPORTS (I):

D-1. Regional Water Authority (Sheehan/Straus).
D-2. Sacramento Groundwater Authority (Sheehan).
D-3. San Juan Water District (All).
D-4. Association of California Water Agencies (Wheaton).
D-5. ACWA Joint Powers Insurance Authority (Wheaton/Moore).
D-6. City of Citrus Heights (Pieri).
D-7. Chamber of Commerce Update (Park-Kim).

D-8. RWA Legislative and Regulatory Affairs Update (Park-Kim).
D-9. Customer Advisory Committee (Riehle/Park-Kim).
D-10. Other Reports.

CLOSED SESSION:

None.

ADJOURNMENT:

There being no other business to come before the Board, the meeting was adjourned at 7:39 p.m.

APPROVED:

____________________________	____________________________
BRITTNEY C. MOORE	CARYL F. SHEEHAN, President
Chief Board Clerk	Board of Directors
Citrus Heights Water District	Citrus Heights Water District

CITRUS HEIGHTS WATER DISTRICT
BOARD OF DIRECTORS SPECIAL MEETING MINUTES
September 6, 2022

The Special Meeting of the Board of Directors was called to order at 6:00 p.m. by President Sheehan and role was called. Present were:

Caryl F. Sheehan, President
Raymond A. Riehle, Vice President
David C. Wheaton, Director

Staff:

Hilary Straus, General Manager
Alberto Preciado, Interim Director of Finance and Administrative Services
Rebecca Scott, Director of Operations
Missy Pieri, Director of Engineering
Lea Park-Kim, Communications and Public Engagement Manager
Josh Nelson, Assistant General Counsel

Also present:

Habib Isaac, IB Consulting
Glenn Lazof, Regional Government Services
Karen Blakley, Regional Government Services

PLEDGE OF ALLEGIANCE:

President Sheehan led the Pledge of Allegiance.

PUBLIC COMMENT:

None.

PRESENTATIONS:

P-1. Financial Planning & 2023 Budget Workshop (I/D)

The Board provided direction to staff to present for further consideration at a Special Board meeting scheduled for Monday, September 19, 2022 at 6 PM: 1) revenue option number 5 with $150,000 transferred to the Water Meter Replacement designated reserve and $150,000 transferred to the Water Supply designated reserve; 2) revenue option number 6 with $200,000 transferred to the Water Meter Replacement designated reserve and Water Supply designated reserve; and revenue option eight (a) with $200,000 transferred to the Water Meter Replacement designated reserve and Water Supply designated reserve. Debt financing for one or more well projects versus the corporation yard project should be analyzed, and the rate model should be adjusted to reflect a corporation yard improvement project cost estimate of $7 million.

DIRECTOR’S AND REPRESENTATIVE'S REPORTS (I):

None.

ADJOURNMENT:

There being no other business to come before the Board, the meeting was adjourned at 8:52 PM to a special Board Meeting scheduled for September 19, 2022 at 6:00 PM.

APPROVED:

HILARY M. STRAUS	CARYL F. SHEEHAN, President
Secretary	Board of Directors
Citrus Heights Water District	Citrus Heights Water District

CITRUS HEIGHTS WATER DISTRICT
BOARD OF DIRECTORS SPECIAL MEETING MINUTES
September 19, 2022

The Special Meeting of the Board of Directors was called to order at 6:04 p.m. by President Sheehan and role was called. Present were:

Caryl F. Sheehan, President
Raymond A. Riehle, Vice President
David C. Wheaton, Director

Staff:

Bryan Abaya, Principal Information Technology Analyst
Steve Anderson, General Counsel
Brittney Moore, Administrative Services Manager/Chief Board Clerk
Lea Park-Kim, Communications and Public Engagement Manager
Missy Pieri, Director of Engineering
Alberto Preciado, Interim Director of Finance and Administrative Services
Rebecca Scott, Director of Operations
Hilary Straus, General Manager

Also present:

Habib Isaac, IB Consulting
Glenn Lazof, Regional Government Services

PLEDGE OF ALLEGIANCE:

President Sheehan led the Pledge of Allegiance.

PUBLIC COMMENT:

None.

PRESENTATIONS:

P-1. Financial Planning & 2023 Budget Workshop (I/D)

The Board provided consensus direction to staff to prepare and present a budget to include revenue option eight (b) with $200,000 transferred to the Water Meter Replacement designated reserve and Water Supply designated reserve, for consideration at a future Board meeting. The direction included preparing a statutorily compliant notice to send to all customers concerning the maximum rate adjustment that the Board will consider a properly noticed public hearing at least forty-five (45) days after the release of the statutorily compliant notice to customers. Further, the Board anticipated that revenue and expenditure plan for 2023 will not be impacted by the planned wholesale agency rate increase as the wholesale rate increase will be passed-through or included in customers' bills for 2023.

DIRECTOR’S AND REPRESENTATIVE'S REPORTS (I):

None.

ADJOURNMENT:

There being no other business to come before the Board, the meeting was adjourned at 7:43 p.m.

APPROVED:

BRITTNEY C. MOORE Chief Board Clerk Citrus Heights Water District	CARYL F. SHEEHAN, President Board of Directors Citrus Heights Water District

CITRUS HEIGHTS WATER DISTRICT
August 2022
REVENUE ANALYSIS

Outstanding Receivables

Aged Trial Balance					
Total	Current	31-90	91-150	>150	Unapplied Current
1,774,892	1,684,732	91,787	42,059	74,300	117,987

General Ledger Balance	Total
Outstanding A/R	1,850,109.68
Outstanding Liens	-
Outstanding Grants	946
A/R Other	(25,348)
Less Unapplied Payments	(119,118)
Total	$ 1,706,590

CITRUS HEIGHTS WATER DISTRICT
ASSESSOR/COLLECTOR'S ROLL ADJUSTMENTS FOR
August 31, 2022

There were no adjustments made for August 2022.

Reason For Cancellation	Charge Type	Amount
		$ -

TREASURER'S REPORT TO THE BOARD OF DIRECTORS
August 2022

Bank of the West			
Beginning Balance			$7,587,552
RECEIPTS:		1,639,846	
DISBURSEMENTS:			
Checks Issued / ACH Payments	1,807,212		
Payroll	505,465		
Returned Checks	2,806		
		2,315,483	(675,637)
Bank of the West			
Balance per Bank 08/31/2022			6,911,915
Outstanding Checks			(182,493)
Deposit in Transit			83,499
Balance Per Books 08/31/2022			$6,812,920

RECONCILEMENT:	
Bank of the West	$6,812,920
Local Agency Investment Fund	14,569,602
Money Mkt Activity Account	545,711
TOTAL BALANCE	$21,928,233

CASH & INVESTMENT SUMMARY:	
Bank of the West (General Account)	6,812,920
Local Agency Investment Fund	14,569,602
Money Mkt Activity Account	545,711
Total	$21,928,233

INSTITUTION	MATURITY DATE	INT RATE	DEPOSIT AMOUNT	DATE OF LAST TRANSACTION
Local Agency Investment Fund	**Daily**	**0.75%**	**27,226.37**	**7/15/2022**

I certify that this report accurately reflects all pooled investments and is in compliance with applicable State of California Government Codes and is in conformity with Investment of District Funds Policy 6300. As Treasurer of the Citrus Heights Water District, I hereby certify that sufficient investment liquidity and anticipated revenue are available to meet the next six months' estimated expenditures.

A Preciado

ALBERTO PRECIADO
Deputy Treasurer

HMStr

HILARY M. STRAUS
Secretary

Signed: 9/21/2022

TREASURER'S REPORT OF FUND BALANCES
August 31, 2022

Fund Name	Beginning Balance 01/01/2022	Year to Date Transfers In / Collections	Year to Date Transfers Out	Current Month Transfers In / Collections	Current Month Transfers Out	Ending Balance 08/31/2022	2022 Target Balance per Policy
Operating Fund	$ 6,844,823	$ 8,557,985	$ (7,889,847)	$ 1,644,266	$ (2,319,903)	$ 6,837,324	$ 2,334,017
Operating Reserve	$ 3,592,065	$ -	$ -	$ -	$ -	$ 3,592,065	N/A
Rate Stabilization Fund	$ 1,000,000	$ -	$ -	$ -	$ -	$ 1,000,000	$ 1,000,000
Capital Improvement Reserve	$ 2,796,860	$ -	$ -	$ -	$ -	$ 2,796,860	$ 2,681,248
Restricted for Debt Service	$ 536,963	$ -	$ -	$ -	$ -	$ 536,963	N/A
Water Supply Reserve	$ 2,623,173	$ -	$ -	$ -	$ -	$ 2,623,173	N/A
Water Efficiency Reserve	$ 200,000	$ -	$ -	$ -	$ -	$ 200,000	$ 200,000
Water Meter Replacement Reserve	$ 1,725,000	$ -	$ -	$ -	$ -	$ 1,725,000	N/A
Fleet Equipment Reserve	$ 334,253	$ -	$ -	$ -	$ -	$ 334,253	$ 318,559
Employment-Related Benefits Reserve	$ 986,962	$ -	$ -	$ -	$ -	$ 986,962	$ 986,962
	$ 20,640,099	**8,557,985**	**$ (7,889,847)**	**$ 1,644,266**	**$ (2,319,903)**	**$ 20,632,600**	**$ 7,520,786**

A Preciado

ALBERTO PRECIADO, Deputy Treasurer

TREASURER'S REPORT OF FUND BALANCES
August 31, 2022

Fund Transfers Summary:

The Operating Fund Transferred:	$	1,644,266	from funds collected in August 2022 per Treasurer's Report
	$	(2,319,903)	disbursements made in August 2022 per Treasurer's Report
	$	(675,637)	

Citrus Heights Water District
Budget Performance Report
As of 8/31/2022

	August Actual	Year-to-Date Actual	Year-to-Date Budget	YTD Variance Amount	YTD Variance Percent	Annual Budget
Revenues						
Metered Service Charges	$1,223,386.53	$7,804,690.16	$7,383,062.00	$421,628.16	5.71%	$11,074,591.00
Metered Water Deliveries	973,578.89	3,462,489.19	3,393,114.00	69,375.19	2.04%	5,799,716.00
Water Main Replacement Revenue	145,510.91	763,672.79	916,066.00	($152,393.21)	-16.64%	1,374,099.00
Non-Metered Service Charges		8,850.94	93,336.00	(84,485.06)	-90.52%	140,000.00
Penalties	594.00	3,227.24	87,757.00	(84,529.76)	-96.32%	150,000.00
Interest	2,779.57	64,241.27	30,664.00	33,577.27	109.50%	45,991.00
Backflow Fees	8,611.39	46,738.42	77,336.00	(30,597.58)	-39.56%	116,000.00
Water Service Install & S&R	1,347.62	75,863.57	382,600.00	(306,736.43)	-80.17%	573,900.00
Grant Funds	(27,308.74)	106,027.81		106,027.81	0.00%	
Miscellaneous *	3,713.68	26,659.94	98,000.00	(71,340.06)	-72.80%	147,000.00
Cost Reimbursements	5,654.66	80,407.72		80,407.72	0.00%	
Income - Wheeling Water		64,559.09	1,800.00	62,759.09	3486.62%	2,700.00
Income - Connection Fees		42,224.48		42,224.48	0.00%	
Total Revenue	2,337,868.51	12,549,652.62	12,463,735.00	85,917.62	0.69%	19,423,997.00
*includes Assessments, New Account, Back Charges & other Miscellaneous Revenue Sources						
Operating Expenses						
Cost of Water						
Purchased Water		1,926,504.87	2,090,502.64	(163,997.77)	-7.84%	3,135,753.96
Ground Water	113,166.86	609,445.79	795,359.04	(185,913.25)	-23.37%	1,193,038.56
	113,166.86	2,535,950.66	2,885,861.68	(349,911.02)	-12.13%	4,328,792.52
Labor & Benefits						
Labor Regular	376,634.32	2,303,765.93	2,490,283.12	(186,517.19)	-7.49%	3,735,424.68
Labor Non-Regular						
Labor Taxes	27,957.38	178,416.53	189,612.00	(11,195.47)	-5.90%	284,418.00
Labor Workers Comp		34,370.01	66,733.36	(32,363.35)	-48.50%	100,100.04
Labor External	5,370.00	27,832.15	72,720.08	(44,887.93)	-61.73%	109,080.12
Benefits Med/Den/Vis	40,993.90	372,433.55	342,934.48	29,499.07	8.60%	514,401.72
Benefits LTD/Life/EAP	9,507.71	49,730.38	97,828.32	(48,097.94)	-49.17%	146,742.48
Benefits CalPers	23,659.68	176,661.16	231,587.44	(54,926.28)	-23.72%	347,381.16
Benefits Other	12,368.84	87,340.71	91,771.12	(4,430.41)	-4.83%	137,656.68
Benefit Retiree Expenses	8,479.32	38,156.94	39,410.72	(1,253.78)	-3.18%	59,116.08
Benefit Unemployment			6,155.04	(6,155.04)	-100.00%	9,232.56
Benefit GASB 68		442,771.00	299,449.68	143,321.32	47.86%	449,174.52
Capitalized Labor & Benefit Contra	(48,549.02)	(414,840.78)	(333,333.28)	(81,507.50)	24.45%	(499,999.92)
	456,422.13	3,296,637.58	3,595,152.08	(298,514.50)	-8.30%	5,392,728.12
General & Administrative						
Fees & Charges	14,285.15	105,554.01	160,923.28	(55,369.27)	-34.41%	241,384.92
Regulatory Compliance/Permits	4,615.00	57,406.53	87,660.00	(30,253.47)	-34.51%	131,490.00
District Events & Recognition	1,395.16	19,513.89	40,366.64	(20,852.75)	-51.66%	60,549.96
Maintenance/Licensing	2,369.76	131,588.56	113,818.00	17,770.56	15.61%	170,727.00

Citrus Heights Water District
Budget Performance Report
As of 8/31/2022

	August Actual	Year-to-Date Actual	Year-to-Date Budget	YTD Variance Amount	YTD Variance Percent	Annual Budget
Equipment Maintenance	6,909.83	46,414.58	85,066.64	(38,652.06)	-45.44%	127,599.96
Professional Development	9,391.71	68,417.11	113,219.36	(44,802.25)	-39.57%	169,829.04
Department Admin		153.97	13,133.44	(12,979.47)	-98.83%	19,700.16
Dues & Subscriptions	4,241.86	191,421.62	129,112.08	62,309.54	48.26%	193,668.12
Fuel & Oil	10,353.04	60,652.53	44,160.00	16,492.53	37.35%	66,240.00
General Supplies	5,702.29	45,836.22	67,066.72	(21,230.50)	-31.66%	100,600.08
Insurance - Auto/Prop/Liab	2,720.15	70,211.75	74,800.00	(4,588.25)	-6.13%	112,200.00
Leasing/Equipment Rental	2,155.88	15,241.25	23,266.72	(8,025.47)	-34.49%	34,900.08
Other Agency Cost Reimbursement		651.86		651.86	0.00%	
Parts & Materials	62,432.14	310,047.34	36,666.64	273,380.70	745.58%	54,999.96
Postage/Shipping/Freight	5,186.54	52,841.56	92,333.36	(39,491.80)	-42.77%	138,500.04
Rebates & Incentives	1,321.78	21,589.84	24,666.64	(3,076.80)	-12.47%	36,999.96
Telecom/Network	5,585.12	31,627.45	34,520.00	(2,892.55)	-8.38%	51,780.00
Tools & Equipment	4,140.68	33,611.18	53,466.72	(19,855.54)	-37.14%	80,200.08
Utilities	3,292.74	24,446.60		24,446.60	0.00%	
Write-Off Bad Debt Exp		65.64	3,333.36	(3,267.72)	-98.03%	5,000.04
Capitalized G&A Contra	(141,815.31)	(396,817.98)		(396,817.98)	0.00%	
Capitalized Equipment Contra	(50,473.26)	(354,022.38)		(354,022.38)	0.00%	
	(46,189.74)	536,453.13	1,197,579.60	(661,126.47)	-55.21%	1,796,369.40
Professional & Contract Services						
Support Services	70,087.11	600,103.17	993,019.92	(392,916.75)	-39.57%	1,489,529.88
Legal Services	17,742.30	173,170.76	190,000.00	(16,829.24)	-8.86%	285,000.00
Printing Services	738.34	16,799.93	32,666.72	(15,866.79)	-48.57%	49,000.08
	88,567.75	790,073.86	1,215,686.64	(425,612.78)	-35.01%	1,823,529.96
Reserves & Debt Services						
Interest Expense		40,863.54	46,502.81	(5,639.27)	-12.13%	69,754.21
Net Increase(Descrease) in Value of Investments		(37,190.54)		(37,190.54)	0.00%	
		3,673.00	46,502.81	(42,829.81)	-92.10%	69,754.21
Total Operating Expenses	611,967.00	7,162,788.23	8,940,782.81	(1,777,994.58)	-19.89%	13,411,174.21
Net Income / (Expense)	1,725,901.51	5,386,864.39	3,522,952.19	1,863,912.20	52.91%	6,012,822.79

Citrus Heights Water District
Capital Projects Summary
Fiscal Period End as of 08/2022

Project Number	Project Name	BUDGET: Project Forecast Budget	BUDGET: Expenditures to 12/2021	AMOUNTS PAID: Month to Date	AMOUNTS PAID: Year to Date	AMOUNTS PAID: Project to Date	Remaining Budget
C16-134	Auburn Blvd-Rusch Park Placer	$167,000	$3,906	$510	$4,233	$8,139	$161,329
C19-108	6230 Sylvan East Wall	$7,653	$16,748	$0	$0	$16,748	$0
C20-108	Corp Yard PreArchitecture Stdy	$100,000	$1,676	$0	$0	$1,676	$98,324
C20-109	Corp Yard Plans Specs Estimate	$400,000	$0	$0	$0	$0	$400,000
Construction in Progress		**$674,653**	**$22,330**	**$510**	**$4,233**	**$26,563**	**$659,653**
C22-010	Water Main Replacements	$50,000	$0	$543	$18,577	$18,577	$31,423
C22-011	Water Valve Replacements	$75,000	$0	$4,826	$71,255	$71,255	$3,745
C22-012	Water Service Connections	$825,000	$0	$148,249	$788,997	$788,997	$36,003
C22-013	Water Meter Replacements	$100,000	$0	$741	$19,334	$19,334	$80,666
C22-014	Fire Hydrants	$125,000	$0	$9,470	$110,122	$110,122	($110,122)
Annual Infrastructure		**$1,175,000**	**$0**	**$163,829**	**$1,008,284**	**$1,008,284**	**$41,716**
C15-104B	Document Management System	$244,639	$95,361	$4,690	$4,890	$100,251	$234,388
C22-003	Fleet/Field Operations Equip	$260,000	$0	$0	$89,957	$89,957	$170,043
C22-004	Technology Hardware/Software	$56,650	$0	$1,685	$1,685	$1,685	$54,965
Fleet and Equipment		**$561,289**	**$95,361**	**$6,375**	**$96,532**	**$191,893**	**$459,396**
C15-109	Blossom Hill Way 6" & 10" Inte	$27,777	$0	$0	$0	$0	$27,777
C15-110	Crestmont Ave 6" Intertie	$24,979	$91	$0	$0	$91	$24,888
C20-105	Walnut Drive	$105,247	$15,283	$0	$0	$15,283	$101,515
C20-106	Wisconsin Drive	$301,990	$42,391	$0	$71	$42,463	$259,527
C21-101	Antelope & Rusch Park	$187,741	$123,724	$17	$21,211	$144,935	$42,806
C21-102	Old Auburn Road	$91,459	$1,003	$0	$1,026	$2,029	$90,433
C21-103	Pratt Ave	$39,043	$46,820	$6,537	$393,312	$440,132	($354,269)
C21-104	Mesa Verde HS	$118,779	$49,767	$162,542	$535,460	$585,227	($416,681)
C21-105	Madison Ave & Dewey Dr	$28,138	$3,147	$1,863	$6,218	$9,365	$21,920
C22-101	Carriage Drive	$427,104	$0	$202,619	$427,621	$427,621	($517)
Water Mains		**$1,352,257**	**$282,227**	**$373,577**	**$1,384,919**	**$1,667,145**	**($202,600)**

Citrus Heights Water District
Capital Projects Summary
Fiscal Period End as of 08/2022

Project Number	Project Name	BUDGET Project Forecast Budget	BUDGET Expenditures to 12/2021	AMOUNTS PAID Month to Date	AMOUNTS PAID Year to Date	AMOUNTS PAID Project to Date	Remaining Budget
C21-040	Other City Partnerships	$52,551	$0	$0	$0	$0	$52,551
C21-040A	Greenback Ln Complete Strts	$0	$30	$0	$16,775	$16,805	($16,775)
C21-040B	Elec. Greenway Bike Trail	$0	$1,647	$0	$150	$1,797	($150)
C21-040C	MSR2S Phase4	$0	$11,007	$6,600	$6,957	$17,964	($6,957)
C21-040E	Bonita Storm Drain	$0	$29,254	$0	$958	$30,212	($958)
C21-041	Other Misc Infrastructure	$12,551	$0	$0	$0	$0	$12,551
C21-041A	Valve Box Raising	$0	$32,407	$0	$8,000	$40,407	($8,000)
C21-041B	Greenback Acquisition	$415,000	$2,159	$0	$297,377	$299,536	$115,464
C22-005	Facilities Improvements	$100,000	$0	$0	$9,763	$9,763	$90,237
C22-040	Other City Partnerships	$100,000	$0	$0	$0	$0	$100,000
C22-040D	SACOG 22 AC Overlay P1	$0	$0	$0	$174	$174	($174)
C22-041	Other Misc Infrastructure	$82,347	$0	$0	$0	$0	$82,347
C22-102	Well Site Acquisition	$0	$0	$4,764	$16,048	$16,048	($16,048)
Miscellaneous Projects		**$762,449**	**$76,504**	**$11,364**	**$356,202**	**$432,706**	**$404,088**
C17-104	Groundwater Well Property Acq	$640,000	$370,943	$0	$0	$370,943	$264,090
C17-104A	Well #7 Patton	$250,000	$181,377	$0	$67,726	$249,103	$897
C17-104B	Well #8 Highland	$0	$251,862	$0	$0	$251,862	($251,862)
C20-107	Well Design & Construction	$1,105,500	$0	$681	$258,926	$258,926	$846,574
C22-020	Groundwater Well Improvements	$150,000	$0	$0	$0	$0	$150,000
C22-102A	SJUSD Property	$0	$0	$5,500	$5,500	$5,500	($5,500)
C22-103	Well #8 Design Construct	$0	$0	$0	$0	$0	$0
Wells		**$2,145,500**	**$804,182**	**$6,181**	**$332,152**	**$1,136,334**	**$1,004,199**
	Grand Totals:	**$6,671,148**	**$1,280,604**	**$561,836**	**$3,182,322**	**$4,462,926**	**$2,366,452**

AUGUST 2022 WARRANTS

CHECK	PAYEE	DESCRIPTION	AMOUNT
74001	Gary L Goulart 2009 Trust	Customer Refund	$700.00
74002	Kirk D/Vonda K Simmons	Customer Refund	$66.89
74003	Stefanos D/Beth N Gordon	Customer Refund	$156.52
74004	Void	Void	$0.00
74005	SAMUEL M/CHRISTINA SEE	Customer Refund	$432.45
74006	Carl Dean	Customer Refund	$44.03
74007	Doon K Louie	Customer Refund	$421.60
74008	Coleene R Dehnert	Customer Refund	$50.09
74009	Gerald G/Dana Naylor	Customer Refund	$75.00
74010	Giri Family Trust	Customer Refund	$310.23
74011	Mei Yu Wang	Customer Refund	$15.27
74012	MCGUIRE AND HESTER	Customer Refund	$1,380.53
74013	Brian/Kimberly Matthews	Customer Refund	$143.19
74014	James Oblizalo Living Trust	Customer Refund	$240.00
74015	MARTIN GENERAL ENGINEERING INC	Customer Refund	$1,585.95
74016	Elisia/Douglas McClure	Customer Refund	$419.57
74017	SHAWNTELL M DUNHAM	Customer Refund	$240.51
74018	FAITH A MCGUIRE	Customer Refund	$251.90
74019	Jerolene G Lazaro	Customer Refund	$201.79
74020	Justin D Chiesa	Customer Refund	$16.08
74021	Stacy Gallman	Customer Refund	$9.27
74022	Kenneth S/Rhonda D Lamb	Customer Refund	$135.68
74023	Shawn A Edwinson	Customer Refund	$224.81
74024	Void	Void	$0.00
74025	AKS Equities Inc	Customer Refund	$170.05
74026	J-2 Transactions Inc	Customer Refund	$213.63
74027	Lewen Shen	Customer Refund	$266.65
74028	Zipporah Care Home LLC	Customer Refund	$1,439.31
74029	Christopher McDougal	Customer Refund	$35.74
74030	Linda/Toni M Baston	Customer Refund	$1,217.80
74031	JUBLI INVESTMENTS LLC	Customer Refund	$189.36
74032	Marisol Silva	Customer Refund	$75.89
74033	Richard J Hall	Customer Refund	$100.07
74034	Donald Brown	Customer Refund	$224.52
74035	Jeanine A Phelps	Customer Refund	$264.41
74036	Russell Beldi	Customer Refund	$246.59
74037	Rodriguez Living Trust	Customer Refund	$247.00
74038	Tom B Moles	Customer Refund	$223.35
74039	Victoria P Knebel	Customer Refund	$300.19
74040	JACQUELINE L WAHLEITHNER	Customer Refund	$178.86
74041	ZILLOW HOMES PROPERTY TRUST	Customer Refund	$345.09
74042	A&A STEPPING STONE MANUFACTURING	Supplies-Field	$20.38
74043	ABA DABA RENTALS & SALES	Supplies-Field	$217.65
74044	ACWA/JPIA	Workers Comp Insurance	$1,695.00
74045	AIA SERVICES, LLC/NDS	Tools/Equipment	$35.41

AUGUST 2022 WARRANTS

CHECK	PAYEE	DESCRIPTION	AMOUNT
74046	ALEXANDER'S CONTRACT SERVICES	Contract Services-Meter Reads	$5,763.39
74047	All Phase Construction, Inc	Contract Services-Engineering	$16,197.50
74048	APPLIED BEST PRACTICES	Contract Services-Financial	$1,200.00
74049	AREA RESTROOM SOLUTIONS	Equipment Rental-Field	$159.76
74050	Marco Armas	Toilet Rebate Program	$75.00
74051	AXIOM TECHNOLOGIES LLC	Contract Services-Other	$642.95
74052	B&M BUILDERS	Contract Services-Engineering	$550.55
74053	BART/RIEBES AUTO PARTS	Repair-Trucks	$232.54
74054	BATTERIES PLUS BULBS	Small Tools	$61.35
74055	BSK ASSOCIATES	Water Analysis	$1,816.00
74056	CALIFORNIA LANDSCAPE ASSOCIATES INC	Janitorial	$245.00
74057	CALIFORNIA SURVEYING & DRAFTING SUPPLY	Small Tools	$20.00
74058	CITY OF CITRUS HEIGHTS	Permit Fees	$15,105.30
74059	COLLEGE OAK TOWING	Repair-Trucks	$171.87
74060	COMCAST	Equipment Rental-Office	$93.45
74061	CONSOLIDATED	Telephone-Local/Long Distance	$2,929.83
74062	ROBIN COPE	Health Insurance	$365.96
74063	R&B COMPANY	Material	$711.15
74064	CORELOGIC INFORMATION SOLUTIONS INC	Dues & Subscriptions	$228.03
74065	COUNTY OF SACRAMENTO MUNICIPAL SERVICES	Field Miscellaneous	$232.15
74066	COUNTY OF SACRAMENTO - CLERK	Publication Notices	$50.00
74067	COUNTY OF SACRAMENTO- EMD	Permit Fees	$884.00
74068	SACRAMENTO COUNTY UTILITIES	Utilities	$392.88
74069	CYBEX	Equipment Rental-Office	$188.60
74070	KELLY R DRAKE	Professional Development	$135.00
74071	FAST ACTION PEST CONTROL	Contract Services-Miscellaneous	$168.00
74072	RARESTEP, INC	Maintenance Agreement-Software	$2,322.00
74073	FUTURE FORD	Repair-Trucks	$238.74
74074	Genuine Parts Company Inc	Repair-Equipment/Hardware	$313.25
74075	GRAINGER	Small Tools	$2,394.90
74076	FERGUSON ENTERPRISES INC #1423	Material	$889.31
74077	HARRIS INDUSTRIAL GASES	Supplies-Field	$55.98
74078	HUNT & SONS INC	Gas & Oil	$2,477.68
74079	IB CONSULTING LLC	Contract Services-Miscellaneous	$1,230.00
74080	INDUSTRIAL SERVICE AND SUPPLY INC	Supplies-Field	$10,598.04
74081	INTEGRITY ADMINISTRATORS INC	Health Insurance	$260.80
74082	Nancy Jackson	Toilet Rebate Program	$150.00
74083	Michael Ladisch/ Patricia Anne Gray	Toilet Rebate Program	$75.00
74084	LIEBERT CASSIDY WHITMORE	Legal & Audit	$39.00
74085	LOWE'S	Supplies-Field	$2,102.13
74086	Jeanne Marshall	Toilet Rebate Program	$50.00
74087	DANA MELLADO	Professional Development	$135.00
74088	MESSENGER PUBLISHING GROUP	Publication Notices	$225.00
74089	MOONLIGHT BPO LLC	Contract Services-Bill Print/Mail	$5,056.26
74090	Ninjio, LLC	Dues & Subscriptions	$130.00

AUGUST 2022 WARRANTS

CHECK	PAYEE	DESCRIPTION	AMOUNT
74091	NOWSPEED INC.	Contract Services-Other	$250.00
74092	OCCU-MED	Office Miscellaneous	$292.25
74093	Void	Void	$0.00
74094	PACE SUPPLY CORP	Material	$15,459.49
74095	ALBERTO PRECIADO	Professional Development	$1,850.00
74096	PRIME AUTO REPAIR	Repair-Trucks	$1,341.56
74097	Void	Void	$0.00
74098	QUICK QUACK CAR WASH	Maintenance Agreement-Equipment	$298.30
74099	RED WING SHOE STORE	Small Tools	$252.10
74100	REPUBLIC SERVICES #922	Utilities	$456.24
74101	REGIONAL GOVERNMENT SERVICES	Contract Services-Other	$12,930.85
74102	RIVER CITY STAFFING GROUP	Temporary Labor	$2,400.00
74103	REGIONAL WATER AUTHORITY	Dues & Subscriptions	$46,111.00
74104	SAGENT	Contract Services-Other	$6,512.47
74105	SCARSDALE SECURITY SECURITY SYSTEMS INC	Contract Services-Other	$284.97
74106	SACRAMENTO GROUNDWATER AUTHORITY	Dues & Subscriptions	$46,678.00
74107	SIMON AND COMPANY INC	Contract Services-Other	$1,000.00
74108	SMUD	Utilities	$46,455.94
74109	SONITROL	Equipment Rental-Office	$204.08
74110	SUNRISE RECREATION & PARK DISTRICT	Materials	$2,000.00
74111	SUPERIOR EQUIPMENT REPAIR	Repair-Trucks	$339.84
74112	T-Mobile	Telecom-Wireless	$2,259.12
74113	TEE JANITORIAL & MAINTENANCE	Contract Services-Other	$2,989.00
74114	THIRDRAIL	Contract Services-Other	$11,781.13
74115	TIAA COMMERCIAL FINANCE INC	Equipment Rental-Office	$522.59
74116	UNDERGROUND SERVICE ALERT OF NORTHERN CA/NEVADA	Dues & Subscriptions	$15,516.37
74117	VERIZON WIRELESS	Telecom-Wireless	$172.60
74118	WATER SYSTEMS CONSULTING, INC	Contract Services-Other	$12,568.25
74119	WILLIAMS+PADDON	Contract Services-Engineering	$872.63
74120	WOLF CONSULTING	Contract Services-Other	$625.00
74121	ZIM INDUSTRIES INC	Contract Services-Wells	$196,704.72
74122	ACWA/JPIA	Workers Comp Insurance	$15,529.21
74123	Abigail Peterson	Customer Refund	$20.70
74124	Zoltan LLC	Customer Refund	$61.82
74125	Barbara/Christopher R Wade	Customer Refund	$54.27
74126	JOSHUA E/MELODY R GLASS	Customer Refund	$405.11
74127	Gabriel Pitts	Customer Refund	$7.73
74128	Trulyella LLC	Customer Refund	$17.22
74129	ACWA/JPIA	Workers Comp Ins	$92.82
74130	AFLAC	Employee Paid Insurance	$176.93
74131	All Phase Construction, Inc	Contract Services-Engineering	$243,047.50
74132	ANSWERNET	Telephone-Answering Service	$414.65
74133	AREA RESTROOM SOLUTIONS	Equipment Rental-Field	$159.76
74134	BENDER ROSENTHAL INCORPORATED	Contract Services-Other	$9,500.00
74135	BRYCE CONSULTING, INC	Legal & Audit	$4,410.00

AUGUST 2022 WARRANTS

CHECK	PAYEE	DESCRIPTION	AMOUNT
74136	CALIFORNIA SURVEYING & DRAFTING SUPPLY	Small Tools	$5.00
74137	CITY OF CITRUS HEIGHTS	Permit Fees	$1,262.75
74138	COLANTUONO, HIGHSMITH & WHATLEY, PC	Legal & Audit	$12,957.00
74139	CONSOLIDATED	Telephone-Local/Long Distance	$2,955.62
74140	R&B COMPANY	Material	$543.06
74141	CORELOGIC INFORMATION SOLUTIONS INC	Dues & Subscriptions	$218.55
74142	COUNTY OF SACRAMENTO	Contract Services-Other	$3,042.75
74143	GRAINGER	Small Tools	$194.03
74144	FERGUSON ENTERPRISES INC #1423	Material	$7,282.41
74145	INTEGRITY ADMINISTRATORS INC	Health Insurance	$5,000.00
74146	MARTIN GENERAL ENGINEERING INC	Contract Services-Engineering	$6,600.00
74147	NAVIANT	Maintenance Agreement-Software	$4,690.00
74148	PACE SUPPLY CORP	Material	$4,948.35
74149	LEA PARK-KIM	Professional Development	$220.00
74150	PIP Marketing Signs Print	Printing	$181.29
74151	HILARY STRAUS	Professional Development	$315.00
74152	SWRCB	Grant Funds	$27,308.74
74153	STATE WATER RESOURCES CONTROL BOARD	Dues & Subscriptions	$60.00
74154	UNI WASTE LLC	Contract Services-Other	$1,945.68
74155	WARREN CONSULTING ENGINEERS INC	Contract Services-Engineering	$750.00
74156	WEST YOST ASSOCIATES	Contract Services-Engineering	$7,604.25
74157	ACWA/JPIA	Workers Comp Insurance	$1,695.00
74158	STATE WATER RESOURCES CONTROL BOARD	Dues & Subscriptions	$105.00
74159	Tien V/Thu Nguyen	Customer Refund	$10.26
74160	Saipin Lally	Customer Refund	$138.13
74161	Stephen W Young	Customer Refund	$14.86
74162	Orest Symk	Customer Refund	$79.79
74163	Valeriy Ivanov	Customer Refund	$9.78
74164	DIANA WAGLE	Customer Refund	$225.00
74165	ACWA/JPIA	Workers Comp Ins	$5,440.30
74166	AQUA SIERRA CONTROLS	Wells Maintenance	$4,861.16
74167	CALIFORNIA-NEVADA SECTION AWWA	Dues & Subscriptions	$100.00
74168	B&M BUILDERS	Contract Services-Engineering	$45,813.00
74169	BART/RIEBES AUTO PARTS	Repair-Trucks	$12.38
74170	BSK ASSOCIATES	Water Analysis	$173.00
74171	CIRCLEPOINT	Contract Services- Other	$496.25
74172	CITY OF CITRUS HEIGHTS	Permit Fees	$5,448.20
74173	COUNTY OF SACRAMENTO	Permit Fees	$365.75
74174	TAMAR DAWSON	Professional Development	$135.52
74175	Barrett Drawdy	Toilet Rebate Program	$75.00
74176	James T Edgar	Toilet Rebate Program	$96.78
74177	FUTURE FORD	Repair-Trucks	$1,299.48
74178	Bradley L/ Teresa Gorman	Toilet Rebate Program	$75.00
74179	Void	Void	$0.00
74180	HUNT & SONS INC	Gas & Oil	$366.85

AUGUST 2022 WARRANTS

CHECK	PAYEE	DESCRIPTION	AMOUNT
74181	J4 SYSTEMS	Contract Services-Other	$2,355.00
74182	KEI WINDOW CLEANING #12	Janitorial	$120.00
74183	Laura Kinsey	Toilet Rebate Program	$50.00
74184	LOWE'S	Supplies-Field	$1,264.65
74185	PACE SUPPLY CORP	Material	$134.90
74186	RIVER CITY STAFFING GROUP	Temporary Labor	$360.00
74187	RANDALL ROZANSKI	Toilet Rebate Program	$75.00
74188	SACRAMENTO LOCAL AGENCY FORMATION COMMISSION	Dues & Subscriptions	$1,816.00
74189	SAN JUAN WATER DISTRICT	Purchased Water	$769,156.73
74190	Pauline Swarat	Toilet Rebate Program	$75.00
74191	WALKER'S OFFICE SUPPLIES	Supplies- Office	$140.97
74192	Doris M Aldrich Living Trust	Customer Refund	$27.29
74193	Kurtz Family Trust	Customer Refund	$26.19
74194	Kip Rahe Separate prop Trust	Customer Refund	$28.44
74195	ERNEST J/YUKIKO I RODRIGUEZ	Customer Refund	$93.64
74196	Marston Family Trust/Geraldine Marston	Customer Refund	$379.09
74197	Cheryl A Paul	Customer Refund	$251.52
74198	Debra D M Hillsman	Customer Refund	$232.11
74199	William/Daniela Bouzeneris	Customer Refund	$163.23
74200	Keith B/Rosemarie M Oconnell	Customer Refund	$26.02
74201	David Muradyan	Customer Refund	$12.86
74202	Gary/Courtney Walmer	Customer Refund	$23.31
74203	Luke/Rosehannah Hewitt	Customer Refund	$13.73
74204	James T Lugar	Customer Refund	$30.18
74205	Brittany/Jess Lima	Customer Refund	$47.73
74206	Jessica K Marty	Customer Refund	$68.58
74207	Jason/Amy B Wister	Customer Refund	$156.63
74208	Christopher M Voudouris	Customer Refund	$99.06
74209	Sarah/Abraham Selzer	Customer Refund	$20.76
74210	Theresa L/Michael R Hernandez	Customer Refund	$735.50
74211	ABA DABA RENTALS & SALES	Supplies-Field	$188.02
74212	ALEXANDER'S CONTRACT SERVICES	Contract Services-Meter Reads	$5,048.15
74213	AUL HEALTH BENEFIT TRUST	Health Insurance	$1,801.56
74214	BART/RIEBES AUTO PARTS	Repair-Trucks	$323.41
74215	BATTERIES PLUS BULBS	Small Tools	$155.38
74216	COMCAST	Equipment Rental-Office	$103.45
74217	COUNTY OF SACRAMENTO MUNICIPAL SERVICES	Field Miscellaneous	$66.80
74218	KELLY R DRAKE	Professional Development	$127.09
74219	FAST ACTION PEST CONTROL	Contract Services-Miscellaneous	$168.00
74220	HUNT & SONS INC	Gas & Oil	$2,515.94
74221	DANA MELLADO	Professional Development	$94.47
74222	MIcrosoft Corporation	Maintenance Agreement-Equipment	$1,933.88
74223	ONE PRINT SOURCE & GRAPHICS	Printing	$1,041.15
74224	RAY RIEHLE	Professional Development	$41.19
74225	RIVER CITY STAFFING GROUP	Temporary Labor	$1,400.00
74226	A. TEICHERT & SON, INC.	Road Base	$3,922.13
74227	VERIZON WIRELESS	Telephone-Wireless	$370.38
74228	WIZIX TECHNOLOGY GROUP INC	Equipment Rental-Office	$344.65
74229	William O. Kuykendall Trust	Customer Refund	$225.00
74230	Ivan Ravlov	Customer Refund	$78.77
74231	Elinor Spector Trust	Customer Refund	$103.96
74232	Oliver/Trisha B Managbanag	Customer Refund	$55.37

AUGUST 2022 WARRANTS

CHECK	PAYEE	DESCRIPTION	AMOUNT
74233	KOTHARI S TRUST	Customer Refund	$87.72
74234	Rick/Karri Corwin	Customer Refund	$647.64
74235	OPENDOOR PROPERTY TRUST I	Customer Refund	$51.53
74236	Volpe Company Inc	Customer Refund	$818.10
74237	CALIFORNIA-NEVADA SECTION AWWA	Dues & Subscriptions	$100.00
74238	BART/RIEBES AUTO PARTS	Repair-Trucks	$239.87
74239	BATTERIES PLUS BULBS	Small Tools	$69.91
74240	BEST BEST & KRIEGER	Legal & Audit	$5,646.30
74241	BSK ASSOCIATES	Water Analysis	$3,309.00
74242	CITY OF CITRUS HEIGHTS	Permit Fees	$3,352.25
74243	COLANTUONO, HIGHSMITH & WHATLEY, PC	Legal & Audit	$14,067.00
74244	COLLEGE OAK TOWING	Repair-Trucks	$330.00
74245	ROBIN COPE	Health Insurance	$365.96
74246	Alfred Solario	Customer Refund	$127.99
74247	KELLY R DRAKE	Professional Development	$155.00
74248	FUTURE FORD	Repair-Trucks	$334.52
74249	FERGUSON ENTERPRISES INC #1423	Material	$5,508.72
74250	IB CONSULTING LLC	Contract Services-Financial	$6,840.00
74251	J4 SYSTEMS	Contract Services-Other	$171.25
74252	MOONLIGHT BPO LLC	Contract Services-Bill Print/Mail	$8,587.84
74253	NOR CAL PERLITE INC	Supplies-Field	$2,364.80
74254	PROUD AV INC	Contract Services-Other	$1,301.72
74255	RED WING SHOE STORE	Small Tools	$813.75
74256	RIVER CITY STAFFING GROUP	Temporary Labor	$1,200.00
74257	SAGENT	Contract Services-Other	$6,437.50
74258	SCARSDALE SECURITY SECURITY SYSTEMS INC	Contract Services-Other	$284.97
74259	SMUD	Utilities	$51,430.22
74260	Alfred Solario	Customer Refund	$10.00
74261	SUPERIOR EQUIPMENT REPAIR	Repair-Trucks	$287.54
74262	STATE WATER RESOURCES CONTROL BOARD	Dues & Subscriptions	$60.00
74263	SYLVAN RANCH COMMUNITY GARDEN	Contract Services- Conservation	$60.00
74264	TEE JANITORIAL & MAINTENANCE	Contract Services-Other	$2,989.00
74265	ZOHO CORPORATION	Maintenance Agreement-Software	$963.00
74266	STATE WATER RESOURCES CONTROL BOARD	Professional Development	$60.00
Total			$1,867,504.82

AUGUST 2022 WARRANTS

CHECK	PAYEE	DESCRIPTION	AMOUNT
ACH	ADP 612008929	Contract Services-Financial	$407.25
ACH	ADP 612955881	Contract Services-Financial	$285.15
ACH	BOW JULY 2022	Bank Fee	$1,412.96
ACH	CA CHOICE SEPT 2022	Health Insurance	$46,334.81
ACH	CHASE JULY 2022	Bank Fee	$4,288.56
ACH	IC 1168-2022-7	Bank Fee	$5,869.55
ACH	ICMA 8/18/22 PAYDAY	Deferred Compensation	$9,580.45
ACH	ICMA 8/4/22 PAYDAY	Deferred Compensation	$9,679.74
ACH	ICMA 9/1/22 PAYDAY	Deferred Compensation	$9,548.89
ACH	JP MORGAN JULY 2022 AP	See August Agenda Item CC-9	$680.97
ACH	JPM JULY2022	See August Agenda Item CC-9	$21,355.16
ACH	MID AMERICA 8/9-8/15/22	Employee Paid Insurance	$384.00
ACH	PERS 7/7/22 PAYDAY	PERS	$22,841.93
ACH	PRINCIPAL SEPT 2022	Health Insurance	$9,169.08
ACH	VALIC 7/7/22 PAYDAY	Deferred Compensation	$2,007.61
ACH	VALIC7/21/22 PAYDAY	Deferred Compensation	$2,007.61
Total			$145,853.72
Grand Total			$2,013,358.54

JP Morgan Purchase Card Distributions
Aug-22

Name	General Supplies	District Events & Recognition	Professional Development	Maintenance/ Licensing	Postage/Shipping/Freight	Dues & Subscription	Tools & Equipment	Fees & Charges	Equipment Maintenance	Total Bill
Moore	$ 25.85	$ 268.15	$ 36.66							$ 330.66
Shockley	$ 469.35	$ 1,364.68	$ 4,074.72	$ 238.90	$ 8.95	$ 10.00	$ 233.34			$ 6,399.94
Abaya	$ 74.31					$ 444.89			$ 180.10	$ 699.30
Pieri		$ 153.81								$ 153.81
Spiers		$ 33.13					$ 430.00		$ 1,649.95	$ 2,113.08
Straus		$ 45.55								$ 45.55
Park-Kim	$ 137.45					$ 125.00		$ 2.00		$ 264.45
Scott		$ 21.76								$ 21.76
Total Bill	**$ 706.96**	**$ 1,887.08**	**$ 4,111.38**	**$ 238.90**	**$ 8.95**	**$ 579.89**	**$ 663.34**	**$ 2.00**	**$ 1,830.05**	**$ 10,028.55**

AGENDA ITEM: CC-10

CITRUS HEIGHTS WATER DISTRICT

DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 REGULAR MEETING

SUBJECT	:	EMPLOYEE RECOGNITION
STATUS	:	Information Item
REPORT DATE	:	September 13, 2022
PREPARED BY	:	Brittney Moore, Administrative Services Manager

The following District employees were recognized for perfect attendance during July 2022, and outstanding customer service and quality of work during the month of August 2022.

Administrative Services

Name	Attendance	Customer Service	Work Quality
Bryan Abaya	Yes	On 08/08/22 engineering staff reported a computer performance issue and Bryan immediately assisted the staff. He identified the computer issue, made repairs, and got the staff's computer back up and running, with minimal downtime.	
Dana Mellado	Yes	Helped a customer on Penny Way where a family member had passed. The customer was very appreciative with Dana for her empathy and patience.	Staffed a District booth at the National Night Out Event.
Brittney Moore			Staffed a District booth at the National Night Out Event.
Lea Park-Kim	Yes		Staffed a District booth at the National Night Out Event. Coordinated site visit with Congressman Ami Bera.
Kayleigh Shepard	Yes		
Beth Shockley			Organized and set up employee appreciation lunch.

Name	Attendance	Customer Service	Work Quality
Desiree Smith		Worked with our bank to determine why a check had been returned for a customer.	

Engineering Department

Name	Attendance	Customer Service	Work Quality
Paul Dietrich	Yes		
Timothy Katkanov	Yes		
Neil Tamagni		Worked after hours and on Friday 8/4/22, 8/11/22, 8/19/22 and 8/26/22 on the District's Mesa Verde High School and Carriage Water Main Project and for a private development to ensure businesses were not out of water.	

Operations Department

Name	Attendance	Customer Service	Work Quality
Christopher Bell	Yes		
James Buford	Yes		
Andrew Callister	Yes		Fabricated and welded rock bag compartment on the front of the vacuum excavator.
Aaron Cater			Fabricated and welded rock bag compartment on the front of the vacuum excavator.
Brady Chamber	Yes		
Tim Cutler			Part of a team that presented a CIP update at the August Board Meeting.

Name	Attendance	Customer Service	Work Quality
James Ferro			8/5 - Assisted Stand-by with an emergency water service repair on Villa Del Sol Lane. 8/22 – Customer on Telegraph Ave. sent an email stating the crew inspecting ARVs on his property was professional and friendly.
Jarrett Flink	Yes		
Brian Hensley	Yes		Presented two items at the August Board Meeting.
Ricky Kelley	Yes		8/22 – Customer on Telegraph Ave. sent an email stating the crew inspecting ARVs on his property was professional and friendly.
Mike Mariedth			8/22 – Customer on Telegraph Ave. sent an email stating the crew inspecting ARVs on his property was professional and friendly.
Chris Nichols	Yes		
Jace Nunes	Yes		

AGENDA ITEM: CC-11

CITRUS HEIGHTS WATER DISTRICT
DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 MEETING

SUBJECT : LONG RANGE AGENDA
STATUS : Consent/Information Item
REPORT DATE : September 13, 2022
PREPARED BY : Brittney Moore, Administrative Services Manager

OBJECTIVE:
Listed below is the current Long Range Agenda.

Legend	
S	Study Session
CC	Consent Calendar
P	Presentation
B	Business
PH	Public Hearing
CL	Closed Session

CITRUS HEIGHTS WATER DISTRICT LONG RANGE AGENDA

MEETING DATE	MEETING TYPE	ITEM DESCRIPTION	ASSIGNED	AGENDA TYPE	AGENDA ITEM
October 19, 2022					
October 19, 2022		ACWA Election -Fall Conference	Moore	CC	A
October 19, 2022		Update to Urban Water Mgt. Plan (UWMP)	Scott	CC	A
October 19, 2022		Electronic Document Records Management System (EDRMS) Project Update	Abaya	P	I/D
October 19, 2022	Annual	Misc. Charges and Fees - Proposed	Preciado	P	A
November 16, 2022					
November 16, 2022		Boring/Potholing/Construction Support Agreement	Pieri/Scott	CC	A
November 16, 2022		Task order Agreement with JDH	Pieri	CC	A
November 16, 2022		Investment Services Agreement	Preciado	B	A
November 16, 2022		District-wide Easement Project	Pieri/Dawson	P	I/D
December 21, 2022					
December 21, 2022	Annual	Operating and Capital Budgets	Straus/Preciado	B	P/A
December 21, 2022		Oath of Office	Moore	B	A
December 21, 2022	Annual	Selection of President and Vice President	Straus	B	A
December 21, 2022	Annual	District Officers	Moore	B	A
December 21, 2022	Annual	Committee Assignments	Moore	B	A
December 21, 2022	Annual	Financing Corp Officer Selection	Preciado/Moore	B	A
January 18, 2023					
January 18, 2023		Operations Policies Updates (5,000 Series)	Scott	CC	A
January 18, 2023		Policy 6500: Purchasing and Procurement	Moore/Preciado	CC	A
January 18, 2023		CIP Update	Pieri	P	I/D
January 18, 2023		Strategic Plan Update/ 2023 Strategic Plan Preview	Moore	SS	I/D
February 15, 2023					
February 15, 2023	Annual	Investment of District Funds	Preciado	CC	A
March 15, 2023					
March 15, 2023	Annual	Poster Contest Presentation	Scott/Nunes	P	I/D
April 19, 2023					
April 19, 2023		2023 Strategic Plan Update	Moore	CC	I/D
May 17, 2023					
May 17, 2023		Annual Financial Report	Preciado	CC	I/D
June 21, 2023					
June 21, 2023	Annual	Status of Finance Corporation	Preciado	B	A
June 21, 2023	Annual	Conflict of Interest	Moore	B	A
JULY - SUMMER RECESS					
August 16, 2023					
August 16, 2023		2024 Strategic Plan Approval	Moore	CC	A

AGENDA ITEM: CC-12

CITRUS HEIGHTS WATER DISTRICT

DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 REGULAR MEETING

SUBJECT : ENGINEERING DEPARTMENT REPORT
STATUS : Information Item
REPORT DATE : September 12, 2022
PREPARED BY : Missy Pieri, Director of Engineering/District Engineer

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Significant assignments and activities for the Engineering Department are summarized below. I will be available at the meeting to answer questions and/or provide additional details.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
PROJECT 2030 Water Main Replacement Project - Pipeline Condition Assessment	Engineering	Director of Engineering and Project Manager	Yes, 06/29/21 (Final Completion Update)	Yes	Pipeline Condition Assessment	Phase 1 of Segment 1 Transmission Main condition assessment complete. Anticipate starting Phase 2 in Oct. 2022.
CAPITAL IMPROVEMENT PROJECT Corporation Yard / Facilities Master Plan Buildout	Engineering	Director of Engineering and Project Manager	Yes, 07/17/19 (Award of Contract)	Yes	Masterplan for office space requirements through 2045.	Staffing Report approved by Board on 06/16/21. Pre-Architectural Study kick-off meeting on 06/28/22.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
CAPITAL IMPROVEMENT PROJECT - Walnut Drive Water Service Project	Engineering	Project Manager and Assistant Engineer	No	Yes	2021 design, 2022 construction.	4 of 5 easements acquired. Plans are 100% complete. Anticipate construction to be completed by Operations in Summer 2022.
CAPITAL IMPROVEMENT PROJECT - Mesa Verde High School Water Main Project	Engineering	Project Manager and Assistant Engineer	Yes, 04/20/22 (Award of Contract)	Yes	2021 design, 2022 construction.	District received easement from SJUSD. CHWD to record once construction is complete. Award of Contract at the 04/20/22 Board meeting. Project started. 90% complete.
CAPITAL IMPROVEMENT PROJECT - Carriage Dr, Mesa Verde High School to Pratt	Engineering	Project Manager and Assistant Engineer	Yes, 04/20/22 (Award of Contract)	Yes	2021 design, 2022 construction.	Award of Contract at the 04/20/22 Board meeting. Project started. 90% complete.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
CAPITAL IMPROVEMENT PROJECT - Old Auburn Road Water Main	Engineering	Project Manager and Assistant Engineer	Yes	Yes	2022 design, 2023 construction.	District to begin design.
CAPITAL IMPROVEMENT PROJECT - Pratt Avenue Water Main	Engineering	Project Manager and Assistant Engineer	Yes, 12/15/21 (Award of Contract)	Yes	2021 design, 2022 construction.	Award of contract occurred at the 12/15/21 Board Meeting. Construction started on 04/05/22. 100% Complete. Punchlist being completed.
CAPITAL IMPROVEMENT PROJECT - Madison Ave & Dewey Dr Water Main	Engineering	Project Manager and Assistant Engineer	Yes	Yes	2022 design, 2022 construction.	Easement received. District to record once project is constructed. Plans 100% complete.
CAPITAL IMPROVEMENT PROJECT - 7515 Greenback Lane Building Demolition	Engineering	Project Manager and Assistant Engineer	Yes	Yes	2022 design, 2022 construction.	Preparing demolition plans. All utilities abandoned except for gas.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
PRIVATE DEVELOPMENT Mitchell Village - 7925 Arcadia Dr	Engineering	Director of Engineering and Senior Construction Inspector	Yes, 03/30/20, 04/15/20 (Deferment of Fees)	No	200-300 unit development by Watt Communities.	Project re-started on 07/14/20. Water portion 99% Complete. CHWD sent conditional project acceptance on 01/12/22.
PRIVATE DEVELOPMENT Lawrence Ave Wyatt Ranch	Engineering	Senior Construction Inspector, Director of Engineering and Assistant Engineer	Yes, 01/20/21 (Deferment of Fees)	No	23 lot subdivision.	District signed plans on 12/04/19. Deferment Agreement signed on 02/11/21. All fees paid. Construction 75% Complete. Construction restarted 08/09/21.
PRIVATE DEVELOPMENT 12057 Fair Oaks Blvd Fair Oaks Senior Apartments	Engineering	Director of Engineering and Assistant Engineer	No	No	Seniors apartment complex with 42 one bedroom and 68 two bedroom units.	All fees paid on 10/18/21. District signed plans on 10/19/21. Construction 5% complete.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
PRIVATE DEVELOPMENT 8043 Holly Dr Parcel Split 1 - 3	Engineering	Director of Engineering and Assistant Engineer	No	No	Parcel being split into 3 for 3 home subdivision.	District received third submittal on 03/10/21 and provided comments on 03/29/21. Awaiting final plans for signature. Plan check fees paid 04/13/21.
PRIVATE DEVELOPMENT 208 Langley Ave Parcel Split 1 - 2	Engineering	Director of Engineering and Assistant Engineer	No	No	Parcel being split into 2 lots. New single family home construction on one lot.	District sent correspondence to property owner on 04/20/20.
PRIVATE DEVELOPMENT 5425 Sunrise Blvd Sunrise Village Phase 2	Engineering	Director of Engineering and Assistant Engineer	No	No	Partial redevelopment of Sunrise Village.	Plans signed on 07/21/22. Construction 25% complete.
PRIVATE DEVELOPMENT 7969 Madison Ave Orchard Apts Storage Units	Engineering	Director of Engineering and Assistant Engineer	No	No	Demolition of tennis courts to make storage unit with sprinkler system.	Payment received for Fees on 04/01/20. District signed plans on 11/23/20. Construction 100% complete.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
PRIVATE DEVELOPMENT 7424 Sunrise Blvd Sunrise Pointe	Engineering	Senior Construction Inspector and Assistant Engineer	No	No	Proposed multi-unit housing complex for low-income and homeless.	All fees paid. Punchlist provided to contractor. Construction 99% complete.
PRIVATE DEVELOPMENT 8220 Sunrise Blvd Carefield Citrus Heights	Engineering	Director of Engineering and Assistant Engineer	No	No	Proposed memory care facility.	Received schematic plans on 05/08/19. Will-Serve letter sent on 05/20/19.
PRIVATE DEVELOPMENT Livoti Development	Engineering	Senior Construction Inspector and Assistant Engineer	No	No	Six Parcel Subdivision.	All fees paid. Plans signed on 11/09/21. Construction 75% complete.
PRIVATE DEVELOPMENT 7951 Antelope Rd American River Collegiate Academy	Engineering	Director of Engineering and Assistant Engineer	No	No	Commercial Development.	Awaiting for payment of fees. Received fourth submittal on 05/02/22. District provided comments on 05/05/22.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
PRIVATE DEVELOPMENT 8556 Pheasant Ridge Ln Fire Improvements	Engineering	Director of Engineering and Assistant Engineer	No	No	Extension of water main, addition of fire hydrant, and fire sprinklers.	All fees paid on 03/11/21. District approved plans on 01/24/22. Awaiting construction.
PRIVATE DEVELOPMENT 6031 Sunrise Vista Dr Apartments & Annexation	Engineering	Director of Engineering and Assistant Engineer	Yes (Resolution adopted for Annexation - 12/16/20)	No	Annexation and proposed apartments.	Annexation fees paid. Adoption of Resolution approving annexation occurred at the 12/16/20 Board Meeting. Received planning level documents on 04/06/21 and District provided comments on 04/13/21.
PRIVATE DEVELOPMENT 7078 Auburn Blvd Auburn Heights Townhomes	Engineering	Senior Construction Engineer and Assistant Engineer	No	No	8 Townhomes on undeveloped property.	All fees paid as of 11/22/21. Water construction 95% complete.
PRIVATE DEVELOPMENT 8136 Auburn Blvd Self Service Coin Laundry	Engineering	Director of Engineering and Assistant Engineer	No	No	Redevelopment of existing building to a self service coin laundry.	Plan check fees paid. Plans signed on 07/19/21. Awaiting construction.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
PRIVATE DEVELOPMENT Talbot Way Citrus Place Subdivision	Engineering	Director of Engineering and Assistant Engineer	No	No	8 lot subdivision	Plan check fees paid 6/2022. Plans signed on 6/21/22. Awaiting other fees and construction.
PRIVATE DEVELOPMENT 7311 Hickory Ave Single Family Home	Engineering	Director of Engineering and Assistant Engineer	No	No	Customer requesting water service for a recently split lot.	Verify lot is split prior to initiating new water service.
PRIVATE DEVELOPMENT 7830 Macy Plaza Dr CSL Plasma	Engineering	Director of Engineering and Assistant Engineer	No	No	Tenant Improvements for a medical office.	Plan check fees paid. Plans signed on 04/13/22. Awaiting construction.
PRIVATE DEVELOPMENT 7527 Linden Ave Multi-duplex	Engineering	Senior Construction Inspector and Assistant Engineer	No	No	3 duplex complex.	Plans approved on 10/21/21. All fees paid on 10/27/21. Pre-construction meeting occurred on 02/15/22.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
PRIVATE DEVELOPMENT 8207 Oak Ave Parcel Split, Annexation & Single Family Home	Engineering	Director of Engineering and Assistant Engineer	Yes, Inclusion approved by Board on 05/18/22.	No	Parcel Split, Annexation & 2 single family homes.	Plan check fees paid. Annexation/Inclusion fees paid and approved by Board on 05/18/22. Plans ready to be signed.
CITY OF CITRUS HEIGHTS PROJECT Auburn Blvd - Complete Streets Phase 2	Engineering	Director of Engineering and Assistant Engineer	No	No	City of Citrus Heights Frontage Improvements and Utility relocation on Auburn Blvd from Rusch Park to north.	District provided Cost Liability letter on 03/25/21 and the City approved on 01/27/22. District provided utility conflict review comments on 8/3/22.
CITY OF CITRUS HEIGHTS PROJECT Arcade-Cripple Creek Trail Project	Engineering	Director of Engineering and Assistant Engineer	No	No	City of Citrus Heights Bike Trail.	District received Cost Liability letter from the City on 10/09/20. Plans completed. Awaiting construction. Pre-bid meeting occurred on 05/19/22.
COUNTY OF SACRAMENTO AC Overlay Project SACOG 2022 Phase 1 to 3	Engineering	Director of Engineering and Assistant Engineer	No	No	County of Sacramento Road Improvements along Greenback Lane from Fair Oaks Blvd. to Hazel Ave.	Received first submittal on 04/20/22. District provided comments on 05/24/22.

Items of Interest	Department	Project Team	To Board? If so, Date	Strategic Planning Item	Item Description	Update from Last Report/ Current Status
District-wide Easement Project	Engineering	Director of Engineering, Project Manager and Assistant Engineer	(06/16/21) Award of Contract	Yes	Research and review District facility locations and easements for potential additions/revisions.	Phase 1 - 99% complete. Phase 2 - 95% complete. Phase 3 - 95% complete.

AGENDA ITEM: CC-13

CITRUS HEIGHTS WATER DISTRICT

DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 REGULAR MEETING

SUBJECT	: OPERATIONS DEPARTMENT REPORT
STATUS	: Information Item
REPORT DATE	: September 6, 2022
PREPARED BY	: Tim Cutler, Water Distribution Supervisor Rebecca Scott, Director of Operations

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Facilities Maintenance

	Completed WO's	
	Aug	**2022 YTD**
Backflow Maintenance	0	0
Blow Off Maintenance	0	3
Hydrant Maintenance	77	438
Leak Investigation	0	0
Mainline Repair/Maintenance	0	1
Meter Box Maintenance	3	25
Meter Register Replacement	21	200
Meter Repair/ Test/Maintenance	0	122
Pot Hole Work	0	2
Water Service Repair/Locate	0	5
Valve, Mainline Maintenance	186	767
Valve Box Maintenance	2	7
TOTAL	**289**	**1,570**

CIP Projects

	Completed WO's	
	Aug	**2022 YTD**
C22-010 Water Mainline	0	2
C22-011 Water Valves	1	15
C22-012 Water Services	41	263
C22-013 Water Meters	1	87
C22-014 Fire Hydrants	1	10
C22-103 Pot Hole Main	0	1
TOTAL	**44**	**378**

Water Quality

Water Analysis Report: Bacteriological testing has met all California Department of Public Health requirements. 96 samples were collected with no positive results.

CITRUS HEIGHTS WATER DISTRICT
DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 REGULAR MEETING

SUBJECT : 2022 WATER SUPPLY - PURCHASED & PRODUCED
STATUS : Information Item
REPORT DATE : September 1, 2022
PREPARED BY : Brian M. Hensley, Water Resources Supervisor
: Rebecca Scott, Director of Operations

OBJECTIVE:

Monthly water supply report, including a comparison to the corresponding month in the prior 5 years. The 2013 data is included for reference as it is the baseline consumption year for water conservation mandates.

Month	**2013**	2017	2018	2019	2020	2021	2022 Surface Water Purchased	2022 Ground Water Produced	2022 Total Water Monthly	2022 Total Water Annual	Year-to-Date Comparison to 2013	
	Total Water Monthly acre feet						acre feet				acre feet	%
Jan	**602.52**	506.81	531.38	520.86	519.03	575.54	332.65	196.08	528.73	528.73	**-73.79**	**-12.2%**
Feb	**606.36**	443.99	525.73	447.48	589.8	485.17	323.56	281.61	605.17	1,133.90	**-74.98**	**-6.2%**
Mar	**819.55**	546.60	540.78	516.87	654.31	601.02	479.25	295.49	774.74	1,908.64	**-119.79**	**-5.9%**
Apr	**1,029.73**	575.52	646.09	682.90	767.24	1,001.96	610.48	153.35	763.83	2,672.47	**-385.69**	**-12.6%**
May	**1,603.43**	1,138.72	1,072.27	977.41	1,168.99	1,277.33	1,032.29	100.77	1,133.06	3,805.53	**-856.06**	**-18.4%**
Jun	**1,816.73**	1,412.94	1,387.03	1,328.07	1,475.82	1,541.32	1,288.62	0.00	1,288.62	5,094.15	**-1,384.17**	**-21.4%**
Jul	**2,059.21**	1,650.76	1,737.13	1,582.40	1,682.83	1,643.73	823.41	713.28	1,536.69	6,630.84	**-1,906.69**	**-22.3%**
Aug	**1,924.28**	1,570.80	1,583.78	1,603.36	1,660.59	1,538.76	949.19	511.96	1,461.15	8,091.99	**-2,369.82**	**-22.7%**
Sep	**1,509.82**	1,441.76	1,330.19	1,297.12	1,381.14	1,333.29						
Oct	**1,297.42**	1,128.97	1,061.88	1,083.17	1,185.00	972.09						
Nov	**911.55**	631.55	807.7	839.06	779.34	576.37						
Dec	**700.94**	574.43	558.97	548.17	620.34	536.97						
Total	**14,881.54**	11,622.85	11,782.93	11,426.87	12,484.43	12,083.55	5,839.45	2,252.54	8,091.99	8,091.99		
% of Total							72.16%	27.84%				

AGENDA ITEM: CC-15

CITRUS HEIGHTS WATER DISTRICT

DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 REGULAR MEETING

SUBJECT	: WATER SUPPLY RELIABILITY
STATUS	: Information Item
REPORT DATE	: September 6, 2022
PREPARED BY	: Brian Hensley, Water Resources Supervisor Rebecca Scott, Director of Operations

OBJECTIVE:
Receive status report on surface water supplies available to the Citrus Heights Water District (District).

BACKGROUND AND ANALYSIS:
As of September 1, 2022, storage in Folsom Lake (Lake) was at 437,798 acre-feet, 45 percent of the total capacity of 977,000 acre-feet. This represents a decrease in storage of 148,079 acre-feet in the past month.

The District's total water use during August 2022 (1,461.15 acre-feet) was 24 percent below that of August 2013 (1,924.28 acre-feet).

The District continues to assist with preserving surface water supplies in the Lake by operating its groundwater wells. The District's groundwater production wells: Bonita, Skycrest, Mitchell Farms, and Sylvan are operational and used on a rotational or as-needed basis. Other District groundwater production wells, Palm and Sunrise, are available for emergency use.

CITRUS HEIGHTS WATER DISTRICT

DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 REGULAR MEETING

SUBJECT	:	WATER EFFICIENCY & SAFETY PROGRAM UPDATE
STATUS	:	Information Item
REPORT DATE	:	September 13, 2022
PREPARED BY	:	Jace Nunes, Management Analyst Rebecca Scott, Director of Operations

Water Efficiency, Safety and Meter Program updates are summarized below.

ACTIVITIES AND PROGRESS REPORT

- Water Efficiency activities during the month of August 2022 included:
  - Nine High Efficiency Toilet (HET) rebates were processed in August.
  - Six High Efficiency Clothes Washer (HECW) rebates were processed in August.
  - There were three smart irrigation controllers installed for customers in August.
- One Pressure Reducing Valve (PRV) rebate was issued in August.
- Forty-Eight reports of water waste were received in August. Staff continues reaching out to customers concerning water waste violations and leak notifications.
- The District holds bi-monthly safety meetings. The August safety meetings covered Fatigue in the Workplace and Dog Bite Prevention.
- The District recently held its last two WaterSmart classes for 2022, and the recordings should be uploaded to YouTube in the next month. Twenty-one people attended the September 10th class, and all attendees were CHWD customers. WaterSmart classes from 2021 to present are archived on CHWD's website and on YouTube, where they can be viewed any time.
- CHWD has three garden plots at the Sylvan Ranch Community Garden featuring water efficient landscaping. CHWD is working with a customer based volunteer "Garden Corps," who maintains the plots by removing weeds and checking the irrigation system and controller timers.

- The following table summarizes the Residential Gallons Per Capita Per Day (R-GPCD) values for CHWD for 2022:

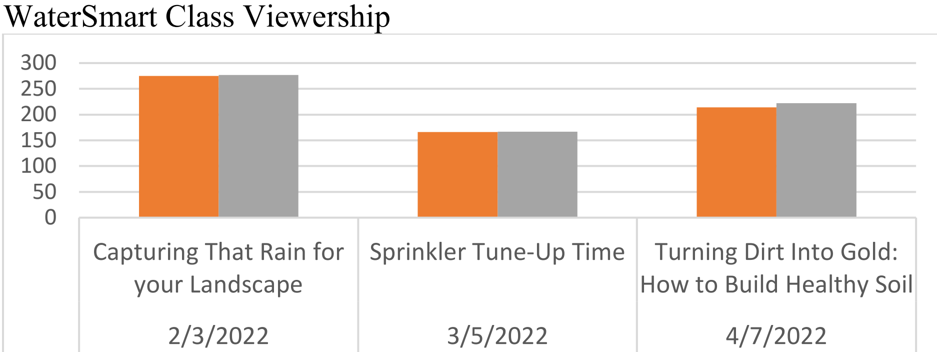
Month	R-GPCD 2021	R-GPCD 2022	% CHANGE
January	84	75	-10%
February	78	85	+8%
March	88	111	+26%
April	135	113	-17%
May	169	162	- 4.2%
June	172	190	+10%
July	230	219	-4.5%
August	187	209	+11.4%

The following table summarizes the service requests and work orders of Water Efficiency staff for August 2022:

Work Orders	Aug 2022	Aug 2021
CHANGE TOUCH-READ TO RADIO READ	0	0
CONVERT TO RADIO-READ METER	5	5
METER BOX MAINTENANCE	2	2
METER REPAIR	1	0
METER REPLACEMENT	1	0
METER TESTING	0	0
REGISTER REPLACEMENT	13	11
RADIO-READ REGISTER REPLACEMENT	4	0
INSTALL METER	0	18
TOTAL	**26**	**36**

Service Requests	Aug 2022	Aug 2021
CONSERVATION REQUEST	48	49
CHECK FOR LEAK	2	0
UNABLE TO OBTAIN METER READ	68	66
TRIM SHRUBS	11	10
METER BURIED	31	52
METER MAINT.	41	12
LOCKED GATE	1	8
RE-READ METER	22	17
READ METER	0	0
METER BOX MAINT.	0	0
MOVE-IN/MOVE-OUT	13	24
CAR OVER METER	13	28
TOTAL	**254**	**294**

WaterSmart Class Viewership



= Viewership, August 1, 2022
= Viewership, September 1, 2022

CITRUS HEIGHTS WATER DISTRICT

DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 REGULAR MEETING

SUBJECT	: DISCUSSION AND POSSIBLE ACTION TO EXTEND RESOLUTION 07-2021 AUTHORIZING REMOTE PUBLIC MEETINGS
STATUS	: Action Item
REPORT DATE	: September 14, 2022
PREPARED BY	: Brittney Moore, Administrative Services Manager Joshua Nelson, Assistant General Counsel

OBJECTIVE:
Consider extending Resolution 07-2021 to permit future hybrid remote public meetings by the Board of Directors.

BACKGROUND AND ANALYSIS:
On September 16, 2021, the Governor signed AB 361, which allows legislative bodies to meet virtually provided there is a state of emergency, and either (1) state or local officials have imposed or recommended measures to promote social distancing; or (2) the legislative body determines by majority vote that meeting in person would present imminent risks to the health and safety of attendees.

On October 20, 2021 CHWD Board of Directors adopted Resolution 07-2021 to permit future hybrid remote public meetings by the Board of Directors consistent with the requirements of AB 361. CHWD Board of Directors voted 3-0 to extend Resolution 07-2021 at its November 17, 2021, December 15, 2021, January 19, 2022, and March 16, 2022 Regular Meetings, and at the February 22, 2022 Special Meeting. The Board approved additional extensions of Resolution 07-2021 at its April 20, 2022, May 18, 2022, June 15, 2022 and August 17, 2022 Regular Meetings.

In order to continue to qualify for AB 361's waiver of in-person meeting requirements, the Board must, within thirty (30) days of its first meeting under AB 361, and every thirty (30) days thereafter, make findings that (a) state or local officials continue to recommend measures to promote social distancing, or that (b) an in-person meeting would constitute an imminent risk to the safety of attendees. The findings need not be in the form of a resolution, but a resolution is helpful in formalizing these findings.

Because the Board meets regularly on the third Wednesday of each month, it is possible that more than thirty days may elapse between consecutive meetings. AB 361 is silent as to whether special meetings are required on a more frequent basis to keep up with the thirty-day renewal of findings requirement, although scheduling such meetings would ensure strict compliance. Alternatively, if the Board does not meet within thirty days after its prior meeting, the Board should make its renewed findings at the beginning of its next meeting prior to any other action or discussion. If the Board wishes to continue meetings remotely, staff recommends the Board extend Resolution 07-2021 by motion, and continuously consider this Resolution as a monthly consent calendar item while there is a declared state of emergency, or until state and local orders aimed at containing the COVID-19 virus are rescinded.

RECOMMENDATION:

Extend Resolution 07-2021 to permit future hybrid remote public meetings by the Board of Directors.

ATTACHMENT:

Resolution No. 07-2021 Resolution of the Board of Directors of the Citrus Heights Water District Authorizing Remote Public Meetings

ACTION:

Moved by Director _____________, Seconded by Director _____________, Carried ______________

CITRUS HEIGHTS WATER DISTRICT
RESOLUTION NO. 07-2021

RESOLUTION OF THE BOARD OF DIRECTORS
OF CITRUS HEIGHTS WATER DISTRICT
AUTHORIZING REMOTE PUBLIC MEETINGS

WHEREAS, CITRUS HEIGHTS WATER DISTRICT ("CHWD") is committed to preserving and nurturing public access and participation in meetings of the Board of Directors; and

WHEREAS, all meetings of CHWD's legislative bodies are open and public, as required by the Ralph M. Brown Act (Cal. Gov. Code 54950 – 54963), so that any member of the public may attend and participate in CHWD's meetings; and

WHEREAS, starting in March 2020, in response to the spread of COVID-19 in the State of California, the Governor issued a number of executive orders aimed at containing the COVID-19 virus; and

WHEREAS, among other things, these orders waived certain requirements of the Brown Act to allow legislative bodies to meet virtually; and

WHEREAS, pursuant to the Governor's executive orders, CHWD has been permitting virtual participation in meetings during the pandemic in the interest of protecting the health and safety of the public, staff, and Directors; and

WHEREAS, the Governor's executive order related to the suspension of certain provisions of the Brown Act expired on September 30, 2021; and

WHEREAS, on September 16, 2021 the Governor signed AB 361 (in effect as of October 1, 2021 – Government Code Section 54953(e)), which allows legislative bodies to meet virtually provided there is a state of emergency, and either (1) state or local officials have imposed or recommended measures to promote social distancing; or (2) the legislative body determines by majority vote that meeting in person would present imminent risks to the health and safety of attendees; and

WHEREAS, such conditions now exist in CHWD, specifically, a state of emergency has been proclaimed related to COVID-19, State and Sacramento County officials are recommending measures to promote social distancing, and because of the ongoing threat of COVID-19, meeting in person would present imminent risks to the health and safety of attendees;

NOW, THEREFORE, THE BOARD OF DIRECTORS OF THE CITRUS HEIGHTS WATER DISTRICT DOES HEREBY RESOLVE AS FOLLOWS:

Section 1. <u>Recitals</u>. The Recitals set forth above are true and correct and are incorporated into this Resolution by this reference.

Section 2. Remote Teleconference Meetings: Consistent with the provisions of Government Code Section 54953(e), the Board of Directors finds and determines that (1) a state of emergency related to COVID-19 is currently in effect; (2) state and local officials in Sacramento County have recommended measures to promote social distancing in connection with COVID-19, including indoor mask recommendations and minimum recommend distance between attendees; and (3) due to the COVID-19 emergency, the transfer of novel coronavirus from person-to-person, and the associated risk of serious illness or death from COVID-19, meeting in person would present imminent risks to the health and safety of attendees. Based on such facts, findings and determinations, the Board authorizes staff to conduct remote teleconference meetings of the Board of Directors and other CHWD legislatives bodies under the provisions of Government Code Section 54953(e).

Section 3. Effective Date of Resolution. This Resolution shall take effect October 20, 2021, and shall be effective for 30 days or until this Resolution is extended by a majority vote of the Board of Directors in accordance with Section 4 of this Resolution.

Section 4. Extension by Motion. The Board of Directors may extend the application of this Resolution by motion and majority vote by up to thirty days at a time, provided that it makes all necessary findings consistent with and pursuant to the requirements of Section 54953(e)(3).

PASSED, APPROVED, AND ADOPTED this 20th day of October, 2021.

AYES:
NOES:
ABSENT:
ABSTAINED:

David C. Wheaton, President

ATTEST:

Brittney Moore, Deputy Board Clerk

CITRUS HEIGHTS WATER DISTRICT

DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 MEETING

SUBJECT	: DISCUSSION AND POSSIBLE ACTION TO APPROVE AGREEMENT WITH TAK COMMUNICATIONS CA, INC. FOR THE 6700 MADISON AVENUE AT DEWEY DRIVE WATER MAIN PROJECT
STATUS	: Action Item
REPORT DATE	: September 1, 2022
PREPARED BY	: Paul Dietrich, Project Manager Missy Pieri, Director of Engineering/District Engineer

OBJECTIVE:
Consider acceptance of a bid to install a water main at 6700 Madison Avenue along the frontage of Dewey Drive. This project will connect two (2) existing 8" water mains thus providing further redundancy to the water system and improved fire flow to the surrounding area.

BACKGROUND AND ANALYSIS:
The 6700 Madison Avenue at Dewey Drive Water Main Project (Project) will complete a capital improvement project that is part of the District's 1999-2029 Capital Improvement Plan. This Project appears in the 2022 Capital Projects Budget as the 6700 Madison Avenue at Dewey Drive Water Main Project (C21-105). The Project includes installing 115 linear feet of 8-inch water main in an easement provided in recent months by the property owner.

The District received two (2) sealed proposals on August 31, 2022, at which time proposals were opened and read publicly. Bids received are as follows:

1. TAK Communications Ca, Inc.	**$57,930.00**
2. Flowline Contractors, Inc.	$76,458.00

The lowest responsive bid received was from TAK Communications Ca, Inc., Sacramento, Ca. at $57,930.00 as noted above. This bid was approximately 0.6% below the final Engineering Estimate of $58,271.00. Staff has determined that there are sufficient funds within the 2022 adopted Capital Projects Budget for this Project, and staff recommends acceptance of the lowest responsive bid.

RECOMMENDATION:
Accept the bid of TAK Communications Ca, Inc. in the amount of $57,930.00 and establish a contingency fund in the amount of $5,793.00 (10%), for a total amount of $63,723.00. Authorize the General Manager to execute an agreement with TAK Communications Ca, Inc.

ATTACHMENT:
6700 Madison Avenue at Dewey Drive Water Main Project Construction Agreement

ACTION:

Moved by Director _____________, Seconded by Director _____________, Carried ______________

6700 MADISON AVENUE AT DEWEY DRIVE WATER MAIN PROJECT

SPECIFICATIONS FOR PROJECT NO. C21-105

CONSTRUCTION AGREEMENT

CITRUS HEIGHTS WATER DISTRICT

6230 Sylvan Rd • PO Box 286
Citrus Heights • California • 95611-0286

916/725-6873 • 916/725-0345 Fax

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NOTICE INVITING BIDS

Citrus Heights Water District ("District") will receive sealed bids for the 6700 Madison Avenue at Dewey Drive Water Main Project no later than August 31, 2022 at 2:00 pm, at the Administrative Office of Citrus Heights Water District, 6230 Sylvan Road, Citrus Heights, CA 95610, at which time said bids will be read aloud. The District will not accept late bids. Bids shall be valid for 60 calendar days after the bid opening date.

The Project must be completed within **35** calendar days, beginning ten (10) calendar days after the date on which the notice to proceed ("Notice to Proceed") is sent by the District to the contractor that is awarded a bid for this Project ("Contractor").

The Project consists of all Work described in the Contract Documents and generally consists of furnishing of all labor, materials, tax, equipment and services for the construction and completion of the following work at 6700 Madison Avenue within Sacramento County. The work to be completed includes, but is not limited to, installing 115 linear feet of 8-inch water main.

Addendums or changes to the Contract Documents, Plans and Specifications prior to the date and time specified of the opening of bids will be performed and validated in writing and distributed by the District to the plan holders of record.

Contract Documents, Plans, and Specifications are now posted on the California Surveying & Drafting Supply (CSDS) website at https://planroom.csdsinc.com/ under heading of Recent Jobs Posted. Citrus Heights Water District will be using CSDS to manage and distribute all Contract Documents, Plans, and Specifications. The entire bid package including plans and any District issued addendums can be ordered at the expense of the Contractor through the website or by calling CSDS at (916) 344-0232, 4733 Auburn Blvd, Sacramento, CA 95841. Prospective bidders may review all the documents on the website without downloading for no charge.

Addendums or changes to the Contract Documents, Plans and Specifications prior to the date and time specified of the opening of bids will be performed and validated in writing and distributed by the District to the plan holders of record.

Complete sets of the Bid Forms must be used in preparing bids. The District does not assume responsibility for errors or misinterpretations resulting from the use of incomplete sets of Contract Documents. Modifications to or withdrawal of bids may be made by the bidder prior to the bid closing deadline. Bids must be accompanied by cash, a certified or cashier's check, or a Bid Bond in favor of the District in an amount not less than (10%) of the submitted Total Bid Price.

Bids will be read aloud. However, bid results are automatically made public by email transmittal to all participants of the Mandatory Pre-Bid Conference and by posting to the District's website at http://chwd.org/. The District reserves the right to reject any or all Bids and to waive any informality or irregularity in any Bid.

A MANDATORY Pre-Bid Conference will be held at **6230 Sylvan Road, Citrus Heights, CA 95611** on the following date and time: August 17, 2022 at 9AM. Each and every Bidder MUST attend the Pre-Bid Conference. Bids WILL NOT be accepted from any bidder who did not attend the Mandatory Pre-Bid Conference.

The last day to submit written questions is August 24, 2022 before 5:00 PM. Submission shall be sent via email to Paul Dietrich at pauld@chwd.org. An addendum will be created to address all questions and sent to all attendees of the Mandatory Pre-Bid Conference via email by end-of-day August 25, 2022.

The District's preliminary cost estimate for this Project is $58,271.00.

Each bid shall be accompanied by the security referred to in the Contract Documents, the non-collusion declaration, the list of proposed subcontractors, and all additional documentation required by the Instructions to Bidders.

The successful bidder will be required to furnish the District with a Performance Bond equal to 100% of the successful bid, and a Payment Bond equal to 100% of the successful bid, prior to execution of the Contract. All bonds are to be secured from a surety that meets all of the State of California bonding requirements, as defined in Code of Civil Procedure Section 995.120, and is admitted by the State of California.

Pursuant to Public Contract Code Section 22300, the successful bidder may substitute certain securities for funds withheld by District to ensure his performance under the Contract.

The Director of Industrial Relations has determined the general prevailing rate of per diem wages in the locality in which this work is to be performed for each craft or type of worker needed to execute the Contract which will be awarded to the successful bidder, copies of which are on file and will be made available to any interested party upon request at the District's offices, 6230 Sylvan Road, Citrus Heights, California 95610, or online at http://www.dir.ca.gov/dlsr. A copy of these rates shall be posted by the successful bidder at the job site. The successful bidder and all subcontractor(s) under him, shall comply with all applicable Labor Code provisions, which include, but are not limited to the payment of not less than the required prevailing rates to all workers employed by them in the execution of the Contract, the employment of apprentices, the hours of labor and the debarment of contractors and subcontractors.

All contractors and subcontractors that wish to bid on, be listed in a bid proposal, or enter into a contract to perform public work must be registered with the Department of Industrial Relations. No bid will be accepted nor any contract entered into without proof of the contractor's and subcontractors' current registration with the Department of Industrial

Relations to perform public work. This Project will be subject to compliance monitoring and enforcement by the Department of Industrial Relations.

Each bidder shall be a licensed contractor pursuant to the Business and Professions Code and shall be licensed in the following appropriate classification(s) of contractor's license(s), for the work bid upon, and must maintain the license(s) throughout the duration of the Contract:

California Class A General Engineering Contractor.

This Project is subject to compliance monitoring and enforcement by the Department of Industrial Relations. In bidding on this project, it shall be the Bidder's sole responsibility to evaluate and include the cost of complying with all labor compliance requirements under this contract and applicable law in its bid.

Award of Contract: The District may award the Contract for the Project to the lowest responsible bidder as determined from the Base Bid by the District. The District reserves the right to reject any or all bids or to waive any irregularities or informalities in any bids or in the bidding process.

The District reserves the right to reject any or all bids or to accept any bid. The District reserves the right to determine which proposal is, in its judgment, the most responsive bid of a responsible bidder and which proposal should be accepted in the best interest of the District. The District also reserves the right to waive any informality in any proposal or bid.

For further information, contact Paul Dietrich at 916-735-7723 or via e-mail (pauld@chwd.org).

END OF NOTICE INVITING BIDS

INSTRUCTIONS TO BIDDERS

1. AVAILABILITY OF CONTRACT DOCUMENTS

Bids must be submitted to the District on the Bid Documents which are a part of the Bid Package for the Project. Prospective bidders may obtain a complete set of Contract Documents as stated in the Notice Inviting Bids.

2. EXAMINATION OF CONTRACT DOCUMENTS

The District has made copies of the Contract Documents available, as indicated above. Bidders shall be solely responsible for examining the Project Site and the Contract Documents, including any Addenda issued during the bidding period, and for informing itself with respect to local labor availability, means of transportation, necessity for security, laws and codes, local permit requirements, wage scales, local tax structure, contractors' licensing requirements, availability of required insurance, and other factors that could affect the Work. Bidders are responsible for consulting the standards referenced in the Contract. Failure of Bidder to so examine and inform itself shall be at its sole risk, and no relief for error or omission will be given except as required under State law.

3. INTERPRETATION OF CONTRACT DOCUMENTS

Discrepancies in, and/or omissions from the Plans, Specifications or other Contract Documents or questions as to their meaning shall be immediately brought to the attention of the District by submission of a written request for an interpretation or correction to the District. Such submission, if any, must be sent via email or U.S. Mail to:

Paul Dietrich
Citrus Heights Water District
6230 Sylvan Road
Citrus Heights, CA 95610
e-mail: pauld@chwd.org

and received no later than August 24, 2022 before 5:00PM.

Any interpretation of the Contract Documents will be made only by written addenda duly issued and provided to all recipients of complete sets of the Contract Documents. The District will not be responsible for any explanations or interpretations provided in any other manner. No person is authorized to make any oral interpretation of any provision in the Contract Documents to any Bidder, and no Bidder should rely on any such oral interpretation.

Bids shall include complete compensation for all items of work to be performed under the Contract Documents.

4. INSPECTION OF SITE; PRE-BID CONFERENCE AND SITE WALK

Each prospective bidder is responsible for fully acquainting itself with the conditions of the Project Site(s), as well as those relating to the construction and labor of the Project, to fully understand the facilities, difficulties and restrictions which may impact the cost or effort required to complete the Project. To this end, a Pre-Bid Conference and Site Walk will be held on the date(s) and time(s) indicated in the Notice Inviting Bids.

5. ADDENDA

The District reserves the right to revise the Contract Documents prior to the bid opening date. Revisions, if any, shall be made by issuing Addenda. All plan holders will be notified when an addendum is posted to the bid management system. All addenda issued by the District shall be included in the bid and made part of the Contract Documents. Pursuant to Public Contract Code Section 4104.5, if the District issues an Addendum which includes material changes to the Project less than **72 hours** prior to the deadline for submission of bids, the District will extend the deadline for submission of bids. The District may determine, in its sole discretion, whether an Addendum warrants postponement of the bid submission date. Announcement of any extension shall be made via the electronic bid management system to all plan holders. Please Note: Bidders are responsible for ensuring that they have received any and all Addenda. To this end, the electronic bid management system requires each bidder acknowledge receipt of all addenda before submission of the bid.

6. ALTERNATE BIDS

If alternate bid items are called for in the Contract Documents, the lowest bid will be determined on the basis of the base bid only, unless otherwise specified in the notice Inviting Bids. The time required for completion of the alternate bid items has been factored into the Contract Time and no additional time will be awarded for any of the alternate bid items. The District may elect to include one or more of the alternate bid items, or to otherwise remove certain work from the Project scope of work, accordingly each Bidder must ensure that each bid item contains a proportionate share of profit, overhead and other costs or expenses which will be incurred by the Bidder.

7. COMPLETION OF BID FORMS

Bids shall only be prepared using copies of the Bid Forms which are included in the Contract Documents. The use of substitute bid forms will not be permitted. Bids shall be executed by an authorized signatory as described in these Instructions to Bidders. Deviations in the bid form may result in the bid being deemed non-responsive.

8. MODIFICATIONS OF BIDS

Each Bidder shall submit its Bid in strict conformity with the requirements of the Contract Documents. Unauthorized additions, modifications, revisions, conditions, limitations, exclusions or provisions attached to a Bid may render it non-responsive and may cause its rejection. Bidders shall neither delete, modify, nor supplement the printed matter on the Bid Forms, nor make substitutions thereon. Oral, telephonic and electronic modifications will not be considered, unless the Notice Inviting Bids authorizes the submission of electronic bids and modifications thereto and such modifications are made in accordance with the Notice Inviting Bids.

9. DESIGNATION OF SUBCONTRACTORS

Pursuant to State law, the Bidders must designate the name and location of each subcontractor who will perform work or render services for the Bidder in an amount that exceeds one-half of one percent (1/2%) of the Bidder's Total Bid Price, as well as the portion of work each such subcontractor will perform on the form provided herein by the District. No additional time will be provided to bidders to submit any of the requested information in the Designation of Subcontractor form.

10. LICENSING REQUIREMENTS

Pursuant to Section 7028.15 of the Business and Professions Code and Section 3300 of the Public Contract Code, all bidders must possess proper licenses for performance of this Contract. Subcontractors must possess the appropriate licenses for each specialty subcontracted. Pursuant to Section 7028.5 of the Business and Professions Code, the District shall consider any bid submitted by a contractor not currently licensed in accordance with state law and pursuant to the requirements found in the Contract Documents to be nonresponsive, and the District shall reject the Bid. The District shall have the right to request, and Bidders shall provide within five (5) calendar Days, evidence satisfactory to the District of all valid license(s) currently held by that Bidder and each of the Bidder's subcontractors, before awarding the Contract.

Notwithstanding anything contained herein, if the Work involves federal funds, the Contractor shall be properly licensed by the time the Contract is awarded, pursuant to the provisions of Public Contract Code Section 20103.5.

11. SIGNING OF BIDS

All Bids submitted shall be executed by the Bidder or its authorized representative. Bidders may be asked to provide evidence in the form of an authenticated resolution of its Board of Directors or a Power of Attorney evidencing the capacity of the person signing the Bid to bind the Bidder to each Bid and to any Contract arising therefrom. Hard copy of bids shall be submitted at the District's offices.

If a Bidder is a joint venture or partnership, it may be asked to submit an authenticated Power of Attorney executed by each joint venturer or partner appointing and designating one of the joint venturers or partners as a management sponsor to execute the Bid on behalf of Bidder. Only that joint venturer or partner shall execute the Bid. The Power of Attorney shall also: (1) authorize that particular joint venturer or partner to act for and bind

Bidder in all matters relating to the Bid; and (2) provide that each venturer or partner shall be jointly and severally liable for any and all of the duties and obligations of Bidder assumed under the Bid and under any Contract arising therefrom. The Bid shall be executed by the designated joint venturer or partner on behalf of the joint venture or partnership in its legal name.

12. BID GUARANTEE (BOND)

Each bid shall be accompanied by: (a) cash; (b) a certified check made payable to the District; (c) a cashier's check made payable to the District; or (d) a bid bond payable to the District executed by the bidder as principal and surety as obligor in an amount not less than 10% of the maximum amount of the bid. Personal sureties and unregistered surety companies are unacceptable. The surety insurer shall be California admitted surety insurer, as defined in Code of Civil Procedure Section 995.120. The cash, check or bid bond shall be given as a guarantee that the bidder shall execute the Contract if it be awarded to the bidder, shall provide the payment and performance bonds and insurance certificates and endorsements as required herein within ten (10) calendar Days after notification of the intent to award the Contract to the bidder. Failure to provide the required documents may result in forfeiture of the bidder's bid deposit or bond to the District and the District may award the Contract to the next lowest responsible bidder, or may call for new bids.

13. SUBMISSION OF SEALED BIDS

Bidders shall submit hard copies of their bids pursuant to Public Contract Code Sections 1600 and 1601. The acceptable method(s) of submission are stated in the Notice Inviting Bids. District shall not accept bids otherwise transmitted. **No oral, telephonic, or facsimile bids will be considered.**

14. DELIVERY AND OPENING OF BIDS

Bids will be received by the District up to the date and time shown in the Notice Inviting Bids. It is the Bidder's sole responsibility to ensure that its Bid is received as specified. Bids may be submitted earlier than the dates(s) and time(s) indicated.

Bids will be opened at the date and time stated in the Notice Inviting Bids, and the amount of each Bid will be read aloud and recorded. All Bidders may, if they desire, attend the opening of Bids. The District may in its sole discretion, elect to postpone the opening of the submitted Bids. District reserves the right to reject any or all Bids and to waive any informality or irregularity in any Bid. In the event of a discrepancy between the written amount of the Bid Price and the numerical amount of the Bid Price, the written amount shall govern.

15. WITHDRAWAL OF BID

Prior to the bid closing deadline, a Bid may be electronically withdrawn by the Bidder. Any request to withdraw a bid after bid opening must be made in accordance with Public Contract Code section 5100 *et seq.* and must be submitted in writing within five (5) working Days, excluding Saturday, Sundays and State holidays, specifying in detail how the mistake was made.

16. **BASIS OF AWARD; BALANCED BIDS**

The District shall award the Contract to the lowest responsible Bidder submitting a responsive Bid. The District may reject any Bid which, in its opinion when compared to other bids received or to the District's internal estimates, does not accurately reflect the cost to perform the Work. The District may reject as non-responsive any bid which unevenly weights or allocates costs, including but not limited to overhead and profit to one or more particular bid items.

17. **DISQUALIFICATION OF BIDDERS; INTEREST IN MORE THAN ONE BID**

No bidder shall be allowed to make, submit or be interested in more than one bid. However, a person, firm, corporation or other entity that has submitted a sub-proposal to a bidder, or that has quoted prices of materials to a bidder, is not thereby disqualified from submitting a sub-proposal or quoting prices to other bidders submitting a bid to the District. No person, firm, corporation, or other entity may submit sub-proposal to a bidder, or quote prices of materials to a bidder, when also submitting a prime bid on the same Project.

18. **INSURANCE REQUIREMENTS**

The successful bidder shall procure the insurance in the form and in the amount specified in the Contract Documents.

19. **AWARD PROCESS**

Once all Bids are opened and reviewed to determine the lowest responsive and responsible Bidder, the District may award the contract, or reject all bids. The apparent successful Bidder should begin to prepare the following documents: (1) the Performance Bond; (2) the Payment Bond; and (3) the required insurance certificates and endorsements. Once the District notifies the Bidder of the intent to award, the Bidder will have ten (10) consecutive calendar Days from the date of this notification to execute the Contract and supply the District with all of the required documents and certifications. Regardless whether the Bidder supplies the required documents and certifications in a timely manner, the Contract time will begin to run ten (10) calendar Days from the date of the notification. Once the District receives all of the properly drafted and executed documents and certifications from the Bidder, the District shall issue a Notice to Proceed to that Bidder.

20. FILING OF BID PROTESTS

Any bid protest relating to the form or content of the Bid or Contract Documents must be submitted in writing via the electronic bid management system at least ten (10) business Days before the original date set for the bid opening. Any bidder who submits a bid without making a protest shall be deemed to have waived any objection to the form of content of the Bid or Contract Documents not previously stated in writing.

Submitted bids will be timely made available for review upon written request of any bidder.

Bidders may file a "protest" of a Bid with the District's General Manager. In order for a Bidder's protest to be considered valid, the protest must:

A. Be filed in writing not later than 5:00 p.m. on the fifth business Day after the bid opening date;

B. Clearly identify the specific irregularity or basis for the protest;

C. Specify, in detail, the factual and legal grounds for the protest; and

D. Include all relevant supporting documentation with the protest at time of filing.

If the protest does not meet all of these requirements, the District may reject it without further review.

If the protest is timely and complies with all of the above requirements, the District's General Manger, or other designated District staff or representative, shall review the protest, any response from the challenged bidder, and all other relevant information. The District will provide a written response to the protestor.

The procedure and time limits set forth in this section are mandatory and are the sole and exclusive remedy in the event of a bid protest. Failure to comply with these procedures shall constitute a failure to exhaust administrative remedies and a waiver of any right to further pursue the bid protest, including filing a Government Code Claim or legal proceedings.

21. WORKERS COMPENSATION

Each bidder shall submit the Contractor's Certificate Regarding Workers' Compensation form.

22. RETENTION AND SUBSTITUTION OF SECURITY

The Contract Documents call for monthly progress payments based upon the percentage of the work completed. Unless the District has made findings pursuant to Public Contract Code section 7201 (that the work included in this Contract is substantially complex, and therefore a retention of 10% shall be withheld from each progress payment as provided by the Contract Documents), the District will retain five percent (5%) of each progress payment as provided by the Contract Documents. At the request and expense of the successful Bidder, the District will substitute securities for the amount so retained in accordance with Public Contract Code Section 22300.

23. PREVAILING WAGES

The District has obtained from the Director of the Department of Industrial Relations the general prevailing rate of per diem wages in the locality in which this work is to be performed for each craft or type of worker needed to execute the Contract. These rates are on file and available at the District's offices, 6230 Sylvan Road, Citrus Heights, California 95610, or may be obtained online at http://www.dir.ca.gov/dlsr. Bidders are advised that a copy of these rates must be posted by the successful Bidder at the job site(s).

If the Work involves federal funds or otherwise requires compliance with the Davis-Bacon Fair Labor Standards Act, the Contractor and all its subcontractors shall pay the higher of the state or federal prevailing wage rates.

24. DEBARMENT OF CONTRACTORS AND SUBCONTRACTORS

In accordance with the provisions of the Labor Code, contractors or subcontractors may not perform work on a public works project with a subcontractor who is ineligible to perform work on a public project pursuant to Section 1777.1 or Section 1777.7 of the Labor Code. Any contract on a public works project entered into between a contractor and a debarred subcontractor is void as a matter of law. A debarred subcontractor may not receive any public money for performing work as a subcontractor on a public works contract. Any public money that is paid to a debarred subcontractor by the Contractor for the Project shall be returned to the District. The Contractor shall be responsible for the payment of wages to workers of a debarred subcontractor who has been allowed to work on the Project.

25. IRAN CONTRACTING ACT CERTIFICATION

Each bidder shall submit the certification required by the Iran Contracting Act of 2010, Public Contract Code section 2200 *et seq.* with its bid. The certification is included in the Contract Documents.

26. PERFORMANCE BOND AND PAYMENT BOND REQUIREMENTS

Within the time specified in the Contract Documents, the Bidder to whom a Contract is awarded shall deliver to the District four identical counterparts of the Performance Bond and Payment Bond in the form supplied by the District and included in the Contract Documents. Failure to do so may, in the sole discretion of District, result in the forfeiture of the Bid Guarantee. The surety supplying the bond must be an admitted surety insurer, as defined in Code of Civil Procedure Section 995.120, authorized to do business as such in the State of California and satisfactory to the District. The Performance Bond and the Payment Bond shall be for one hundred percent (100%) of the Total Bid Price.

27. REQUEST FOR SUBSTITUTIONS

The successful bidder shall comply with the substitution request provisions set forth in the Special Conditions, including any deadlines for substitution requests **which may occur prior to the bid opening date**.

28. SALES AND OTHER APPLICABLE TAXES, PERMITS, LICENSES AND FEES

Contractor and its subcontractors performing work under this Contract will be required to pay California sales tax and other applicable taxes, and to pay for permits, licenses and fees required by the agencies with authority in the jurisdiction in which the work will be located, unless otherwise expressly provided by the Contract Documents. Bidders shall include all applicable taxes and fees that are in effect or reasonably anticipated on the bid date in their bid price.

29. EXECUTION OF CONTRACT

As required herein, the Bidder to whom an award is made shall execute two identical counterparts of the Contract in the amount determined by the Contract Documents. The District may require appropriate evidence that the persons executing the Contract are duly empowered to do so.

END OF INSTRUCTIONS TO BIDDERS

BID FORM

NAME OF BIDDER: TAK Communications CA Inc

The undersigned, hereby declare that we have carefully examined the location of the proposed Work, and have read and examined the Contract Documents, including all plans, specifications, and all addenda, if any, for the following Project:

6700 MADISON AVENUE AT DEWEY DRIVE
WATER MAIN PROJECT

We hereby propose to furnish all labor, materials, equipment, tools, transportation, and services, and to discharge all duties and obligations necessary and required to perform and complete the Project in strict accordance with the Contract Documents for the TOTAL BID PRICE.

In the event the bid schedule requires unit pricing, final payment shall be determined by the District from measured quantities of work performed based upon the unit price.

Bid Item	Description	Quantity	Units	Unit Cost	Price
1	Mobilization. (8% Max. of total)	1	Lump Sum		3690 00
2	Sheeting, shoring and bracing. (1% Max. total)	1	Lump Sum		460 00
3	Traffic control plan and implementation. (5% Max. of total)	1	Lump Sum		2300 00
4	Storm water pollution prevention implementation. (1% Max. of total)	1	Lump Sum		460 00
5	Install 8" Pressure Class 350 Ductile Iron Pipe (PC350 DIP) water main.	115	Lineal Feet	250 00	28,750 00
6	8" connection to existing 8" water main.	2	Each	6500 00	13,000 00
7	3" to 4" Max. depth Asphaltic Concrete (AC) paving restoration.	140	Square Feet	23 00	3220 00
8	Concrete Planter Curb Restoration.	10	Lineal Feet	80 00	800 00
9	Landscape Restoration.	750	Square Feet	7 00	5,250 00
				Total Cost	57,930 00

Bidders must provide pricing for every bid item.

The estimated quantities for unit price items are for purposes of comparing bids only and the District makes no representation that the actual quantities of work performed will not vary from the estimates.

In case of discrepancy between the unit price and the line item cost set forth for a unit price item, the line item cost, calculated at the unit price multiplied by the estimated quantity, shall prevail and shall be utilized as the basis for determining the lowest responsive, responsible bidder. However, if the amount set forth as a unit price is ambiguous, unintelligible or uncertain for any cause, or is omitted, or is the same amount as the entry in the "Line Item Cost" column, then the amount set forth in the "Line Item Cost" column for the item shall prevail and shall be divided by the estimated quantity for the item and the price thus obtained shall be the unit price. If any of the above discrepancies exist, the District may recalculate the bid price on the basis of the unit price and the bidder agrees to be bound by such recalculation. Final payment for unit price items shall be determined by the Engineer from measured quantities of work performed based upon the unit price.

TOTAL BID PRICE (BASED ON BID SCHEDULE TOTAL OF UNIT PRICES):

$ 57,930.00
Total Bid Price in Numbers

Fifty Seven Thousand and Nine Hundred Thirty Dollars
Total Bid Price in Written Form

In case of discrepancy between the written price and the numerical price, the written price shall prevail.

The undersigned agrees that the bid accompanied by this Bid Form constitutes a firm offer to the District which cannot be withdrawn for the number of calendar Days indicated in the Notice Inviting Bids from and after the bid opening, or until a Contract for the Work is fully executed by the District and a third party, whichever is earlier.

If the Contract Documents specify alternate bid items, the Alternate Additive or Deductive Bid amounts shall be added to or deducted from the Total Bid Price at the District's sole option. The District can choose to include one or more of the Alternate Bids in the Project. If any of the Alternate Bids are selected by the District, the resulting amount shall be added to or deducted from Total Bid Price for the Project. The District may select one or more of the Alternate Bids at the stated Bid Price up to sixty (60) Days following award of the Contract. The District can award/select Alternate Bid items at any time(s).

The Contract duration shall commence on the date stated in the District's Notice to Proceed, and shall be completed by the Contractor in the time specified in the Contract Documents. In no case shall the Contractor commence construction prior to the date stated in the District's Notice to Proceed, or before providing the required bonds and evidence of insurance.

Bidder certifies that it is licensed in accordance with the law providing for the registration of Contractors, License No. 1042947, Expiration Date 8/31/24, class of license A. Bidder certifies that it and all sub-contractors are registered with the Department of Industrial Relations to perform public work, Registration No. __________ (provide DIR for all sub-contractors, separate pages may be attached as needed). If the bidder is a joint venture, each member of the joint venture must include the above information.

The undersigned acknowledges understanding and full consideration of any issued addenda to the Contract Documents.

1. Attached is the required bid security in the amount of not less than 10% of the Total Bid Price.
2. Attached is the fully executed Non-Collusion Declaration form.
3. Attached is the completed Designation of Subcontractors form.
4. Attached is the completed Bidder Information Form.
5. Attached is the completed Iran Contracting Act Certification.
6. Attached is the completed Contractor's Certificate Regarding Workers' Compensation form.

I hereby certify under penalty of perjury under the laws of the State of California, that all of the information submitted in connection with this Bid and all of the representations made herein are true and correct.

Name of Bidder TAK Communications CA Inc

Signature S C Medley

Name and Title Steven Medley Director of Water

Dated 8/30/2022

END OF BID FORM

CONTRACTOR'S CERTIFICATE REGARDING WORKERS' COMPENSATION

I am aware of the provisions of Section 3700 of the Labor Code which require every employer to be insured against liability for workers' compensation or to undertake self-insurance in accordance with the provisions of that code, and I will comply with such provisions before commencing the performance of the work of this Contract.

Name of Bidder TAK Communications CA Inc

Signature [signature]

Name Steven Medley

Title Director of Water

Dated 8/30/2021

END OF CONTRACTOR'S CERTIFICATE REGARDING WORKERS' COMPENSATION

MERCHANTS
BONDING COMPANY

POWER OF ATTORNEY

Know All Persons By These Presents, that MERCHANTS BONDING COMPANY (MUTUAL) and MERCHANTS NATIONAL BONDING, INC., both being corporations of the State of Iowa (herein collectively called the "Companies") do hereby make, constitute and appoint, individually,

Kesha Greene

their true and lawful Attorney(s)-in-Fact, to sign its name as surety(ies) and to execute, seal and acknowledge any and all bonds, undertakings, contracts and other written instruments in the nature thereof, on behalf of the Companies in their business of guaranteeing the fidelity of persons, guaranteeing the performance of contracts and executing or guaranteeing bonds and undertakings required or permitted in any actions or proceedings allowed by law.

This Power-of-Attorney is granted and is signed and sealed by facsimile under and by authority of the following By-Laws adopted by the Board of Directors of Merchants Bonding Company (Mutual) on April 23, 2011 and amended August 14, 2015 and adopted by the Board of Directors of Merchants National Bonding, Inc., on October 16, 2015.

"The President, Secretary, Treasurer, or any Assistant Treasurer or any Assistant Secretary or any Vice President shall have power and authority to appoint Attorneys-in-Fact, and to authorize them to execute on behalf of the Company, and attach the seal of the Company thereto, bonds and undertakings, recognizances, contracts of indemnity and other writings obligatory in the nature thereof."

"The signature of any authorized officer and the seal of the Company may be affixed by facsimile or electronic transmission to any Power of Attorney or Certification thereof authorizing the execution and delivery of any bond, undertaking, recognizance, or other suretyship obligations of the Company, and such signature and seal when so used shall have the same force and effect as though manually fixed."

In connection with obligations in favor of the Florida Department of Transportation only, it is agreed that the power and authority hereby given to the Attorney-in-Fact includes any and all consents for the release of retained percentages and/or final estimates on engineering and construction contracts required by the State of Florida Department of Transportation. It is fully understood that consenting to the State of Florida Department of Transportation making payment of the final estimate to the Contractor and/or its assignee, shall not relieve this surety company of any of its obligations under its bond.

In connection with obligations in favor of the Kentucky Department of Highways only, it is agreed that the power and authority hereby given to the Attorney-in-Fact cannot be modified or revoked unless prior written personal notice of such intent has been given to the Commissioner-Department of Highways of the Commonwealth of Kentucky at least thirty (30) days prior to the modification or revocation.

In Witness Whereof, the Companies have caused this instrument to be signed and sealed this 4th day of August, 2022.

MERCHANTS NATIONAL BONDING, INC. INCORPORATED -o- 2003

MERCHANTS BONDING COMPANY (MUTUAL) INCORPORATED -o- 1933

MERCHANTS BONDING COMPANY (MUTUAL)
MERCHANTS NATIONAL BONDING, INC.

By Larry Taylor
President

STATE OF IOWA
COUNTY OF DALLAS ss.
On this 4th day of August, 2022, before me appeared Larry Taylor, to me personally known, who being by me duly sworn did say that he is President of MERCHANTS BONDING COMPANY (MUTUAL) and MERCHANTS NATIONAL BONDING, INC.; and that the seals affixed to the foregoing instrument are the Corporate Seals of the Companies; and that the said instrument was signed and sealed in behalf of the Companies by authority of their respective Boards of Directors.

NOTARIAL SEAL IOWA
POLLY MASON
Commission Number 750576
My Commission Expires
January 07, 2023

Polly Mason
Notary Public

(Expiration of notary's commission does not invalidate this instrument)

I, William Warner, Jr., Secretary of MERCHANTS BONDING COMPANY (MUTUAL) and MERCHANTS NATIONAL BONDING, INC., do hereby certify that the above and foregoing is a true and correct copy of the POWER-OF-ATTORNEY executed by said Companies, which is still in full force and effect and has not been amended or revoked.

In Witness Whereof, I have hereunto set my hand and affixed the seal of the Companies on this 4th day of August, 2022.

MERCHANTS NATIONAL BONDING, INC. INCORPORATED -o- 2003

MERCHANTS BONDING COMPANY (MUTUAL) INCORPORATED -o- 1933

William Warner Jr.
Secretary

POA 0018 (1/20)

MERCHANTS
BONDING COMPANY™

Merchants Bonding Company (Mutual) P.O. BOX 14498, DES MOINES, IOWA 50306-3498
PHONE: (800) 678-8171 FAX: (515) 243-3854

Bid Bond

CONTRACTOR:
(Name, legal status and address)
TAK Communications CA
4125 Northgate Blvd.
Sacramento, CA 95834

SURETY:
Bond Number: Bid Bond
(Name, legal status and principal place of business)
Merchants Bonding Company (Mutual)
A Corporation
6700 Westown Parkway, West Des Moines, IA 50266

OWNER:
(Name, legal status and address)
Citrus Heights Water District
6230 Sylvan Road
Citrus Heights, CA 95610

BOND AMOUNT:
10% Ten Percent of Amount Bid

PROJECT:
(Name, location or address, and Project number, if any)
6700 Madison Avenue at Dewey Drive Water Main Project

This document has important legal consequences. Consultation with an attorney is encouraged with respect to its completion or modification.

Any singular reference to Contractor, Surety, Owner or other party shall be considered plural where applicable.

The Contractor and Surety are bound to the Owner in the amount set forth above, for the payment of which the Contractor and Surety bind themselves, their heirs, executors, administrators, successors and assigns, jointly and severally, as provided herein. The conditions of this Bond are such that if the Owner accepts the bid of the Contractor within the time specified in the bid documents, or within such time period as may be agreed to by the Owner and Contractor, and the Contractor either (1) enters into a contract with the Owner in accordance with the terms of such bid, and gives such bond or bonds as may be specified in the bidding or Contract Documents, with a surety admitted in the jurisdiction of the Project and otherwise acceptable to the Owner, for the faithful performance of such Contract and for the prompt payment of labor and material furnished in the prosecution thereof; or (2) pays to the Owner the difference, not to exceed the amount of this Bond, between the amount specified in said bid and such larger amount for which the Owner may in good faith contract with another party to perform the work covered by said bid, then this obligation shall be null and void, otherwise to remain in full force and effect. The Surety hereby waives any notice of an agreement between the Owner and Contractor to extend the time in which the Owner may accept the bid. Waiver of notice by the Surety shall not apply to any extension exceeding sixty (60) days in the aggregate beyond the time for acceptance of bids specified in the bid documents, and the Owner and Contractor shall obtain the Surety's consent for an extension beyond sixty (60) days.

If this Bond is issued in connection with a subcontractor's bid to a Contractor, the term Contractor in this Bond shall be deemed to be Subcontractor and the term Owner shall be deemed to be Contractor.

When this Bond has been furnished to comply with a statutory or other legal requirement in the location of the Project, any provision in this Bond conflicting with said statutory or legal requirement shall be deemed deleted herefrom and provisions conforming to such statutory or other legal requirement shall be deemed incorporated herein. When so furnished, the intent is that this Bond shall be construed as a statutory bond and not as a common law bond.

Signed and sealed this 4th day of August, 2022

TAK Communications CA
(Principal) *(Seal)*
By: Director of Water [signature]
(Title)

(Witness)

Merchants Bonding Company (Mutual)
(Surety) *(Seal)*
By: [signature]
(Title) Kesha Greene, Attorney-in-Fact

Julian Thelen [signature]
(Witness) Julian Thelen

ACKNOWLEDGMENT BY SURETY

STATE OF Minnesota
County of Hennepin } ss.

On this 4th day of August . 2022, before me personally appeared Kesha Greene, known to, me to be the Attorney-in-Fact of Merchants Bonding Company (Mutual), the corporation that executed the within instrument, and acknowledged to me that such corporation executed the same.

IN WITNESS WHEREOF, I have hereunto set my hand and affixed my official seal, at my office in the aforesaid County, the day and year in this certificate first above written.

KEVIN CHENG
NOTARY PUBLIC
MINNESOTA
My Commission Expires 01/31/2027

Notary Public in the State of Minnesota
County of Hennepin

S-0230/GE 10/99

XDP

CONTRACTOR INFORMATION AND EXPERIENCE FORM

A. INFORMATION ABOUT BIDDER

Failure to complete all information may render your bid non-responsive. [**Indicate not applicable ("N/A") where appropriate.**]

NOTE: Where Bidder is a joint venture, pages shall be duplicated and information provided for all parties to the joint venture.

1.0 Name of Bidder: TAK Communications CA Inc

2.0 Type, if Entity: California Corporation

3.0 Bidder Address: 4125 Northgate Blvd

Sacramento CA 95828

916.514.9800

Facsimile Number Telephone Number

4.0 How many years has Bidder's organization been in business as a Contractor? 4

5.0 How many years has Bidder's organization been in business under its present name? 4

5.1 Under what other or former names has Bidder's organization operated?: GM Construction & Developers Inc

6.0 If Bidder's organization is a corporation, answer the following:

6.1 Date of Incorporation: 2018

6.2 State of Incorporation: California

6.3 President's Name: Micah Mauney

6.4 Vice-President's Name(s): Larry Wray

6.5 Secretary's Name: Justin Hansen

6.6 Treasurer's Name: Dick Hylland

7.0 If an individual or a partnership, answer the following:

7.1 Date of Organization: ______________________

7.2 Name and address of all partners (state whether general or limited partnership):

____

____

____

8.0 If other than a corporation or partnership, describe organization and name principals:

____

____

9.0 List other states in which Bidder's organization is legally qualified to do business.

____

____

____

10.0 What type of work does the Bidder normally perform with its own forces?

Water & Communications

____

11.0 Has Bidder ever failed to complete any work awarded to it? If so, note when, where, and why:

NO

____

12.0 Within the last five years, has any officer or partner of Bidder's organization ever been an officer or partner of another organization when it failed to complete a contract? If so, attach a separate sheet of explanation:

No

13.0 List Trade References:

14.0 List Bank References (Bank and Branch Address):

Central Bank
2500 S Minnesota Ave
Sioux Falls SD 57105

15.0 Name of Bonding Company and Name and Address of Agent:

B. LIST OF CURRENT PROJECTS (Backlog)
[**Duplicate Page if needed for listing additional current projects.**]

Project	Description of Bidder's Work	Completion Date	Cost of Bidder's Work	Contact Name/ Phone Number
SSWD 2022-2023 Maintenance WSA	ER Repairs Water Service Lines Hydrants Mainlines	7/31/2023	500,000	Saramento Suburban Water District
	Service Line accross Fair OAKS Blvd	9/15/2022	18,000-	Fair Oaks Water District
Dyno Nobel	Serviceline acxross street on McClellan Park	9/15/2022	18,000-	Dyno Nobel John Townes

C. LIST OF COMPLETED PROJECTS - LAST THREE YEARS

[**Duplicate Page if needed for listing additional completed projects.**]

Please include only those projects which are similar enough to demonstrate Bidder's ability to perform the required Work.

Project Client	Description of Bidder's Work	Period of Performance	Cost of Bidder's Work	Contact Name/ Phone Number
Whitney Well CO	Mainline Pipe & Valve Replace	7/01/22 8/15/22	214,099	SSWD
Enos Ave Pipeline	Main line Extention	09/01/21- 12/15/21	168,745	Golden state Warter CO
Ambrose Mainline	Mainline	11/01/21 3/31/22	504,445	Golden State Water CO

Burton Court Mainline Extention	Mainline Extention & Water services	11/01/21 3/31/21	122,471	Golden State Water CO
Agnes Mainline	Mainline & Services	10/20 8/21	2,448,383	Golden State Water CO
SSWD Maintenance 2020-2021	ER Repair Hydrants Services	8/1/20 7/31/20	568,508	Sacramento Suburban Water
SSWD Maintenance 2021-2022	ER Repairs Hydrants Services Mainline	8/1/20 7/31/22	600,646	Sacramento Suburban Water Dist.

D. EXPERIENCE AND TECHNICAL QUALIFICATIONS QUESTIONNAIRE

Personnel:

The Bidder shall identify the key personnel to be assigned to this project in a management, construction supervision or engineering capacity.

1. List each person's job title, name and percent of time to be allocated to this project:
   Steven Medley Project Manager 20%
   William McDonnell Project Foreman 100%
   ____
2. Summarize each person's specialized education:
   ____
   ____
   ____
3. List each person's years of construction experience relevant to the project:
   ____
   Steven Medley 30 years
   William McDonnel 10 years
4. Summarize such experience:
   ____
   ____
   ____

Bidder agrees that personnel named in this Bid will remain on this Project in their designated capacities until completion of all relevant Work, unless substituted by personnel of equivalent experience and qualifications approved in advance by the District.

Additional Bidder's Statements:

If the Bidder feels that there is additional information which has not been included in the questionnaire above, and which would contribute to the qualification review, it may add that information in a statement here or on an attached sheet, appropriately marked:

____
____
____
____
____
____

E. VERIFICATION AND EXECUTION

These Bid Forms shall be executed only by a duly authorized official of the Bidder:

I declare under penalty of perjury under the laws of the State of California that the foregoing information is true and correct:

Name of Bidder TAK Communications CA Inc

Signature S C Medley

Name Steven Medley

Title Director of Water

Dated 8/30/2022

END OF CONTRACTOR INFORMATION AND EXPERIENCE FORM

LIST OF SUBCONTRACTORS FORM

In compliance with the Subletting and Subcontracting Fair Practices Act of the Public Contract Code of the State of California, each bidder shall set forth below: (a) the name, contractor's license number and the location of the place of business of and (b) the portion of the work which will be done by each subcontractor who will perform work or labor or render service to the Contractor in or about the construction of the work in an amount in excess of one-half of one percent (1/2%) of the Contractor's Total Bid Price. Notwithstanding the foregoing, if the work involves streets and highways, then the Contractor shall list each subcontractor who will perform work or labor or render service to Contractor in or about the work in an amount in excess of one-half of one percent (1/2%) of the Contractor's Total Bid Price or $10,000, whichever is greater. The District may, within its sole discretion, grant additional time to provide the below requested information.

If no subcontractor is specified for a portion of the Work, or if more than one subcontractor is specified for the same portion of Work, to be performed under the Contract in excess of one-half of one percent (1/2%) of the Contractor's Total Bid Price or $10,000, whichever is greater, or if the work involves streets or highways, then the Contractor shall be deemed to have agreed that it is fully qualified to perform that Work, and that it shall perform that portion itself.

The completed form shall include a Department of Industrial Relations registration number for all subcontractors. Failure to include a registration number may cause the bid to be non-responsive.

Portion of the Work	Subcontractor	Location of Business	% of the Work	License & Registration Numbers
NA				

Portion of the Work	Subcontractor	Location of Business	% of the Work	License & Registration Numbers

Name of Bidder TAK Communication CA Inc

Signature [signature]

Name and Title Steven Medley Director of Water

Dated 8/30/2022

END OF LIST OF SUBCONTRACTORS FORM

IRAN CONTRACTING ACT CERTIFICATION

(Public Contract Code section 2200 *et seq.*)

As required by California Public Contract Code section 2204, the Contractor certifies subject to penalty for perjury that the option checked below relating to the Contractor's status in regard to the Iran Contracting Act of 2010 (Public Contract Code section 2200 *et seq.*) is true and correct:

☐ The Contractor is not:
   (i) identified on the current list of persons and entities engaging in investment activities in Iran prepared by the California Department of General Services in accordance with subdivision (b) of Public Contract Code section 2203; or
   (ii) a financial institution that extends, for 45 Days or more, credit in the amount of $20,000,000 or more to any other person or entity identified on the current list of persons and entities engaging in investment activities in Iran prepared by the California Department of General Services in accordance with subdivision (b) of Public Contract Code section 2203, if that person or entity uses or will use the credit to provide goods or services in the energy sector in Iran.

☐ District has exempted the Contractor from the requirements of the Iran Contracting Act of 2010 after making a public finding that, absent the exemption, District will be unable to obtain the goods and/or services to be provided pursuant to the Contract.

☐ The amount of the Contract payable to the Contractor for the Work does not exceed $1,000,000.

Signed____

Titled____

Firm____

Date____

Note: In accordance with Public Contract Code section 2205, false certification of this form shall be reported to the California Attorney General and may result in civil penalties equal to the greater of $250,000 or twice the Contract Price, termination of the Contract and/or ineligibility to bid on contracts for three years.

END OF IRAN CONTRACTING ACT CERTIFICATION

CONTRACT

THIS CONTRACT is made this _____ Day of _________, 2022, in the County of Sacramento, State of California, by and between the Citrus Heights Water District, hereinafter called District, and TAK Communications Ca, Inc., hereinafter called Contractor. The District and the Contractor for the considerations stated herein agree as follows:

ARTICLE 1. SCOPE OF WORK. The Contractor shall perform all Work within the time stipulated the Contract and shall provide all labor, materials, equipment, tools, utility services, and transportation to complete all of the Work required in strict compliance with the Contract Documents as specified in Article 5 below for the following Project:

6700 Madison Avenue at Dewey Drive Water Main Project

The Contractor and its surety shall be liable to the District for any damages arising as a result of the Contractor's failure to comply with this obligation.

ARTICLE 2. TIME FOR COMPLETION. Time is of the essence in the performance of the Work. The Work shall be commenced on the date stated in the District's Notice to Proceed. The Contractor shall complete all Work required by the Contract Documents within **45** calendar Days from the commencement date stated in the Notice to Proceed, herein after the Contract Time. By its signature hereunder, Contractor agrees the Contract Time for completion set forth above is adequate and reasonable to complete the Work.

ARTICLE 3. CONTRACT PRICE. The District shall pay to the Contractor as full compensation for the performance of the Contract, subject to any additions or deductions as provided in the Contract Documents, and including all applicable taxes and costs, the sum of Fifty-Seven Thousand Nine Hundred Thirty Dollars and Zero Cents ($57,930.00), hereinafter the Contract Price. Payment shall be made as set forth in the General Conditions.

ARTICLE 4. LIQUIDATED DAMAGES. The Contractor acknowledges that the District will sustain actual damages for each and every Day completion of the Project is delayed beyond the Contract Time. Because of the nature of the Project, it would be impracticable or extremely difficult to determine the District's actual damages. Accordingly, as provided in Government Code section 53069.85, it is agreed that the Contractor will pay the District the sum of **$500.00** for each and every calendar Day of delay in completing the Work beyond the time prescribed in the Contract Documents for finishing the Work, as Liquidated Damages and not as a penalty or forfeiture. In the event the Liquidated Damages are not paid, the Contractor agrees the District may deduct that amount from any money due or that may become due the Contractor under the Contract. This Article does not affect the District's rights to other damages or remedies specified in the Contract Documents or allowed by law.

Should Contractor be inexcusably delayed in the performance of the Work, District may deduct Liquidated Damages based on its estimate of when Contractor will achieve Final Completion or other milestones. District need not wait until Final Completion to withhold Liquidated Damages from Contractor.

Liquidated Damages are not a penalty but an agreed upon estimate of the actual damages that would be sustained by the District for delay, including but not limited to loss of revenue, inconvenience to the District and the public, and increased Project administration expenses, such as extra inspection, construction management, staff time and architectural and engineering expenses. Liquidated Damages do not include actual damages the District incurs on account of claims by third parties against the District on account of any delay.

Should money due or to become due to the Contractor be insufficient to cover Liquidated Damages or other offsets due, then Contractor forthwith shall pay the remainder of the assessed liquidated damages to District.

ARTICLE 5. COMPONENT PARTS OF THE CONTRACT. The “Contract Documents” include the following documents, each of which is incorporated into this Contract by reference:

- Notice Inviting Bids
- Instructions to Bidders
- Bid Form
- Contractor’s Certificate Regarding Workers’ Compensation
- Bid Bond
- Non-Collusion Declaration form
- Contractor Information and Experience Form
- List of Subcontractors Form
- Iran Contracting Act Certification
- Contract
- Performance Bond
- Payment Bond
- General Conditions
- Special Conditions
- General Specifications
- Special Provisions
- Construction Details
- Project Plans
- Encroachment Permit Documents
- Any other documents contained in or incorporated into the Contract

The Contactor shall complete the Work in strict accordance with all of the Contract Documents.

All of the Contract Documents are intended to be complementary. Work required by one of the Contract Documents and not by others shall be done as if required by all. This Contract shall supersede any prior agreement of the parties.

ARTICLE 6. PROVISIONS REQUIRED BY LAW. Each and every provision of law required to be included in these Contract Documents shall be deemed to be included in these Contract Documents. The Contractor shall comply with all requirements of applicable federal, state and local laws, rules and regulations, including but not limited to, the provisions of the California Labor Code and Public Contract Code applicable to this Project.

If the Work involves federal funds, the Contractor and all its subcontractors shall comply with all requirements set forth in the attached Federal Requirements.

ARTICLE 7. INDEMNIFICATION. Contractor shall provide indemnification as set forth in the General Conditions.

ARTICLE 8. PREVAILING WAGES. Contractor shall be required to pay the prevailing rate of wages in accordance with the Labor Code which such rates shall be made available at the District's offices, 6230 Sylvan Road, Citrus Heights, California 95610, or may be obtained online at http//www.dir.ca.gov/dlsr. and which must be posted at the job site.

IN WITNESS WHEREOF, this Contract has been duly executed by the above-named parties, on the Day and year above written.

TAK Communications Ca, Inc.	**CITRUS HEIGHTS WATER DISTRICT**
By ________________________________	By________________________________
Name and Title:	Name and Title:
__________________________________	Hilary M. Straus, General Manager
License No.	
__________	
DIR Registration No.	
______________	

END OF CONTRACT

PERFORMANCE BOND

KNOW ALL PERSONS BY THESE PRESENTS:

THAT WHEREAS, the Citrus Heights Water District (hereinafter referred to as "District") has awarded to ____________________, (hereinafter referred to as the "Contractor") ________________________ an agreement for _______________________________ (hereinafter referred to as the "Project").

WHEREAS, the work to be performed by the Contractor is more particularly set forth in the Contract Documents for the Project dated ________________, (hereinafter referred to as "Contract Documents"), the terms and conditions of which are expressly incorporated herein by reference; and

WHEREAS, the Contractor is required by said Contract Documents to perform the terms thereof and to furnish a bond for the faithful performance of said Contract Documents.

NOW, THEREFORE, we, ________________, the undersigned Contractor and ____ as Surety, a corporation organized and duly authorized to transact business under the laws of the State of California, are held and firmly bound unto the District in the sum of ____________________________ DOLLARS, ($____________), said sum being not less than one hundred percent (100%) of the total amount of the Contract, for which amount well and truly to be made, we bind ourselves, our heirs, executors and administrators, successors and assigns, jointly and severally, firmly by these presents.

THE CONDITION OF THIS OBLIGATION IS SUCH, that, if the Contractor, his or its heirs, executors, administrators, successors or assigns, shall in all things stand to and abide by, and well and truly keep and perform the covenants, conditions and agreements in the Contract Documents and any alteration thereof made as therein provided, on its part, to be kept and performed at the time and in the manner therein specified, and in all respects according to their intent and meaning; and shall faithfully fulfill all obligations including the one-year guarantee of all materials and workmanship; and shall indemnify and save harmless the District, its officers and agents, as stipulated in said Contract Documents, then this obligation shall become null and void; otherwise it shall be and remain in full force and effect.

As a condition precedent to the satisfactory completion of the Contract Documents, unless otherwise provided for in the Contract Documents, the above obligation shall hold good for a period of one (1) year after the acceptance of the work by District, during which time if Contractor shall fail to make full, complete, and satisfactory repair and replacements and totally protect the District from loss or damage resulting from or caused by defective materials or faulty workmanship, Surety shall undertake and faithfully fulfill all such obligations. The obligations of Surety hereunder shall continue so long as any obligation of Contractor remains. Nothing herein shall limit the District's rights or the

Contractor or Surety's obligations under the Contract, law or equity, including, but not limited to, California Code of Civil Procedure section 337.15.

Whenever Contractor shall be, and is declared by the District to be, in default under the Contract Documents, the Surety shall remedy the default pursuant to the Contract Documents, or shall promptly, at the District's option:

(1) Take over and complete the Project in accordance with all terms and conditions in the Contract Documents; or

(2) Obtain a bid or bids for completing the Project in accordance with all terms and conditions in the Contract Documents and upon determination by Surety of the lowest responsive and responsible bidder, arrange for a Contract between such bidder, the Surety and the District, and make available as work progresses sufficient funds to pay the cost of completion of the Project, less the balance of the contract price, including other costs and damages for which Surety may be liable. The term "balance of the contract price" as used in this paragraph shall mean the total amount payable to Contractor by the District under the Contract and any modification thereto, less any amount previously paid by the District to the Contractor and any other set offs pursuant to the Contract Documents.

(3) Permit the District to complete the Project in any manner consistent with local, California and federal law and make available as work progresses sufficient funds to pay the cost of completion of the Project, less the balance of the contract price, including other costs and damages for which Surety may be liable. The term "balance of the contract price" as used in this paragraph shall mean the total amount payable to Contractor by the District under the Contract and any modification thereto, less any amount previously paid by the District to the Contractor and any other set offs pursuant to the Contract Documents.

Surety expressly agrees that the District may reject any contractor or subcontractor which may be proposed by Surety in fulfillment of its obligations in the event of default by the Contractor.

Surety shall not utilize Contractor in completing the Project nor shall Surety accept a bid from Contractor for completion of the Project if the District, when declaring the Contractor in default, notifies Surety of the District's objection to Contractor's further participation in the completion of the Project.

The Surety, for value received, hereby stipulates and agrees that no change, extension of time, alteration or addition to the terms of the Contract Documents or to the Project to be performed thereunder shall in any way affect its obligations on this bond, and it does hereby waive notice of any such change, extension of time, alteration or addition to the terms of the Contract Documents or to the Project, including but not limited to the provisions of sections 2819 and 2845 of the California Civil Code.

IN WITNESS WHEREOF, we have hereunto set our hands and seals this _______ Day of ______________, 20__).

(Corporate Seal)

____
Contractor/ Principal

By ______________________________

Title ______________________________

____

(Corporate Seal)

Surety

By ______________________________
Attorney-in-Fact

Signatures of those signing for the Contractor and Surety must be notarized and evidence of corporate authority attached.

(Attach Attorney-in-Fact Certificate)

Title ______________________________

The rate of premium on this bond is ____________ per thousand. The total amount of premium charges, $_______________________________.
(The above must be filled in by corporate attorney.)

<u>THIS IS A REQUIRED FORM</u>

Any claims under this bond may be addressed to:

(Name and Address of Surety) ____

____

____

(Name and Address of Agent or Representative for service of process in California, if different from above) ____

____

____

(Telephone number of Surety and Agent or Representative for service of process in California ____

Notary Acknowledgment

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

STATE OF CALIFORNIA
COUNTY OF ______________

On ___________________, 20___, before me, _______________________________, Notary Public, personally appeared ____, who proved to me on the basis of satisfactory
Name(s) of Signer(s)
evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

Signature of Notary Public ______________________________________

OPTIONAL

Though the information below is not required by law, it may prove valuable to persons relying on the document and could prevent fraudulent removal and reattachment of this form to another document.

CAPACITY CLAIMED BY SIGNER

- ☐ Individual
- ☐ Corporate Officer

____
Title(s)

- ☐ Partner(s) ☐ Limited ☐ General
- ☐ Attorney-In-Fact
- ☐ Trustee(s)
- ☐ Guardian/Conservator
- ☐ Other:

Signer is representing:
Name Of Person(s) Or Entity(ies)

____
____

DESCRIPTION OF ATTACHED DOCUMENT

____
Title or Type of Document

____
Number of Pages

____
Date of Document

____
Signer(s) Other Than Named Above

PAYMENT BOND

KNOW ALL MEN BY THESE PRESENTS That

WHEREAS, the Citrus Heights Water District (hereinafter designated as the "District"), by action taken or a resolution passed____________, 20____has awarded to ________________ hereinafter designated as the "Principal," a contract for the work described as follows:

____ (the "Project"); and

WHEREAS, the work to be performed by the Principal is more particularly set forth in the Contract Documents for the Project dated __________________ ("Contract Documents"), the terms and conditions of which are expressly incorporated by reference; and

WHEREAS, said Principal is required to furnish a bond in connection with said contract; providing that if said Principal or any of its Subcontractors shall fail to pay for any materials, provisions, provender, equipment, or other supplies used in, upon, for or about the performance of the work contracted to be done, or for any work or labor done thereon of any kind, or for amounts due under the Unemployment Insurance Code or for any amounts required to be deducted, withheld, and paid over to the Employment Development Department from the wages of employees of said Principal and its Subcontractors with respect to such work or labor the Surety on this bond will pay for the same to the extent hereinafter set forth.

NOW THEREFORE, we, the Principal and ___________________________ as Surety, are held and firmly bound unto the District in the penal sum of _______________ ____________________________ Dollars ($___________) lawful money of the United States of America, for the payment of which sum well and truly to be made, we bind ourselves, our heirs, executors, administrators, successors and assigns, jointly and severally, firmly by these presents.

THE CONDITION OF THIS OBLIGATION IS SUCH that if said Principal, his or its subcontractors, heirs, executors, administrators, successors or assigns, shall fail to pay any of the persons named in Section 9100 of the Civil Code, fail to pay for any materials, provisions or other supplies, used in, upon, for or about the performance of the work contracted to be done, or for any work or labor thereon of any kind, or amounts due under the Unemployment Insurance Code with respect to work or labor performed under the contract, or for any amounts required to be deducted, withheld, and paid over to the Employment Development Department or Franchise Tax Board from the wages of employees of the Contractor and his subcontractors pursuant to Section 18663 of the Revenue and Taxation Code, with respect to such work and labor the Surety or Sureties will pay for the same, in an amount not exceeding the sum herein above specified.

This bond shall inure to the benefit of any of the persons named in Section 9100 of the Civil Code so as to give a right of action to such persons or their assigns in any suit brought upon this bond.

It is further stipulated and agreed that the Surety on this bond shall not be exonerated or released from the obligation of this bond by any change, extension of time for performance, addition, alteration or modification in, to, or of any contract, plans, Specifications, or agreement pertaining or relating to any scheme or work of improvement herein above described, or pertaining or relating to the furnishing of labor, materials, or equipment therefore, nor by any change or modification of any terms of payment or extension of the time for any payment pertaining or relating to any scheme or work of improvement herein above described, nor by any rescission or attempted rescission of the contract, agreement or bond, nor by any conditions precedent or subsequent in the bond attempting to limit the right of recovery of claimants otherwise entitled to recover under any such contract or agreement or under the bond, nor by any fraud practiced by any person other than the claimant seeking to recover on the bond and that this bond be construed most strongly against the Surety and in favor of all persons for whose benefit such bond is given, and under no circumstances shall Surety be released from liability to those for whose benefit such bond has been given, by reason of any breach of contract between the owner or District and original Contractor or on the part of any obligee named in such bond, but the sole conditions of recovery shall be that claimant is a person described in Section 9100 of the Civil Code, and has not been paid the full amount of his claim and that Surety does hereby waive notice of any such change, extension of time, addition, alteration or modification herein mentioned and the provisions of sections 2819 and 2845 of the California Civil Code.

IN WITNESS WHEREOF, we have hereunto set our hands and seals this _______ Day of ______________, 20__.

(Corporate Seal)

____
Contractor/ Principal

By ______________________________

Title ____________________________

____

(Corporate Seal)

Surety

By ______________________________
Attorney-in-Fact

Title ____________________________

Signatures of those signing for the Contractor and Surety must be notified and evidence of corporate authority attached. A Power-of-Attorney authorizing the person signing on behalf of the Surety to do so much be attached hereto.

Notary Acknowledgment

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

STATE OF CALIFORNIA
COUNTY OF ______________

On ___________________, 20___, before me, _______________________________, Notary Public, personally appeared ____, who proved to me on the basis of satisfactory
Name(s) of Signer(s)

evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

Signature of Notary Public _______________________________________

OPTIONAL

Though the information below is not required by law, it may prove valuable to persons relying on the document and could prevent fraudulent removal and reattachment of this form to another document.

CAPACITY CLAIMED BY SIGNER

☐ Individual
☐ Corporate Officer

____
Title(s)

☐ Partner(s) ☐ Limited
☐ General
☐ Attorney-In-Fact
☐ Trustee(s)
☐ Guardian/Conservator
☐ Other:

Signer is representing:
Name Of Person(s) Or Entity(ies)

____
____

DESCRIPTION OF ATTACHED DOCUMENT

____
Title or Type of Document

____
Number of Pages

____
Date of Document

____
Signer(s) Other Than Named Above

GENERAL CONDITIONS

ARTICLE 1. DEFINITIONS

a. Acceptable, Acceptance or words of similar import shall be understood to be the acceptance of the Engineer and/or the District .

b. Act of God is an earthquake of magnitude 3.5 or higher on the Richter scale or a tidal wave.

c. Applicable Laws means laws, statutes, ordinances, rules, codes, regulations permits and licenses of any kind, issued by local, state or federal governmental authorities or private authorities with jurisdiction (including utilities), to the extent they apply to the Work.

d. Approval means written authorization by Engineer and/or District .

e. Contract Documents includes all documents as stated in the Contract.

f. Day shall mean calendar Day unless otherwise specifically designated.

g. District and Contractor are those stated in the Contract. The terms District, CHWD, and Owner may be used interchangeably.

h. Engineer shall mean the District Engineer or his or her designee, of Citrus Heights Water District, acting either directly or through properly authorized agents, such as agents acting within the scope of the particular duties entrusted to them. Also sometimes referred to as the “District’s Representative” or “Representative” in the Contract Documents.

i. Equal, Equivalent, Satisfactory, Directed, Designated, Selected, As Required and similar words shall mean the written approval, selection, satisfaction, direction, or similar action of the Engineer and/or District.

j. Indicated, Shown, Detailed, Noted, Scheduled or words of similar meaning shall mean that reference is made to the drawings, unless otherwise noted. It shall be understood that the direction, designation, selection, or similar import of the Engineer and/or District is intended, unless stated otherwise.

k. Install means the complete installation of any item, equipment or material.

l. Material shall include machinery, equipment, manufactured articles, or construction such as form work, fasteners, etc., and any other classes of material to be furnished in connection with the Contract. All materials shall be new unless specified otherwise.

m. Perform shall mean that the Contractor, at Contractor's expense, shall take all actions necessary to complete The Work, including furnishing of necessary labor, tools, and equipment, and providing and installing Materials that are indicated, specified, or required to complete such performance.

n. Project is The Work planned by District as provided in the Contract Documents.

o. Provide shall include provide complete in place, that is furnish, install, test and make ready for use.

p. Recyclable Waste Materials shall mean materials removed from the Project site which are required to be diverted to a recycling center rather than an area landfill. Recyclable Waste Materials include asphalt, concrete, brick, concrete block, and rock. The Contractor shall coordinate with the appropriate local government agency and comply with local waste disposal ordinances.

q. Specifications means that portion of the Contract Documents consisting of the written requirements for materials, equipment, construction systems, standards and workmanship for the work. In the case of conflict between the Specifications and the Contract Documents, the Contract Documents shall prevail.

r. The Work means the entire improvement planned by the District pursuant to the Contract Documents.

s. Work means labor, equipment and materials incorporated in, or to be incorporated in the construction covered by the Contract Documents.

ARTICLE 2. CONTRACT DOCUMENTS

a. **Contract Documents**. The Contract Documents are complementary, and what is called for by one shall be as binding as if called for by all.

b. **Interpretations**. The Contract Documents are intended to be fully cooperative and to be complementary. If Contractor observes that any documents are in conflict, the Contractor shall promptly notify the Engineer in writing. In case of conflicts between the Contract Documents, the order of precedence shall be as follows:

1. Change Orders or Work Change Directives, the most recent first
2. Addenda, the most recent first
3. Environmental documents and approvals
4. Special Provisions (or Special Conditions)
5. Technical Specifications
6. Plans (Contract Drawings)
7. Contract
8. General Conditions

9. Instructions to Bidders
10. Notice Inviting Bids
11. Contractor's Bid Forms
12. Standard Specifications/Greenbook
13. Standard Plans
14. Reference Documents

With reference to the Drawings, the order of precedence shall be as follows:

1. Figures govern over scaled dimensions
2. Detail drawings govern over general drawings
3. Addenda or Change Order drawings govern over Contract Drawings
4. Contract Drawings govern over Standard Drawings
5. Contract Drawings govern over Shop Drawings

c. **Conflicts in Contract Documents**. Notwithstanding the orders of precedence established above, in the event of conflicts, the higher standard shall always apply.

d. **Organization of Contract Documents**. Organization of the Contract Documents into divisions, sections, and articles, and arrangement of drawings shall not control the Contractor in dividing The Work among subcontractors or in establishing the extent of Work to be performed by any trade.

ARTICLE 3. CONTRACTS DOCUMENTS: COPIES & MAINTENANCE

Contractor will be furnished, free of charge, **3 (three)** copies of the Contract Documents. Additional copies may be obtained at cost of reproduction.

ARTICLE 4. CONTRACTOR SHALL MAINTAIN A CLEAN, UNDAMAGED SET OF CONTRACT DOCUMENTS AT THE PROJECT SITE.

a. **Examination of Contract Documents.** Before commencing any portion of The Work, Contractor shall again carefully examine all applicable Contract Documents, the Project site and other information given to Contractor as to materials and methods of construction and other Project requirements. Contractor shall immediately notify the Engineer in writing of any potential error, inconsistency, ambiguity, conflict or lack of detail or explanation. If Contractor performs, permits, or causes the performance of any Work which is in error, inconsistent or ambiguous, or not sufficiently detailed or explained, Contractor shall bear any and all resulting costs, including, without limitation, the cost of correction. In no case shall the Contractor or any subcontractor proceed with Work if uncertain as to the applicable requirements.

b. **Request for Information; Additional Instructions.** Contractor may make a written request for information to address any error, inconsistency, ambiguity, conflict or lack of detail or explanation in the Contract Documents. The Engineer will provide any required additional instructions, by means of drawings or other written direction, necessary for proper execution of Work.

c. **Quality of Parts, Construction and Finish.** All parts of The Work shall be of the best quality of their respective kinds and the Contractor must use all diligence to inform itself fully as to the required construction and finish. In no case shall Contractor proceed with The Work without obtaining first from the Engineer such written Approval as may be necessary for the proper performance of Work.

d. **Contractor's Variation from Contract Document Requirements.** If it is found that the Contractor has varied from the requirements of the Contract Documents including the requirement to comply with all Applicable Laws, ordinances, rules and regulations, the Engineer may at any time, before or after completion of the Work, order the improper Work removed, remade or replaced by the Contractor at the Contractor's expense.

ARTICLE 5. EXISTENCE OF UTILITIES AT THE WORK SITE

a. **Existing Utilities**

i. General – Known existing utilities and pipelines are shown on the Plans in their approximate locations. However, nothing herein shall be deemed to require the District to indicate the presence of existing service laterals or appurtenances whenever the presence of such utilities can be inferred from the presence of other visible facilities, such as buildings, cleanouts, meter and junction boxes, on or adjacent to the site of the Project.

ii. The District will assume the responsibility for the timely removal, relocation, or protection of existing main or trunk line utility facilities located on the Project site if such utilities are not identified by the District in the Contract Documents or cannot reasonably be inferred from the presence of other visible facilities.

b. **Utility Location**

i. It shall be the Contractor's responsibility to determine the exact location and depth of all utilities, including service connections, which have been marked by the respective utility owners and which the Contractor believes may affect or be affected by the Contractor's operations. The Contractor shall not be entitled to additional compensation or time extensions for work necessary to avoid interferences or for repair to damaged utilities if the Contractor does not expose all such existing utilities as required by this section.

ii. The locating of utilities shall be in conformance with Government Code section 4216 except for the District's utilities located on the District's property and not in public right-of-way.

iii. A "High Priority Subsurface Installation" is defined in section 4216 (e) as "high-pressure natural gas pipelines with normal operating pressures greater than 415kPA gauge (60psig) or greater than six inches nominal pipe diameter, petroleum pipelines, pressurized sewage pipelines, high-voltage electric supply lines, conductors, or cables that have a potential to ground of greater than or equal to 60kv, or hazardous materials pipelines that are potentially hazardous to workers or the public if damaged."

iv. A "Subsurface Installation" is defined in section 4216 (l) as "any underground pipeline, conduit, duct, wire, or other structure, except non-pressurized sewer lines, non-pressurized storm drains, or other non-pressurized drain lines."

v. Pursuant to Government Code section 4216.2 the Contractor shall contact the appropriate regional notification center at least two (2) working Days but not more than fourteen (14) Days before performing any excavation. The Contractor shall request that the utility owners conduct a utility survey and mark or otherwise indicate the location of their service. The Contractor shall furnish to the District written documentation of its contact(s) with the regional notification center prior to commencing excavation at such locations.

vi. After the utility survey is completed, the Contractor shall commence "potholing" or hand digging to determine the actual location of the pipe, duct, or conduit. The District shall be given written notice prior to commencing potholing operations. The Contractor shall uncover all piping and conduits, to a point one (1) foot below the pipe, where crossings, interferences, or connections are shown on the Drawings, prior to trenching or excavating for any pipe or structures, to determine actual elevations. New pipelines shall be laid to such grade as to clear all existing facilities, which are to remain in service for any period subsequent to the construction of the run of pipe involved.

vii. The Contractor's attention is directed to the requirements of Government Code section 4216.2 (a)(2) which provides: "When the excavation is proposed within 10 feet of a high priority subsurface installation, the operator of the high priority subsurface installation shall notify the excavator of the existence of the high priority subsurface installation prior to the legal excavation start date and time, as such date and time are authorized pursuant to paragraph (1) of subdivision (a) of section 4216.2. The excavator and the operator or its representative shall conduct an onsite meeting at a mutually-agreed-on time to determine actions or activities required to verify the location of the high priority subsurface installation prior to start time." The Contractor shall notify the District in advance of this meeting.

c. **Utility Relocation and Repair**

i. If interferences occur at locations other than those indicated in the Contract Documents with reasonable accuracy, Contractor shall notify the District in writing.

ii. Care shall be exercised by the Contractor to prevent damage to adjacent existing facilities and public or private works; where equipment will pass over these obstructions, suitable planking shall be placed. If high priority subsurface installations are damaged and the operator cannot be contacted, Contractor shall call 911 emergency services.

iii. District will compensate the Contractor for the costs of locating and repairing damage not due to the failure of the Contractor to exercise reasonable care, and for removing or relocating such main or trunk line utility facilities not indicated in the Contract Documents with reasonable accuracy, and for the cost of equipment on the Project necessarily idled during such work. The payment for such costs will be made as provided in ARTICLE 46 (Changes and Extra Work). The Contractor shall not be assessed liquidated damages for delay in completion of the Project when such delay is caused by the failure of the District or utility company to provide for removal or relocation of such utility facilities. Requests for extensions of time arising out of utility relocation or repair delays shall be filed in accordance with ARTICLE 46.

iv. The public utility, where they are the owner of the affected utility, shall have the sole discretion to perform repairs or relocation work or permit the Contractor to do such repairs or relocation work at a reasonable price. The right is reserved to the District and the owners of utilities or their authorized agents to enter upon the Work area for the purpose of making such changes as are necessary for the rearrangement of their facilities or for making necessary connections or repairs to their properties. The Contractor shall cooperate with forces engaged in such work and shall conduct its operations in such a manner as to avoid any unnecessary delay or hindrance to the work being performed by such forces and shall allow the respective utilities time to relocate their facility.

v. When the Contract Documents indicate that a utility is to be relocated, altered or constructed by others, the District will conduct all negotiations with the utility company and the work will be done at no cost to the Contractor, unless otherwise stipulated in the Contract.

vi. Temporary or permanent relocation or alteration of utilities desired by the Contractor for its own convenience shall be the Contractor's responsibility and it shall make arrangements and bear all costs for such work.

ARTICLE 6. SCHEDULE

a. **General Requirements.** The schedule shall be prepared in a Critical Path Method ("CPM") format and in an electronic scheduling program acceptable to the District. Contractor shall deliver the schedule and all updates to the District in both paper and electronic form. The electronic versions shall be in the format and include all data used to prepare the schedule; pdf. Copies are not acceptable.

b. **Initial Schedule.** Within ten (10) Days after the issuance of the Notice to Proceed, Contractor shall prepare a schedule for the performance of the Work and shall submit this to the Engineer for Approval. The receipt or Approval of any schedules by the Engineer or the District shall not in any way relieve the Contractor of its obligations under the Contract Documents. The Contractor is fully responsible to determine and provide for any and all staffing and resources at levels which allow for good quality and timely completion of the Project. Contractor's failure to incorporate all elements of Work required for the performance of the Contract or any inaccuracy in the schedule shall not excuse the Contractor from performing all Work required for a completed Project within the specified Contract time period. If the required schedule is not received by the time the first payment under the Contract is due, Contractor shall not be paid until the schedule is received, reviewed and accepted by the Engineer.

c. **Schedule Contents.** The schedule shall allow enough time for inclement weather that can reasonably be expected at the Site. The schedule shall indicate the beginning and completion dates of all phases of construction; critical path for all critical, sequential time related activities; and "float time" for all "slack" or "gaps" in the non-critical activities. The schedule shall clearly identify all staffing and other resources which in the Contractor's judgment are needed to complete the Project within the Contract Time. Schedule duration shall match the Contract Time. Schedules indicating early completion will be rejected.

d. **Schedule Updates.** Contractor shall continuously update its construction schedule to show the actual status of the Work and incorporate changes in the Work. Contractor shall submit an updated and accurate construction schedule to the Engineer whenever requested to do so by Engineer and with each progress payment request. The Engineer may withhold progress payments or other amounts due under the Contract Documents if Contractor fails to submit an updated and accurate construction schedule.

ARTICLE 7. SUBSTITUTIONS

a. Pursuant to Public Contract Code Section 3400(b) the District may make a finding that is described in the invitation for bids that designates certain products, things, or services by specific brand or trade name.

b. Unless specifically designated in the Contract Documents, whenever any material, process, or article is indicated or specified by grade, patent, or proprietary name or by name of manufacturer, such Specifications shall be deemed to be used for the purpose of facilitating the description of the material, process or article desired and shall be deemed to be followed by the words "or equal." Contractor may, unless otherwise stated, offer for substitution any material, process or article which shall be substantially equal or better in every respect to that so indicated or specified in the Contract Documents. However, the District may have adopted certain uniform standards for certain materials, processes and articles.

c. Contractor shall submit written requests, together with substantiating data, for substitution of any "or equal" material, process or article no later than thirty-five (35) Days after award of the Contract. To facilitate the construction schedule and sequencing, some requests may need to be submitted before thirty-five (35) Days after award of Contract. Provisions regarding submission of "or equal" requests shall not in any way authorize an extension of time for performance of this Contract. If a proposed "or equal" substitution request is rejected, Contractor shall be responsible for providing the specified material, process or article without adjustment to the Contract Price or Contract Time. The burden of proof as to the equality of any material, process or article shall rest with the Contractor. The District has the complete and sole discretion to determine if a material, process or article is an "or equal" material, process or article that may be substituted.

d. Data required to substantiate requests for substitutions of an "or equal" material, process or article data shall include a signed affidavit from the Contractor stating that, and describing how, the substituted "or equal" material, process or article is equivalent to that specified in every way except as listed on the affidavit. Substantiating data shall include any and all illustrations, Specifications, and other relevant data including catalog information which describes the requested substituted "or equal" material, process or article, and substantiates that it is an "or equal" to the material, process or article. The substantiating data must also include information regarding the durability and lifecycle cost of the requested substituted "or equal" material, process or article. Failure to submit all the required substantiating data, including the signed affidavit, to the District in a timely fashion will result in the rejection of the proposed substitution.

e. The Contractor shall bear all of the District's costs associated with the review of substitution requests.

f. The Contractor shall be responsible for all costs related to a substituted "or equal" material, process or article.

g. Contractor is directed to the Special Conditions (if any) to review any findings made pursuant to Public Contract Code section 3400.

ARTICLE 8. SHOP DRAWINGS

a. Contractor shall check and verify all field measurements and shall submit with such promptness as to provide adequate time for review and cause no delay in his own Work or in that of any other contractor, subcontractor, or worker on the Project, three (3) hard copies and one electronic copy of all shop or setting drawings, calculations, schedules, and materials list, and all other provisions required by the Contract. Contractor shall sign all submittals affirming that submittals have been reviewed and approved by Contractor prior to submission to Engineer. Each signed submittal shall affirm that the submittal meets all the requirements of the Contract Documents except as specifically and clearly noted and listed on the cover sheet of the submittal.

b. Contractor shall make any corrections required by the Engineer, and file with the Engineer three (3) hard copies and one electronic copy each, and furnish such other copies as may be needed for completion of the Work. Engineer's approval of shop drawings shall not relieve Contractor from responsibility for deviations from the Contract Documents unless Contractor has, in writing, called Engineer's attention to such deviations at time of submission and has secured the Engineer's written Approval. Engineer's Approval of shop drawings shall not relieve Contractor from responsibility for errors in shop drawings.

ARTICLE 9. SUBMITTALS

a. Contractor shall furnish to the Engineer for approval, prior to purchasing or commencing any Work, a log of all samples, material lists and certifications, mix designs, schedules, and other submittals, as required in the Specifications. The log shall indicate whether samples will be provided in accordance with other provisions of this Contract.

b. Contractor will provide samples and submittals, together with catalogs and supporting data required by the Engineer, to the Engineer within a reasonable time period to provide for adequate review and avoid delays in the Work.

c. These requirements shall not authorize any extension of time for performance of this Contract. Engineer will check and approve such samples, but only for conformance with design concept of work and for compliance with information given in the Contract Documents. Work shall be in accordance with approved samples and submittals.

d. Contractor shall not be entitled to any extension of the Contract Time on account of the requirements of ARTICLE 9.

ARTICLE 10. MATERIALS

a. Except as otherwise specifically stated in the Contract Documents, Contractor shall provide and pay for all materials, labor, tools, equipment, water, lights, power, transportation, superintendence, temporary constructions of every nature, and all other services and facilities of every nature whatsoever necessary to execute and complete this Contract within the Contract Time.

b. Unless otherwise specified, all materials shall be new and the best of their respective kinds and grades as noted and/or specified, and workmanship shall be of good quality.

c. Materials shall be furnished in ample quantities and at such times as to ensure uninterrupted progress of The Work and shall be stored properly and protected as required by the Contract Documents. Contractor shall be entirely responsible for damage or loss by weather or other causes to materials or Work.

d. No materials, supplies, or equipment for Work under this Contract shall be purchased subject to any chattel mortgage or under a conditional sale or other agreement by which an interest therein or in any part thereof is retained by the seller or supplier. Contractor warrants good title to all material, supplies, and equipment installed or incorporated in the work and agrees upon completion of all work to deliver the Project, to the District free from any claims, liens, or charges.

e. Materials shall be stored on the Project site in such manner so as not to interfere with any operations of the District or any independent contractor.

ARTICLE 11. CONTRACTOR'S SUPERVISION

Contractor shall continuously keep at the Project site, a competent and experienced full-time Project superintendent approved by the District. Superintendent must be able to proficiently speak, read and write in English. Contractor shall continuously provide efficient supervision of the Project.

ARTICLE 12. WORKERS

a. Contractor shall at all times enforce strict discipline and good order among its employees and subcontractors. Contractor shall not employ or allow subcontractors to employ on the Project any unfit person or any one not skilled in the Work assigned to him or her.

b. Any person in the employ of the Contractor whom the District may deem incompetent or unfit shall be dismissed from The Work and shall not be employed on this Project except with the written Approval of the District.

ARTICLE 13. SUBCONTRACTORS

a. Contractor agrees to bind every subcontractor to the terms of the Contract Documents as far as such terms are applicable to subcontractor's portion of The Work. Contractor shall be as fully responsible to the District for the acts and omissions of its subcontractors and of persons either directly or indirectly employed by its subcontractors, as Contractor is for acts and omissions of persons directly employed by Contractor. Nothing contained in these Contract Documents shall create any contractual relationship between any subcontractor and the District.

b. The District reserves the right to Approve all subcontractors. The District's Approval of any subcontractor under this Contract shall not in any way relieve Contractor of its obligations in the Contract Documents.

c. Prior to substituting any subcontractor listed in the Bid Forms, Contractor must comply with the requirements of the Subletting and Subcontracting Fair Practices Act pursuant to California Public Contract Code section 4100 et seq.

ARTICLE 14. VERIFICATION OF EMPLOYMENT ELIGIBILITY

By executing this Contract, Contractor verifies that it fully complies with all requirements and restrictions of state and federal law respecting the employment of undocumented aliens, including, but not limited to, the Immigration Reform and Control Act of 1986, as may be amended from time to time, and shall require all subcontractors, sub-subcontractors and consultants to comply with the same. Each person executing this Contract on behalf of Contractor verifies that he or she is a duly authorized officer of Contractor and that any of the following shall be grounds for the District to terminate the Contract for cause: (1) failure of the Contractor or its subcontractors, sub-subcontractors or consultants to meet any of the requirements provided for in this ARTICLE 14; (2) any misrepresentation or material omission concerning compliance with such requirements; or (3) failure to immediately remove from the Work any person found not to be in compliance with such requirements.

ARTICLE 15. PERMITS AND LICENSES

Permits and licenses necessary for prosecution of The Work shall be secured and paid for by Contractor, unless otherwise specified in the Contract Documents.

a. Contractor shall obtain and pay for all other permits and licenses required for The Work, including excavation permit and permits for plumbing, mechanical and electrical work and for operations in or over public streets or right of way under jurisdiction of public agencies other than the District.

b. The Contractor shall arrange and pay for all off-site inspection of the Work related to permits and licenses, including certification, required by the Specifications, drawings, or by governing authorities, except for such off-site inspections delineated as the District's responsibility pursuant to the Contract Documents.

c. Before Acceptance of the Project, the Contractor shall submit all licenses, permits, certificates of inspection and required approvals to the District.

ARTICLE 16. UTILITY USAGE

a. All temporary utilities, including but not limited to electricity, water, gas, and telephone, used on the Work shall be furnished and paid for by Contractor. Contractor shall Provide necessary temporary distribution systems, including meters, if necessary, from distribution points to points on The Work where the utility is needed. Upon completion of The Work, Contractor shall remove all temporary distribution systems.

b. Contractor shall provide necessary and adequate utilities and pay all costs for water, electricity, gas, oil, and sewer charges required for completion of the Project, including but not limited to startup and testing required in the Contract Documents.

c. All permanent meters Installed shall be listed in the Contractor’s name until Project Acceptance.

d. If the Contract is for construction in existing facilities, Contractor may, with prior written Approval of the District, use the District’s existing utilities. If Contractor uses District utilities, it shall compensate the District for utilities used by Contractor.

ARTICLE 17. INSPECTION FEES FOR PERMANENT UTILITIES

All inspection fees and other municipal charges for permanent utilities including, but not limited to, sewer, electrical, phone, gas, water, and irrigation shall be paid for by the District. Contractor shall be responsible for arranging the payment of such fees, but inspection fees and other municipal fees relating to permanent utilities shall be paid by the District. Contractor may either request reimbursement from the District for such fees, or shall be responsible for arranging and coordination with District for the payment of such fees.

ARTICLE 18. TRENCHES

a. Trenches Five Feet or More in Depth. The Contractor shall submit to the District, in advance of excavation, a detailed plan showing the design of shoring, bracing, sloping or other provisions to be made for worker protection from the hazard of caving ground during the excavation of any trench or trenches five feet or more in depth. If the plan varies from shoring system standards, the plan shall be prepared by a registered civil or structural engineer. The plan shall not be less effective than the shoring, bracing, sloping, or other provisions of the Construction Safety Orders, as defined in the California Code of Regulations, and all costs therefor shall be included in the Contract Price. Nothing in this section shall be deemed to allow the use of a shoring, bracing, sloping or other protective system less effective than that required by the Construction Safety Orders. Nothing in this section shall be construed to impose a tort liability on the owner, any of its officers, officials, partners, employees, agents, consultants or volunteers. The Owner's review of the Contractor's excavation plan is only for general conformance to the Construction Safety Orders and does not relieve the Contractor of any obligation hereunder. Prior to commencing any excavation, the Contractor shall designate in writing to the District the "competent person(s)" with authority and responsibilities designated in the Construction Safety Orders.

b. Excavations Deeper than Four Feet. If work under this Contract involves digging trenches or other excavation that extends deeper than four feet below the surface, Contractor shall promptly, and before the following conditions are disturbed, notify the District, in writing, of any:

1) Material that the Contractor believes may be material that is hazardous waste, as defined in Section 25117 of the Health and Safety Code, that is required to be removed to a Class I, Class II, or Class III disposal site in accordance with provisions of existing law.

2) Subsurface or latent physical conditions at the site differing from those indicated by information made available to bidders prior to the deadline for submitting bids.

3) Unknown physical conditions at the site of any unusual nature, different materially from those ordinarily encountered and generally recognized as inherent in work of the character provided for in the Contract.

The District shall promptly investigate the conditions, and if it finds that the conditions do so materially differ, or do involve hazardous waste, and cause a decrease or increase in Contractor's cost of, or the time required for, performance of any part of The Work, shall issue a change order under the procedures described in the Contract Documents.

In the event that a dispute arises between the District and the Contractor as to whether the conditions materially differ, or involve hazardous waste, or cause a decrease or increase in the Contractor's cost of, or time required for, performance of any part of The Work, the Contractor shall not be excused from any scheduled completion date provided for by the Contract, but shall proceed with all Work to be performed under the Contract. Contractor shall retain any and all rights provided either by contract or by law which pertain to the resolution of disputes and protests between the parties.

ARTICLE 19. DIVERSION OF RECYCLABLE WASTE MATERIALS

In compliance with the applicable District's waste reduction and recycling efforts, Contractor shall divert all Recyclable Waste Materials to appropriate recycling centers. Contractor will be required to submit weight tickets and written proof of diversion with its monthly progress payment requests. Contractor shall complete and execute any certification forms required by District or other applicable agencies to document Contractor's compliance with these diversion requirements. All costs incurred for these waste diversion efforts shall be the responsibility of the Contractor. The Contractor shall coordinate with the appropriate local government agency and comply with local waste disposal ordinances.

ARTICLE 20. REMOVAL OF HAZARDOUS MATERIALS

Should Contractor encounter material reasonably believed to be polychlorinated biphenyl (PCB) or other toxic wastes and hazardous materials (as defined in section 25117 of the Health and Safety Code) which have not been rendered harmless at the Project site, the Contractor shall immediately stop work at the affected Project site and shall report the condition to the District in writing. The District shall contract for any services required to directly remove and/or abate PCBs and other toxic wastes and hazardous materials, if required by the Project site(s), and shall not require the Contractor to subcontract for such services. The Work in the affected area shall not thereafter be resumed except by written agreement of the District and Contractor.

ARTICLE 21. SANITARY FACILITIES

Contractor shall provide sanitary temporary toilet buildings for the use of all workers. All toilets shall comply with local codes and ordinances. Toilets shall be kept supplied with toilet paper and shall have workable door fasteners. Toilets shall be serviced no less than once weekly and shall be present in a quantity of not less than 1 per 20 workers as required by CAL-OSHA regulation. The toilets shall be maintained in a sanitary condition at all times. Use of toilet facilities in The Work under construction shall not be permitted. Any other Sanitary Facilities required by CAL-OSHA shall be the responsibility of the Contractor.

ARTICLE 22. AIR POLLUTION CONTROL

Contractor shall comply with all air pollution control rules, regulations, ordinances and statutes. All containers of paint, thinner, curing compound, solvent or liquid asphalt shall be labeled to indicate that the contents fully comply with the applicable material requirements. Without limiting the foregoing, Contractor must fully comply with all Applicable Laws, rules and regulations in furnishing or using equipment and/ or providing services, including but not limited to, emissions limits and permitting requirements imposed by the Air Quality Management District with jurisdiction over the Project and/ or California Air Resources Board (CARB). Contractor shall specifically be aware of the application of these limits and requirements to "portable equipment" which definition is considered to include any item of equipment with a fuel-powered engine. Contractor shall indemnify District against any fines or penalties imposed by the air quality management district, CARB, or any other governmental or regulatory agency for its violations of Applicable laws as well as those of its subcontractors or others for whom Contractor is responsible under its indemnity obligations provided for in ARTICLE 48.

ARTICLE 23. COMPLIANCE WITH STATE STORM WATER PERMIT

a. Contractor shall be required to comply with all conditions of the State Water Resources Control Board ("State Water Board") Water Quality Order No. 2009-00009-DWQ as modified by Order No. 2010-0014-DWQ, National Pollutant Discharge Elimination System General Permit for Waste Discharge Requirements for Discharges of Storm Water Discharges Associated with Construction Activity ("Permit") for all construction activity which results in the disturbance of in excess of one acre of total land area or which is part of a larger common area of development or sale. Contractor shall be responsible for filing the Notice of Intent and for obtaining the Permit. Contractor shall be solely responsible for preparing and implementing a Storm Water Pollution Prevention Plan ("SWPPP") prior to initiating Work. In bidding on this Contract, it shall be Contractor's responsibility to evaluate the cost of procuring the Permit and preparing the SWPPP as well as complying with the SWPPP and any necessary revision to the SWPPP. Contractor shall comply with all requirements of the State Water Resources Control Board. Contractor shall include all costs of compliance with specified requirements in the Contract amount.

b. Contractor shall be responsible for procuring, implementing and complying with the provisions of the Permit and the SWPPP, including the standard provisions, monitoring and reporting requirements as required by the Permit. Contractor shall provide copies of all reports and monitoring information to the Engineer.

c. Contractor shall comply with the lawful requirements of any applicable municipality, the District, drainage District, and other local agencies regarding discharges of storm water to separate storm drain system or other watercourses under their jurisdiction, including applicable requirements in municipal storm water management programs.

d. Storm, surface, nuisance, or other waters may be encountered at various times during construction of The Work. Therefore, the Contractor, by submitting a Bid, hereby acknowledges that it has investigated the risk arising from such waters, has prepared its Bid accordingly, and assumes any and all risks and liabilities arising therefrom.

e. Failure to comply with the Permit is in violation of federal and state law. Contractor hereby agrees to indemnify and hold harmless District, its officials, officers, agents, employees and authorized volunteers from and against any and all claims, demands, losses or liabilities of any kind or nature which District, its officials, officers, agents, employees and authorized volunteers may sustain or incur for noncompliance with the Permit arising out of or in connection with the Project, except for liability resulting from the sole established negligence, willful misconduct or active negligence of the District, its officials, officers, agents, employees or authorized volunteers. District may seek damages from Contractor for delay in completing the Contract in accordance with the Contract Documents, caused by Contractor's failure to comply with the Permit.

ARTICLE 24. CLEANING UP

a. Contractor at all times shall keep premises free from debris such as waste, rubbish, and excess materials and equipment. Contractor shall not store debris under, in, or about the premises. The contractor shall also remove temporary fencing, barricades, planking and construction toilet and similar temporary facilities from site. Contractor shall also clean all buildings, asphalt and concrete areas to the degree necessary to remove oil, grease, fuel, or other stains caused by Contractor operations or equipment.

b. Contractor shall fully clean up the site at the completion of The Work. If the Contractor fails to immediately clean up at the completion of The Work, the District may do so and the cost of such clean up shall be charged back to the Contractor.

ARTICLE 25. LAYOUT AND FIELD ENGINEERING

All field engineering required for laying out The Work and establishing grades for earthwork operations shall be furnished by the District at its expense. Layout shall be done by a qualified individual Approved by the Engineer. Any required "as-built" drawings of civil engineering elements of the Work shall be prepared by a registered civil engineer.

ARTICLE 26. EXCESSIVE NOISE

a. The Contractor shall use only such equipment on the work and in such state of repair so that the emission of sound therefrom is within the noise tolerance level of that equipment as established by CAL-OSHA.

b. The Contractor shall comply with the most restrictive of the following: (1) local sound control and noise level rules, regulations and ordinances and (2) the requirements contained in these Contract Documents, including hours of operation requirements. No internal combustion engine shall be operated on the Project without a muffler of the type recommended by the manufacturer. Should any muffler or other control device sustain damage or be determined to be ineffective or defective, the Contractor shall promptly remove the equipment and shall not return said equipment to the job until the device is repaired or replaced. Said noise and vibration level requirements shall apply to all equipment on the job or related to the job, including but not limited to, trucks, transit mixers or transit equipment that may or may not be owned by the Contractor.

c. The Contractor shall comply with all the environmental provisions contained in the Contract Documents.

ARTICLE 27. TESTS AND INSPECTIONS

a. If the Contract Documents, the Engineer, or any instructions, laws, ordinances, or public authority require any part of The Work to be tested or Approved, Contractor shall provide the Engineer at least two (2) working Days' notice of its readiness for observation or inspection. If inspection is by a public authority other than the District, Contractor shall promptly inform the District of the date fixed for such inspection. Required certificates of inspection (or similar) shall be secured by Contractor. Costs for District testing and District inspection shall be paid by the District. Costs of tests for Work found not to be in compliance with the Contract Documents or Applicable Law shall be paid by the Contractor.

b. If any Work is done or covered up without the required testing or approval, the Contractor shall uncover or deconstruct the Work, and the Work shall be redone after completion of the testing at the Contractor's cost in compliance with the Contract Documents, at the Contractor's cost.

c. Where inspection and testing are to be conducted by an independent laboratory or agency, materials or samples of materials to be inspected or tested shall be selected by such laboratory or agency, or by the District, and not by Contractor. All tests or inspections of materials shall be made in accordance with the commonly recognized standards of national organizations.

d. In advance of manufacture of materials to be supplied by Contractor which must be tested or inspected, Contractor shall notify the District so that the District may arrange for testing at the source of supply. Any materials which have not satisfactorily passed such testing and inspection shall not be incorporated into The Work.

e. If the manufacture of materials to be inspected or tested will occur in a plant or location outside the geographic limits of District, the Contractor shall pay for any excessive or unusual costs associated with such testing or inspection, including but not limited to excessive travel time, standby time and required lodging.

f. Reexamination of Work may be ordered by the District. If so ordered, Work must be uncovered or deconstructed by Contractor. If Work is found to be in accordance with the Contract Documents, the District shall pay the costs of reexamination and reconstruction. If such work is found not to be in accordance with the Contract Documents, Contractor shall pay all costs.

ARTICLE 28. PROTECTION OF WORK AND PROPERTY

a. The Contractor shall be responsible for all damages to persons or property that occur as a result of The Work. Contractor shall be responsible for the proper care and protection of all materials delivered and Work performed until completion and final Acceptance by the District. All Work shall be solely at the Contractor's risk. Contractor shall adequately protect adjacent property from settlement or loss of lateral support as necessary. Contractor shall comply with all applicable safety laws and building codes to prevent accidents or injury to persons on, about, or adjacent to the Project site where Work is being performed. Contractor shall erect and properly maintain at all times, as required by field conditions and progress of work, all necessary safeguards, signs, barriers, lights, and watchmen for protection of workers and the public, and shall post danger signs warning against hazards created in the course of construction.

b. In an emergency affecting safety of life or of work or of adjoining property, Contractor, without special instruction or authorization from the Engineer, is hereby permitted to act to prevent such threatened loss or injury; and Contractor shall so act, without appeal, if so authorized or instructed by the Engineer or the District. Any compensation claimed by Contractor on account of emergency work shall be determined by and agreed upon by the District and the Contractor in accordance with ARTICLE 46.

c. Contractor shall provide such heat, covering, and enclosures as are necessary to protect all Work, materials, equipment, appliances, and tools against damage by weather conditions.

d. Contractor shall take adequate precautions to protect existing sidewalks, curbs, pavements, utilities, and other adjoining property and structures, and to avoid damage thereto, and Contractor shall repair any damage thereto caused by The Work operations. Contractor shall:

1) Enclose the working area with a substantial barricade, and arrange work to cause minimum amount of inconvenience and danger to the public.

2) Provide substantial barricades around any shrubs or trees indicated to be preserved.

3) Deliver materials to the Project site over a route designated by the Engineer.

4) Provide any and all dust control required and follow the Applicable air quality regulations as appropriate. If the Contractor does not comply, the District shall have the immediate authority to provide dust control and deduct the cost from payments to the Contractor.

5) Confine Contractor’s apparatus, the storage of materials, and the operations of its workers to limits required by law, ordinances, permits, or directions of the Engineer. Contractor shall not unreasonably encumber the Project site with its materials.

6) Take care to prevent disturbing or covering any survey markers, monuments, or other devices marking property boundaries or corners. If such markers are disturbed by accident, they shall be replaced by an approved civil engineer or land surveyor, at no cost to the District.

7) Ensure that existing facilities, fences and other structures are all adequately protected and that, upon completion of all Work, all facilities that may have been damaged are restored to a condition acceptable to the District.

8) Preserve and protect from injury all buildings, pole lines and all direction, warning and mileage signs that have been placed within the right-of-way.

9) At the completion of work each Day, leave the Project site in a clean, safe condition.

10) Comply with any stage construction and traffic handling plans. Access to residences and businesses shall be maintained at all times.

These precautionary measures will apply continuously and not be limited to normal working hours. Full compensation for the Work involved in the preservation of life, safety and property as above specified shall be considered as included in the prices paid for the various contract items of Work, and no additional allowance will be made therefor.

e. Should damage to persons or property occur as a result of The Work, Contractor shall promptly notify the District, in writing. Contractor shall be responsible for proper investigation, documentation, including video or photography, to adequately memorialize and make a record of what transpired. The District shall be entitled to inspect and copy any such documentation, video, or photographs.

ARTICLE 29. CONTRACTORS MEANS AND METHODS

Contractor is solely responsible for the means and methods utilized to Perform The Work. In no case shall the Contractor's means and methods deviate from commonly used industry standards.

ARTICLE 30. AUTHORIZED REPRESENTATIVES

The District shall designate representatives, who shall have the right to be present at the Project site at all times. The District may designate an inspector who shall have the right to observe all of the Contractor's Work. The inspector is not authorized to make changes in the Contract Documents or excuse Contractor from performing in accordance with the Contract Documents. The inspector shall not be responsible for the Contractor's failure to carry out The Work in accordance with the Contract Documents. Contractor shall provide safe and proper facilities for such access.

ARTICLE 31. HOURS OF WORK

a. Eight (8) hours of work shall constitute a legal Day's work. The Contractor and each subcontractor shall forfeit, as penalty to the District, twenty-five dollars ($25) for each worker employed in the execution of Work by the Contractor or any subcontractor for each Day during which such worker is required or permitted to work more than eight (8) hours in any one Day and forty (40) hours in any week in violation of the provisions of the Labor Code, and in particular, Section 1810 to Section 1815, except as provided in Labor Code Section 1815.

b. Work shall be accomplished on a regularly scheduled eight (8) hour per Day work shift basis, Monday through Friday, between the hours of 7:00 a.m. and 5:00 p.m.

c. It shall be unlawful for any person to operate, permit, use, or cause to operate any of the following at the Project site, other than between the hours of 7:00 a.m. to 5:00 p.m., Monday through Friday, with no Work allowed on District-observed holidays, unless otherwise Approved by the Engineer:

    1) Powered Vehicles

    2) Construction Equipment

    3) Loading and Unloading Vehicles

    4) Domestic Power Tools

ARTICLE 32. PAYROLL RECORDS

a. Pursuant to Labor Code Section 1776, the Contractor and each subcontractor shall maintain weekly certified payroll records showing the name, address, social security number, work classification, straight time and overtime hours paid each Day and week, and the actual per diem wages paid to each journeyman, apprentice, worker or other employee employed in connection with the work. Contractor shall certify under penalty of perjury that records maintained and submitted by Contractor are true and accurate. Contractor shall also require subcontractor(s) to certify weekly payroll records under penalty of perjury.

b. The payroll records described herein shall be certified and submitted by the Contractor at a time designated by the District. The Contractor shall also provide the following:

1) A certified copy of the employee's payroll records shall be made available for inspection or furnished to such employee or his or her authorized representative on request.

2) A certified copy of all payroll records described herein shall be made available for inspection or furnished upon request of the Department of Industrial Relations ("DIR").

c. The certified payroll records shall be on forms provided by the Division of Labor Standards Enforcement ("DLSE") of the DIR or shall contain the same information as the forms provided by the DLSE.

d. Any copy of records made available for inspection and furnished upon request to the public shall be marked or obliterated in such a manner as to prevent disclosure of an individual's name, address, and social security number. The name and address of the Contractor or any subcontractor shall not be marked or obliterated.

e. In the event of noncompliance with the requirements of this Section, the Contractor shall have ten (10) Days in which to comply subsequent to receipt of written notice specifying any item or actions necessary to ensure compliance with this section. Should noncompliance still be evident after such ten (10) Day period, the Contractor shall, as a penalty to the District, forfeit One Hundred Dollars ($100.00) for each Day, or portion thereof, for each worker until strict compliance is effectuated. Upon the request of the DIR, such penalties shall be withheld from contract payments.

ARTICLE 33. PREVAILING RATES OF WAGES

a. The Contractor is aware of the requirements of Labor Code Sections 1720 et seq. and 1770 et seq., as well as California Code of Regulations, Title 8, Section 16000 et seq. ("Prevailing Wage Laws"), which require the payment of prevailing wage rates and the performance of other requirements on certain “public works” and “maintenance” projects. Since this Project involves an applicable “public works” or “maintenance” project, as defined by the Prevailing Wage Laws, and since the total compensation is $1,000 or more, Contractor agrees to fully comply with such Prevailing Wage Laws. The Contractor shall obtain a copy of the prevailing rates of per diem wages at the commencement of this Agreement from the website of the Division of Labor Statistics and Research of the Department of Industrial Relations located at www.dir.ca.gov/dlsr/. Contractor shall make copies of the prevailing rates of per diem wages for each craft, classification or type of worker needed to perform work on the Project available to interested parties upon request, and shall post copies at the Contractor’s principal place of business and at the Project site. Contractor shall defend, indemnify and hold the District, its elected officials, officers, employees and agents free and harmless from any claims, liabilities, costs, penalties or interest arising out of any failure or allege failure to comply with the Prevailing Wage Laws.

b. The Contractor and each subcontractor shall forfeit as a penalty to the District not more than Two Hundred dollars ($200.00) for each Day, or portion thereof, for each worker paid less than the stipulated prevailing wage rate for any work done by him, or by any subcontract under him, in violation of the provisions of the Labor Code. The difference between such stipulated prevailing wage rate and the amount paid to each worker for each Day or portion thereof for which each worker was paid less than the stipulated prevailing wage rate shall be paid to each worker by the Contractor.

c. Contractor shall post, at appropriate conspicuous points on the Project site, a schedule showing all determined general prevailing wage rates and all authorized deductions, if any, from unpaid wages actually earned.

ARTICLE 34. EMPLOYMENT OF APPRENTICES

The Contractor’s attention is directed to the provisions of Sections 1777.5, 1777.6, and 1777.7 of the Labor Code concerning employment of apprentices by the Contractor or any subcontractor. The Contractor shall obtain a certificate of apprenticeship before employing any apprentice pursuant to Section 1777.5, 1777.6, and 1777.7 of the Labor Code. Information relative to apprenticeship standards, wage schedules, and other requirements may be obtained from the Director of Industrial Relations, the Administrator of Apprenticeships, San Francisco, California, or from the Division of Apprenticeship Standards and its branch offices.

ARTICLE 35. LABOR COMPLIANCE

This Project is subject to labor compliance monitoring and enforcement by the Department of Industrial Relations. It shall be the Contractor’s sole responsibility to evaluate and include the cost of complying with all labor compliance requirements under this contract and applicable law in its bid.

Contractor shall post, at each job site, the notice required by Section 16451(d) of Title 8 of the California Code of Regulations. Template notices are available by emailing a request to CMU@dir.ca.gov or at the following location.

District Office of the Division of Labor Standards Enforcement
1515 Clay Street, Suite 801
Oakland, CA 94612

In accordance with Labor Code section 1771.4, the Contractor and each subcontractor shall furnish the certified payroll records directly to the Department of Industrial Relations on a weekly basis and in the format prescribed by the Department of Industrial Relations, which may include electronic submission. Contractor shall comply with all requirements and regulations from the Department of Industrial Relations relating to labor compliance monitoring and enforcement.

ARTICLE 36. CONTRACTOR AND SUBCONTRACTOR REGISTRATION

If the bids subject to the Notice Inviting Bids are due on or after March 1, 2015, then pursuant to Labor Code sections 1725.5 and 1771.1, all contractors and subcontractors that wish to bid on, be listed in a bid proposal, or enter into a contract to perform public work must be registered with the Department of Industrial Relations. No bid will be accepted nor any contract entered into without proof of the contractor's and subcontractors' current registration with the Department of Industrial Relations to perform public work.

ARTICLE 37. NONDISCRIMINATION/EQUAL EMPLOYMENT OPPORTUNITY/EMPLOYMENT ELIGIBILITY

Pursuant to Labor Code Section 1735 and other applicable provisions of law, the Contractor and its subcontractors shall not discriminate against any employee or applicant for employment because of race, color, religion, sex, national origin, age, political affiliation, marital status, or handicap on this Work. The Contractor will take affirmative action to insure that employees are treated during employment or training without regard to their race, color, religion, sex, national origin, age, political affiliation, marital status, or handicap.

Employment Eligibility; Contractor. By executing this Contract, Contractor verifies that it fully complies with all requirements and restrictions of state and federal law respecting the employment of undocumented aliens, including, but not limited to, the Immigration Reform and Control Act of 1986, as may be amended from time to time. Such requirements and restrictions include, but are not limited to, examination and retention of documentation confirming the identity and immigration status of each employee of the Contractor. Contractor also verifies that it has not committed a violation of any such law within the five (5) years immediately preceding the date of execution of this Contract, and shall not violate any such law at any time during the term of the Contract. Contractor shall avoid any violation of any such law during the term of this Contract by participating in an electronic verification of work authorization program operated by the United States Department of Homeland Security, by participating in an equivalent federal work authorization program operated by the United States Department of Homeland Security to verify information of newly hired employees, or by some other legally acceptable method. Contractor shall maintain records of each such verification, and shall make them available to the District or its representatives for inspection and copy at any time during normal business hours. The District shall not be responsible for any costs or expenses related to Contractor's compliance with the requirements provided for or referred to herein.

Employment Eligibility; Subcontractors, Sub-subcontractors and Consultants. To the same extent and under the same conditions as Contractor, Contractor shall require all of its subcontractors, sub-subcontractors and consultants performing any part of the Work or of this Contract to make the same verifications and comply with all requirements and restrictions provided for herein.

Employment Eligibility; Failure to Comply. Each person executing this Contract on behalf of Contractor verifies that he or she is a duly authorized officer of Contractor, and understands that any of the following shall be grounds for the District to terminate the Contract for cause: (1) failure of Contractor or its subcontractors, sub-subcontractors or consultants to meet any of the requirements provided for herein; (2) any misrepresentation or material omission concerning compliance with such requirements; or (3) failure to immediately remove from the Work any person found not to be in compliance with such requirements.

ARTICLE 38. LABOR/EMPLOYMENT SAFETY

In the performance of this Contract the Contractor shall comply with all applicable federal, state and local statutory and regulatory requirements including, but not limited to California Department of Industrial Relations (Cal/OSHA) regulations; and the U.S. Department of Transportation Omnibus Transportation Employee Testing Act, related to their scope of work and operations. In case of conflict in regulations, the most stringent shall apply. The Contractor shall provide all safeguards, safety devices and protective equipment and take any other needed actions necessary to protect the life and health of employees on the job and the safety of the public and to protect property in connection with the performance of the Work covered by the Contract. Safety precautions shall include but shall not be limited to: adequate life protection and lifesaving equipment; adequate illumination; instructions in accident prevention for all employees, such as the use of machinery guards, safe walkways, scaffolds, ladders, bridges, gang planks, confined space procedures, trenching and shoring, fall protection, and other safety devices; equipment and wearing apparel as are necessary or lawfully required to prevent accidents, injuries, or illnesses (including but not limited to exposure to the Coccidioides fungus and Valley Fever); and adequate facilities for the proper inspection and maintenance of all safety measures.

Contractor must obtain all applicable Division of Occupational Safety and Health (CAL-OSHA) permit(s) and others required by California Labor Code and California Government Code, prior to the initiation of any practices, Work, method, operation, or process related to the Work covered in the Contract. Permits required by governmental authorities will be obtained at Contractor's expense.

It is a condition of this Contract, and shall be made a condition of each subcontract which the Contractor enters into pursuant to this Contract, that the Contractor and any subcontractor shall not permit any employee, in performance of the Contract, to work in surroundings or under conditions which are unsanitary, hazardous or dangerous to his/her health or safety, as determined under Cal/OSHA safety and health standards.

The Contractor shall be responsible for the safeguarding of all utilities. At least two working Days before beginning Work, the Contractor shall call the Underground Service Alert (USA) in order to determine the location of sub-structures. The Contractor shall immediately notify District and the utility owner if he/she disturbs, disconnects, or damages any utility.

In accordance with Section 6705 of the California Labor Code, the Contractor shall submit to District specific plans to show details of provisions for worker protection from caving ground during excavations of trenches of five feet or more in depth. The excavation/trench safety plan shall be submitted to and accepted by District prior to starting excavation. The trench safety plan shall have details showing the design of shoring, bracing, sloping or other provisions to be made for worker protection from the hazard of caving ground. If such a plan varies from the shoring system standards established by the Construction Safety Orders of the California Department of Industrial Relations (Cal/OSHA), the plan shall be prepared by a California registered civil or structural engineer. As part of the plan, a note shall be included stating that the registered civil or structural engineer certifies that the plan complies with the Cal/OSHA Construction Safety Orders, or that the registered civil or structural engineer certifies that the plan is not less effective than the shoring, bracing, sloping or other provisions of the Safety Orders. In no event shall the Contractor use a shoring, sloping, or protective system less effective than that required by said Construction Safety Orders. Submission of this plan in no way relieves the Contractor of the requirement to maintain safety in all areas. If excavations or trench Work requiring a Cal/OSHA permit are to be undertaken, the Contractor shall submit his/her permit with the excavation/trench Work safety plan to District before Work begins.

ARTICLE 39. INSURANCE

a. Minimum Scope and Limits of Insurance. Contractor shall procure and maintain for the duration of the Contract, and for 5 years thereafter, insurance against claims for injuries or death to persons or damages to property which may arise from or in connection with the performance of the Work hereunder by the Contractor, his agents, representatives, employees, or subcontractors.

b. Coverage. Coverage shall be at least as broad as the following:

1. General Liability - Commercial General Liability (CGL). Insurance Services Office (ISO) Commercial General Liability Coverage (Occurrence Form CG 00 01) including products and completed operations, property damage, bodily injury, personal and advertising injury with limit of at least five million dollars ($5,000,000) per occurrence or the full per occurrence limits of the policies available, whichever is greater. If a general aggregate limit applies, either the general aggregate limit shall apply separately to this Project/location (coverage as broad as the ISO CG 25 03, or ISO CG 25 04 endorsement provided to District) or the general aggregate limit shall be twice the required occurrence limit.

2. Automobile Liability. Insurance Services Office (ISO) Business Auto Coverage (Form CA 00 01), covering Symbol 1 (any auto) with limit of two million dollars ($2,000,000) for bodily injury and property damage each accident.

3. Workers' Compensation Insurance. The Contractor shall provide workers' compensation coverage as required by the State of California, with Statutory Limits, and Employer's Liability Insurance with limit of no less than $1,000,000 per accident for bodily injury or disease. Waiver of Subrogation (also known as Transfer of Rights of Recovery Against Others to Us): The Contractor hereby agrees to waive rights of subrogation to obtain endorsement necessary to affect this waiver of subrogation in favor of the District, its directors, officers, employees, and authorized volunteers, for losses paid under the terms of this coverage which arise from Work performed by the Named Insured for the District; this provision applies regardless of whether or not the District has received a waiver of subrogation from the insurer.

4. Builder's Risk. (Course of Construction) if necessary, insurance utilizing an "All Risk" (Special Perils) coverage form with limits equal to the completed value of the Project and no coinsurance penalty provision. See Responsibility of Work.

5. Contractor's Pollution Liability. With limits no less than $5,000,000 per occurrence or claim, and $10,000,000 policy aggregate.

If the Contractor maintains broader coverage and or/higher limits than the minimums shown above, the District requires and shall be entitled to the broader coverage and/or higher limits maintained by the Contractor. Any available insurance proceeds in excess of the specified minimum of insurance and coverage shall be available to the District.

c. Other Required Provisions. The Commercial General Liability policy, Automobile Liability policy and Contractors Pollution (if necessary) are to contain, or be endorsed to contain, the following provisions:

1. Additional Insured Status. District, its directors, officers, employees, and authorized volunteers are to be given insured status (at least as broad as ISO Form CG 20 10 11 85 or if not available, through the addition of both CG 20 10 10 01 and CG 20 37 10 01 for the Commercial General Liability policy) with respect to liability arising out of Work or operations performed by or on behalf of the Contractor including materials, parts, or equipment furnished in connection with such Work or operations. General liability coverage can be provided in the form of an endorsement to the Contractor's insurance.

2. Primary and Non-Contributory Coverage. For any claims related to this Project, the Contractor's insurance coverage shall be primary, at least as broad as ISO CG 20 01 04 13 for the Commercial General Liability policy, as respects to the District, its directors, officers, employees, and authorized volunteers. Any insurance or self-insurance maintained by the District, its directors, officers, employees, and authorized volunteers shall be excess of the Contractor's insurance and shall not contribute with it.

3. Waiver of Subrogation. All policies shall permit and Contractor does hereby waive any right of subrogation which any insurer of Contractor may acquire from Contractor by virtue of the payment of any loss.

d. Notice of Cancellation. Each insurance policy required above shall provide that coverage shall not be canceled, except with notice to the District.

e. Acceptability of Insurers. Insurance is to be placed with insurers having a current A.M. Best rating of no less than A: VII or equivalent or as otherwise approved by District.

The Contractor agrees and he/she will comply with such provisions before commencing Work. All of the insurance shall be provided on policy forms and through companies satisfactory to District. The District reserves the right to obtain complete, certified copies of all required insurance policies, including the policy declarations page with endorsement number. Failure to continually satisfy the Insurance requirements is a material breach of contract.

f. Responsibility for Work. Until the completion and final Acceptance by District of all The Work under and implied by this Contract, The Work shall be under the Contractor's responsible care and charge. The Contractor shall rebuild, repair, restore and make good all injuries, damages, re-erections, and repairs occasioned or rendered necessary by causes of any nature whatsoever.

The Contractor shall provide and maintain builder's risk (course of construction) or an installation floater (for materials and equipment) covering all risks of direct physical loss, damage or destruction to The Work in the amount specified in the General Conditions, to insure against such losses until final Acceptance of The Work by District. Such insurance shall insure at least against the perils of fire and extended coverage, theft, vandalism and malicious mischief, and collapse. The Policy shall be endorsed with District, its directors, officers, employees, and authorized volunteers named as loss payee, as their interest may appear. The making of progress payments to the Contractor shall not be construed as creating an insurable interest by or for District or be construed as relieving the Contractor or his/her subcontractors of responsibility for loss from any direct physical loss, damage or destruction occurring prior to final Acceptance of The Work by District.

g. Deductibles and Self-Insured Retentions. Insurance deductibles or self-insured retentions must be declared by the Contractor, and approved by the District. At the election of District the Contractor shall either cause the insurer to reduce or eliminate such self-insured retentions as respects the District, its directors, officers, employees, and authorized volunteers or the Contractor shall provide a financial guarantee satisfactory to the District guaranteeing payment of losses and related investigations, claim administration, and defense expenses. The policy language shall provide, or be endorsed to provide, that the self-insured retention may be satisfied by either the named insured or the District.

h. Verification of Coverage - Evidences of Insurance. Contractor shall furnish the District with copies of certificates and amendatory endorsements effecting coverage required by this Contract. All certificates and endorsements are to be received and approved by the District before Work commences. However, failure to obtain the required documents prior to the Work beginning shall not waive the Contractor's obligation to provide them. The District reserves the right to require complete, certified copies of all required insurance policies, including policy Declaration pages and Endorsement pages, required by these Specifications, at any time. Failure to continually satisfy the Insurance requirements is a material breach of contract.

i. Continuation of Coverage. The Contractor shall, upon demand of District deliver evidence of coverage showing continuation of coverage for at least (5) years after completion of the Project. Contractor further waives all rights of subrogation under this Contract When any of the required coverages expire during the term of this Contract, the Contractor shall deliver the renewal certificate(s) including the general liability additional insured endorsement and evidence of waiver of rights of subrogation against District (if builder's risk insurance is applicable) to District at least ten (10) Days prior to the expiration date.

j. Subcontractors. In the event that the Contractor employs other Contractors (subcontractors) as part of the Work covered by this Contract, it shall be the Contractor's responsibility to require and confirm that each subcontractor meets the minimum insurance requirements specified above (via as broad as ISO CG 20 38 04 13). The Contractor shall, upon demand of District, deliver to District copies such policy or policies of insurance and the receipts for payment of premiums thereon.

ARTICLE 40. FORM AND PROOF OF CARRIAGE OF INSURANCE

a. Any insurance carrier providing insurance coverage required by the Contract Documents shall be authorized to do business in the State of California unless waived, in writing, by the District's General Manager. Carrier(s) shall have an A.M. Best rating of not less than an A:IIX. Insurance deductibles or self-insured retentions must be declared by the Contractor. At the election of the District, the Contractor shall either 1) reduce or eliminate such deductibles or self-insured retentions, or 2) procure a bond which guarantees payment of losses and related investigations, claims administration, and defense costs and expenses. If umbrella or excess liability coverage is used to meet any required limit(s) specified herein, the Contractor shall provide a "follow form" endorsement satisfactory to the District indicating that such coverage is subject to the same terms and conditions as the underlying liability policy.

b. Each insurance policy required by this Contract shall be endorsed to state that: (1) should any of the above described be cancelled before the expiration date thereof, notice will be delivered in accordance with the policy provisions; and (2) any failure to comply with reporting or other provisions of the policies, including breaches of warranties, shall not affect coverage provided to the District its directors, officials, officers, employees, agents and volunteers.

c. The Certificates(s) and policies of insurance shall contain or shall be endorsed to contain the covenant of the insurance carrier(s) that it shall provide no less than thirty (30) Days written notice be given to the District prior to any material modification or cancellation of such insurance. In the event of a material modification or cancellation of coverage, the District may terminate the Contract or stop the Work in accordance with the Contract Documents, unless the District receives, prior to such effective date, another properly executed original Certificate of Insurance and original copies of endorsements or certified original policies, including all endorsements and attachments thereto evidencing coverage's set forth herein and the insurance required herein is in full force and effect. Contractor shall not take possession, or use the Site, or commence operations under this Contract until the District has been furnished original Certificate(s) of Insurance and certified original copies of endorsements or policies of insurance including all endorsements and any and all other attachments as required in this section. The original endorsements for each policy and the Certificate of Insurance shall be signed by an individual authorized by the insurance carrier to do so on its behalf.

d. The Certificate(s) of Insurance, policies and endorsements shall so covenant and shall be construed as primary, and the District's insurance and/or deductibles and/or self-insured retentions or self-insured programs shall not be construed as contributory.

e. The District reserves the right to adjust the monetary limits of insurance coverages during the term of this Contract including any extension thereof if in the District's reasonable judgment, the amount or type of insurance carried by the Contractor becomes inadequate.

f. Contractor shall report to the District, in addition to Contractor's insurer, any and all insurance claims submitted by the Contractor in connection with the Work under this Contract.

ARTICLE 41. TIME FOR COMPLETION AND LIQUIDATED DAMAGES

a. **Time for Completion/Liquidated Damages.** Work shall be commenced within ten (10) Days of the date stated in the District's Notice to Proceed and shall be completed by Contractor in the Contract Time. The District is under no obligation to consider early completion of the Project; and the Contract completion date shall not be amended by the District's receipt or acceptance of the Contractor's proposed earlier completion date. Furthermore, Contractor shall not, under any circumstances, receive additional compensation from the District (including but not limited to indirect, general, administrative or other forms of overhead costs) for the period between the time of earlier completion proposed by the Contractor and the Contract completion date. If The Work is not completed within the Contract Time, it is understood that the District will suffer damage. In accordance with Government Code section 53069.85, being impractical and infeasible to determine the amount of actual damage, it is agreed that Contractor shall pay to the District as fixed and liquidated damages, and not as a penalty, the sum stipulated in the Contract for each Day of delay until The Work is fully completed. Contractor and its surety shall be liable for any liquidated damages. Any money due or to become due the Contractor may be retained to cover liquidated damages.

b. **Inclement Weather.** Contractor shall abide the Engineer's determination of what constitutes inclement weather. Time extensions for inclement weather shall only be granted when the Work stopped during inclement weather is on the critical path of the then-current Project schedule.

c. **Extension of Time.** Contractor shall not be charged liquidated damages because of any delays in completion of The Work due to unforeseeable causes beyond the control and without the fault or negligence of Contractor (or its subcontractors or suppliers). Contractor shall within five (5) Days of identifying any such delay notify the District in writing of causes of delay. The District shall ascertain the facts and extent of delay and grant extension of time for completing The Work when, in its judgment, the facts justify such an extension. Time extensions to the Project shall be requested by the Contractor as they occur and without delay. No delay claims shall be permitted unless the event or occurrence delays the completion of the Project beyond the Contract completion date.

d. **No Damages for Reasonable Delay.** The District's liability to Contractor for delays for which the District is responsible shall be limited to only an extension of time unless such delays were unreasonable under the circumstances. In no case shall the District be liable for any costs which are borne by the Contractor in the regular course of business, including, but not limited to, home office overhead and other ongoing costs. Damages caused by unreasonable District delay, including delays caused by items that are the responsibility of the District pursuant to Government Code section 4215, shall be based on actual costs only, no proportions or formulas shall be used to calculate any delay damages.

ARTICLE 42. COST BREAKDOWN AND PERIODIC ESTIMATES

Contractor shall furnish on forms Approved by the District:

a. Within ten (10) Days of award of the Contract a detailed Schedule of Values giving a complete breakdown of the Contract price. The Schedule of Values shall be adjusted as directed by the District;

b. A monthly itemized estimate of Work done for the purpose of making progress payments. In order for the District to consider and evaluate each progress payment application, the Contractor shall submit a detailed measurement of Work performed and a progress estimate of the value thereof before the tenth (10th) Day of the following month.

c. Contractor shall submit, with each of its payment requests, an adjusted list of actual quantities, verified by the Engineer, for unit price items listed, if any, in the Bid Form.

d. Following the District's Acceptance of the Work, the Contractor shall submit to the District a written statement of the final quantities of unit price items for inclusion in the final payment request.

e. The District shall have the right to adjust any estimate of quantity and to subsequently correct any error made in any estimate for payment.

Contractor shall certify under penalty of perjury, that all cost breakdowns and periodic estimates accurately reflect the Work on the Project.

ARTICLE 43. MOBILIZATION

a. When a bid item is included in the Bid Form for mobilization, the costs of Work in advance of construction operations and not directly attributable to any specific bid item will be included in the progress estimate ("Initial Mobilization"). When no bid item is provided for "Initial Mobilization," payment for such costs will be deemed to be included in the other items of The Work.

b. Payment for Mobilization shall be based on the lump sum provided in the Bid Form, which shall constitute full compensation for all such Work. The first payment for mobilization shall be one hundred percent (100%) of the bid item amount. The Contractor shall submit an invoice to the District for payment of mobilization upon execution of the Agreement for Construction Services. The scope of the Work included under Mobilization shall include, but shall not be limited to, the following principal items, if applicable:

1) Obtaining and paying for all bonds, insurance, and permits.

2) Moving on to the Project site of all Contractor's plant and equipment required for first month's operations.

3) Developing and installing a construction water supply.

4) Providing on-site sanitary facilities and potable water facilities as specified per Cal-OSHA and these Contract Documents.

5) Furnishing, installing, and maintaining all storage buildings or sheds required for temporary storage of products, equipment, or materials, and for all security.

6) Arranging for and erection of Contractor's work and storage yard.

7) Posting all OSHA required notices and establishment of safety programs per Cal-OSHA.

8) Full-time presence of Contractor's superintendent at the job site as required herein.

9) Submittal of Construction Schedule as required by the Contract Documents.

ARTICLE 44. PAYMENTS

a. The District shall make monthly progress payments following receipt of undisputed and properly submitted payment requests. Unless the District has made findings pursuant to Public Contract Code section 7201 (that the work included in this Contract is substantially complex, and therefore a retention of 10% shall be withheld from each progress payment as provided by the Contract Documents), Contractor shall be paid a sum equal to ninety-five percent (95%) of the value of Work performed up to the last Day of the previous month, less the aggregate of previous payments. District will, within forty-five (45) Days after receipt of an undisputed and properly submitted application for payment, pay the Contractor the amount so approved.

b. The Contractor shall, after the full completion of The Work, submit a final payment application. All prior progress estimates shall be subject to correction in the final estimate and payment.

c. Unless otherwise required by law or unless the District has made findings pursuant to Public Contract Code section 7201 (that the work included in this Contract is substantially complex, and therefore a retention of 10% shall be withheld from each progress payment as provided by the Contract Documents), the final payment of five percent (5%) of the value of the Work, if unencumbered, shall be paid no later than sixty (60) Days after the date of recordation of the Notice of Completion.

d. Acceptance by Contractor of the final payment shall constitute a waiver of all claims against the District arising from this Contract.

e. Payments to the Contractor shall not be construed to be an acceptance of any defective work or improper materials, or to relieve the Contractor of its obligations under the Contract Documents.

f. The Contractor shall submit with each payment request the Contractor's conditional waiver of lien for the entire amount covered by such payment request, as well as a valid unconditional waiver of lien from the Contractor and all subcontractors and materialmen for all work and materials included in any prior invoices. Waivers of lien shall be in the forms prescribed by California Civil Code Section 8132, 8132, 8136 and 8138. Prior to final payment by the District, the Contractor shall submit a final conditional waiver of lien for the Contractor's work, together with unconditional releases of lien from any subcontractor or materialmen.

ARTICLE 45. PAYMENTS WITHHELD AND BACKCHARGES

In addition to amounts which the District may retain under other provisions of the Contract Documents the District may withhold payments due to Contractor as the District may consider to be necessary to cover:

a. Stop Notice Claims.

b. Defective work not remedied.

c. Failure of Contractor to make proper payments to its subcontractors or suppliers.

d. Completion of the Contract if there exists a reasonable doubt that the work can be completed for balance then unpaid.

e. Damage to another contractor or third party.

f. Amounts which may be due the District for claims against Contractor.

g. Failure of Contractor to keep the record ("as-built") drawings up to date.

h. Failure to provide updates on the construction schedule.

i. Site cleanup.

j. Failure of the Contractor to comply with requirements of the Contract Documents.

k. Liquated damages.

l. Legally permitted penalties.

Upon completion of the Contract, the District will reduce the final Contract amount to reflect costs charged to the Contractor, back charges or payments withheld pursuant to the Contract Documents.

ARTICLE 46. CHANGES AND EXTRA WORK

a. **Change Order Work.**

1) The District, without invalidating the Contract, may order changes in the Work consisting of additions, deletions or other revisions, the Contract Price and Contract Time being adjusted accordingly. All such changes in the Work shall be authorized by Change Order, and shall be performed under the applicable conditions of the Contract Documents. A Change Order signed by the Contractor indicates the Contractor's agreement therewith, including any adjustment in the Contract amount or the Contract time, and the full and final settlement of all costs (direct, indirect and overhead) related to the Work authorized by the Change Order.

2) Contractor shall promptly execute changes in the Work as directed in writing by the District even when the parties have not reached agreement on whether the change increases the scope of Work or affects the Contract Price or Contract Time. All claims for additional compensation to the Contractor shall be presented in writing. No claim will be considered after the work in question has been done unless a written contract change order has been issued or a timely written notice of claim has been made by Contractor. Contractor shall not be entitled to claim or bring suit for damages, whether for loss of profits or otherwise, on account of any

decrease or omission of any item or portion of Work to be done. Whenever any change is made as provided for herein, such change shall be considered and treated as though originally included in the Contract, and shall be subject to all terms, conditions and provisions of the original Contract.

3) Owner Initiated Change. The Contractor must submit a complete cost proposal, including any change in the Contract time, within seven (7) Days after receipt of a scope of a proposed change order initiated by the District, unless the District requests that proposals be submitted in less than seven (7) Days.

4) Contractor Initiated Change. The Contractor must give written notice of a proposed change order required for compliance with the Contract Documents within seven (7) Days of discovery of the facts giving rise to the proposed change order.

5) Whenever possible, any changes to the Contract amount shall be in a lump sum mutually agreed to by the Contractor and the District.

6) Price quotations from the Contractor shall be accompanied by sufficiently detailed supporting documentation to permit verification by the District, including but not limited to estimates and quotations from subcontractors or material suppliers, as District may reasonably request.

7) If the Contractor fails to submit a complete cost proposal within the seven (7) Day period (or as requested), the District has the right to order the Contractor in writing to commence the work immediately on a force account basis and/or issue a lump sum change to the Contract Price and/ or Contract Time in accordance with the District's estimate. If the change is issued based on the District estimate, the Contractor will waive its right to dispute the action unless within fifteen (15) Days following completion of the added/deleted work, the Contractor presents written proof that the District's estimate was in error.

8) Estimates for lump sum quotations and accounting for cost-plus-percentage work shall be limited to direct expenditures necessitated specifically by the subject extra work, and shall be segregated as follows:

   (a) Labor. The costs of labor will be the actual cost for wages prevailing locally for each craft or type of worker at the time the extra work is done, plus employer payments of payroll taxes and insurance, health and welfare, pension, vacation, apprenticeship funds, and other direct costs resulting from Federal, State or local laws, as well as assessment or benefits required by lawful collective bargaining agreements. The use of a labor classification which would increase the extra work cost will not be permitted unless the contractor establishes the necessity for such additional costs. Labor costs for equipment operators and helpers shall be reported only when such costs are not included in the invoice for equipment rental.

(b) Materials. The cost of materials reported shall be at invoice or lowest current price at which such materials are locally available in the quantities involved, plus sales tax, freight and delivery. Materials cost shall be based upon supplier or manufacturer's invoice. If invoices or other satisfactory evidence of cost are not furnished within fifteen (15) Days of delivery, then the Engineer shall determine the materials cost, at its sole discretion.

(c) Tool and Equipment Use. Costs for the use of small tools, tools which have a replacement value of $1,000 or less shall be considered included in the markups described below. Regardless of ownership, the rates to be used in determining equipment use costs shall not exceed listed rates prevailing locally at equipment rental agencies, or distributors, at the time the work is performed.

(d) Overhead, Profit and Other Charges. The mark-up for overhead (including supervision) and profit on work added to the Contract shall be according to the following:

i. "Net Cost" is defined as consisting of costs of labor, materials and tools and equipment only excluding overhead and profit. The costs of applicable insurance and bond premium will be reimbursed to the Contractor and subcontractors at cost only, without mark-up. Contractor shall provide District with documentation of the costs, including but not limited to payroll records, invoices and such other information as District may reasonably request.

ii. For Work performed by the Contractor's forces the added cost for overhead and profit shall not exceed fifteen (15%) percent of the Net Cost of the Work.

iii. For Work performed by a subcontractor, the added cost for overhead and profit shall not exceed fifteen (15%) percent of the subcontractor's Net Cost of the Work to which the Contractor may add five (5%) percent of the subcontractor's Net Cost.

iv. For Work performed by a sub-subcontractor the added cost for overhead and profit shall not exceed fifteen (15 %) percent of the sub-subcontractor's Net Cost for Work to which the subcontractor and general contractor may each add an additional five (5%) percent of the Net Cost of the lower tier subcontractor.

iv. No additional markup will be allowed for lower tier subcontractors, and in no case shall the added cost for overhead and profit payable by District exceed twenty-five (25%) percent of the Net Cost as defined herein, of the party that performs the Work.

9) All of the following costs are included in the markups for overhead and profit described above, and Contractor shall not receive any additional compensation for: Submittals, drawings: field drawings, Shop Drawings, including submissions of drawings; field inspection; General Superintendence; General administration and preparation of cost proposals, schedule analysis, Change Orders, and other supporting documentation; computer services; reproduction services; Salaries of project engineer, superintendent, timekeeper, storekeeper, and secretaries; Janitorial services; Small tools, incidentals and consumables; Temporary on-Site facilities (Offices, Telephones, Internet access, Plumbing, Electrical Power, lighting; Platforms, Fencing, Water), Jobsite and Home office overhead or other expenses; vehicles and fuel used for work otherwise included in the Contract Documents; Surveying; Estimating; Protection of Work; Handling and disposal fees; Final cleanup; Other incidental Work; Related warranties; insurance and bond premiums.

10) For added or deducted Work by subcontractors, the Contractor shall furnish to the District the subcontractor's signed detailed record of the cost of labor, material and equipment, including the subcontractor markup for overhead and profit. The same requirement shall apply to sub-subcontractors.

11) For added or deducted work furnished by a vendor or supplier, the Contractor shall furnish to the District a detailed record of the cost to the Contractor, signed by such vendor or supplier.

12) Any change in The Work involving both additions and deletions shall indicate a net total cost, including subcontracts and materials. Allowance for overhead and profit, as specified herein, shall be applied if the net total cost is an increase in the Contract Price; overhead and profit allowances shall not be applied if the net total cost is a deduction to the Contract Price. The estimated cost of deductions shall be based on labor and material prices on the date the Contract was executed.

13) Contractor shall not reserve a right to assert impact costs, extended job site costs, extended overhead, constructive acceleration and/or actual

acceleration beyond what is stated in the change order for work. No claims shall be allowed for impact, extended overhead costs, constructive acceleration and/or actual acceleration due to a multiplicity of changes and/or clarifications. The Contractor may not change or modify the District's change order form in an attempt to reserve additional rights.

14) If the District disagrees with the proposal submitted by Contractor, it will notify the Contractor and the District will provide its opinion of the appropriate price and/or time extension. If the Contractor agrees with the District, a change order will be issued by the District. If no agreement can be reached, the District shall have the right to issue a unilateral change order setting forth its determination of the reasonable additions or savings in costs and time attributable to the extra or deleted work. Such determination shall become final and binding if the Contractor fails to submit a claim in writing to the District within fifteen (15) Days of the issuance of the unilateral change order, disputing the terms of the unilateral change order, and providing such supporting documentation for its position as the District may require.

15) No dispute, disagreement or failure of the parties to reach agreement on the terms of the change order shall relieve the Contractor from the obligation to proceed with performance of the work, including extra work, promptly and expeditiously.

16) Any alterations, extensions of time, extra work or any other changes may be made without securing consent of the Contractor's surety or sureties.

ARTICLE 47. OCCUPANCY

The District reserves the right to occupy or utilize any portion of The Work at any time before completion, and such occupancy or use shall not constitute Acceptance of any part of Work covered by this Contract. This use shall not relieve the Contractor of its responsibilities under the Contract.

ARTICLE 48. INDEMNIFICATION

To the extent permitted by law, Contractor shall defend, indemnify and hold harmless District, its directors, officers, employees, and authorized volunteers from and against all claims, damages, losses and expenses, including reasonable attorneys' fees and costs to defend arising out of the performance of the Work described herein, and caused in whole or in part by any negligent act or omission of the Contractor, any subcontractor, anyone directly or indirectly employed by any of them, or anyone whose acts any of them may be liable, except where caused by the active negligence, sole negligence, or willful misconduct of the District, its directors, officers, employees, and authorized volunteers.

To the fullest extent allowed by law, Contractor shall defend (with Counsel of District's choosing), indemnify and hold the District, its elected officials, officers, employees, agents and authorized volunteers free and harmless from any and all claims, demands, causes of action, costs, expenses, liabilities, losses, damages or injuries, at law or in equity, regardless of whether the allegations are false, fraudulent, or groundless, to property or persons, including wrongful death, to the extent arising out of or incident to any acts, omissions or willful misconduct of Contractor, its officials, officers, employees, agents, consultants and contractors arising out of or in connection with the performance of the Work or this Contract, including claims made by subcontractors for nonpayment, including without limitation the payment of all consequential damages and attorneys' fees and other related costs and expenses. Contractor shall defend, at Contractor's own cost, expense and risk, with Counsel of District's choosing, any and all such aforesaid suits, actions or other legal proceedings of every kind that may be brought or instituted against District, its elected officials, officers, employees, agents and authorized volunteers. To the extent of its liability, Contractor shall pay and satisfy any judgment, award or decree that may be rendered against District, its elected officials, officers, employees, agents and authorized volunteers in any such suit, action or other legal proceeding. Contractor shall reimburse District, its elected officials, officers, employees, agents and authorized volunteers for any and all legal expenses and costs incurred by each of them in connection therewith or in enforcing the indemnity herein provided. The only limitations on this provision shall be those imposed by Civil Code Section 2782.

ARTICLE 49. RECORD ("AS BUILT") DRAWINGS

a. Contractor shall prepare and maintain a complete set of record drawings (herein referred to as "as-builts") and shall require each trade to prepare its own as-builts. Contractor shall mark the as-builts to show the actual installation where the installation varies from the Work as originally shown. Contractor shall mark whichever drawings are most capable of showing conditions fully and where shop drawings are used, Contractor must record a cross-reference at the corresponding location on the contract drawings. Contractor shall give particular attention to concealed elements that would be difficult to measure and record at a later date.

Contractor shall use colors to distinguish variations in separate categories of The Work.

b. Contractor shall note related change order numbers where applicable. Contractor shall organize as-builts into manageable sets, bound with durable paper cover sheets and shall print suitable title, dates and other identification on the cover of each set. The suitability of the as-builts will be determined by the Engineer.

ARTICLE 50. RESOLUTION OF CONSTRUCTION CLAIMS

a. Contractor shall timely comply with all notices and requests for changes to the Contract Time or Contract Price, including but not limited to all requirements of Article 47, Changes and Extra Work, as a prerequisite to filing any claim governed by this Article. The failure to timely submit a notice of delay or notice of change, or to timely request a change to the Contract Price or Contract Time, or to timely provide any other notice or request required by this agreement shall constitute a waiver of the right to procedures of this Article.

b. Effective January 1, 1991, Section 20104 et seq., of the California Public Contract Code prescribes a process utilizing informal conferences, non-binding judicial supervised mediation, and judicial arbitration to resolve disputes on construction claims of $375,000 or less.

c. Effective January 1, 2017, Section 9204 of the Public Contract Code prescribes a process for negotiation and mediation to resolve disputes on construction claims. The intent of this Article is to implement Sections 20104 et seq. and Section 9204 of the California Public Contract Code. This Article shall be construed to be consistent with said statutes.

d. For purposes of this Article, “Claim” means a separate demand by the Contractor, after a change order duly requested in accordance with Article 47 “Changes and Extra Work” has been denied, for (A) a time extension, (B) payment of money or damages arising from work done by or on behalf of the Contractor pursuant to the Contract for a public work and payment of which is not otherwise entitled to, or (C) an amount the payment of which is disputed by the District.

e. **Claims governed by this Article may not be filed unless and until the Contractor completes all procedures for giving notice of delay or change and for the requesting of a time extension or change order, including but not necessarily limited to the procedures contained in Article 47 “Changes and Extra Work,” and Contractor’s request for a change has been denied in whole or in part. Claims governed by this Article must be filed no later than the date of final payment.**

f. The claim shall be submitted in writing to the District and shall include on its first page the following in 16 point capital font: “THIS IS A CLAIM.” Furthermore, the claim shall include the documents necessary to substantiate the claim. Nothing in this subdivision is intended to extend the time limit or supersede notice requirements otherwise provided by contract for the filing of claims, including all requirements pertaining to compensation or payment for extra work, disputed work, and/or changed conditions. Failure to follow such contractual requirements shall bar any claims or subsequent lawsuits for compensation or payment thereon.

g. **Supporting Documentation**: The Contractor shall submit all claims in the following format:

1) Summary of claim merit and price, reference Contract Document provisions pursuant to which the claim is made

2) List of documents relating to claim:

i. Specifications

ii. Drawings

iii. Clarifications (Requests for Information)

iv. Schedules

v. Other

3) Chronology of events and correspondence

4) Analysis of claim merit

5) Analysis of claim cost

6) Time impact analysis in CPM format

h. **District's Response**. Upon receipt of a claim pursuant to this Article, District shall conduct a reasonable review of the claim and, within a period not to exceed 45 Days, shall provide the Contractor a written statement identifying what portion of the claim is disputed and what portion is undisputed. Any payment due on an undisputed portion of the claim will be processed and made within 60 Days after the public entity issues its written statement.

1) If the District needs approval from the District Board to provide the Contractor a written statement identifying the disputed portion and the undisputed portion of the claim, and the District Board does not meet within the 45 Days or within the mutually agreed to extension of time following receipt of a claim sent by registered mail or certified mail, return receipt requested, the District shall have up to three Days following the next duly publicly noticed meeting of the District Board after the 45-Day period, or

extension, expires to provide the Contractor a written statement identifying the disputed portion and the undisputed portion.

2) Within 30 Days of receipt of a claim, the District may request in writing additional documentation supporting the claim or relating to defenses or claims the District may have against the Contractor. If additional information is thereafter required, it shall be requested and provided pursuant to this subdivision, upon mutual agreement of District and the Contractor. The District's written response to the claim, as further documented, shall be submitted to the Contractor within 30 Days (if the claim is less than $15,000, within 15 Days) after receipt of the further documentation, or within a period of time no greater than that taken by the Contractor in producing the additional information or requested documentation, whichever is greater.

i. **Meet and Confer**. If the Contractor disputes the District's written response, or the District fails to respond within the time prescribed, the Contractor may so notify the District, in writing, either within 15 Days of receipt of the District's response or within 15 Days of the District's failure to respond within the time prescribed, respectively, and demand in writing an informal conference to meet and confer for settlement of the issues in dispute. Upon receipt of a demand, the District shall schedule a meet and confer conference within 30 Days for settlement of the dispute.

j. **Mediation**. Within 10 business Days following the conclusion of the meet and confer conference, if the claim or any portion of the claim remains in dispute, the public entity shall provide the Contractor a written statement identifying the portion of the claim that remains in dispute and the portion that is undisputed. Any payment due on an undisputed portion of the claim shall be processed and made within 60 Days after the public entity issues its written statement. Any disputed portion of the claim, as identified by the contractor in writing, shall be submitted to nonbinding mediation, with the public entity and the Contractor sharing the associated costs equally. The public entity and Contractor shall mutually agree to a mediator within 10 business Days after the disputed portion of the claim has been identified in writing, unless the parties agree to select a mediator at a later time.

1) If the parties cannot agree upon a mediator, each party shall select a mediator and those mediators shall select a qualified neutral third party to mediate with regard to the disputed portion of the claim. Each party shall bear the fees and costs charged by its respective mediator in connection with the selection of the neutral mediator.

2) For purposes of this section, mediation includes any nonbinding process, including, but not limited to, neutral evaluation or a dispute review board, in which an independent third party or board assists the parties in dispute

resolution through negotiation or by issuance of an evaluation. Any mediation utilized shall conform to the timeframes in this section.

3) Unless otherwise agreed to by the public entity and the contractor in writing, the mediation conducted pursuant to this section shall excuse any further obligation under Section 20104.4 to mediate after litigation has been commenced.

4) The mediation shall be held no earlier than the date the Contractor completes the Work or the date that the Contractor last performs Work, whichever is earlier. All unresolved claims shall be considered jointly in a single mediation, unless a new unrelated claim arises after mediation is completed.

k. If following the mediation, the claim or any portion remains in dispute, the Contractor must file a claim pursuant to Chapter 1 (commencing with Section 900) and Chapter 2 (commencing with Section 910) of Part 3 of Division 3.6 of Title 1 of the Government Code prior to initiating litigation. For purposes of those provisions, the running of the period of time within which a claim must be filed shall be tolled from the time the Contractor submits his or her written claim pursuant to subdivision (a) until the time the claim is denied, including any period of time utilized by the meet and confer conference.

l. The following procedures are established for all civil actions filed to resolve claims of $375,000 or less:

1) Within 60 Days, but no earlier than 30 Days, following the filing or responsive pleadings, the court shall submit the matter to non-binding mediation unless waived by mutual stipulation of both parties or unless mediation was held prior to commencement of the action in accordance with Public Contract Code section 9204 and the terms of this Agreement. The mediation process shall provide for the selection within 15 Days by both parties of a disinterested third person as mediator, shall be commenced within 30 Days of the submittal, and shall be concluded within 15 Days from the commencement of the mediation unless a time requirement is extended upon a good cause showing to the court.

2) If the matter remains in dispute, the case shall be submitted to judicial arbitration pursuant to Chapter 2.5 (commencing with Section 1141.10) of Title 3 of Part 3 of the Code of Civil Procedure, notwithstanding Section 1114.11 of that code. The Civil Discovery Act of 1986 (Article 3 (commencing with Section 2016) of Chapter 3 of Title 3 of Part 4 of the Code of Civil Procedure) shall apply to any proceeding brought under this subdivision consistent with the rules pertaining to judicial arbitration.

i. In addition to Chapter 2.5 (commencing with Section 1141.10) of Title 3 of Part 3 of the Code of Civil Procedure, (A) arbitrators shall, when possible, be experienced in construction law, and (B) any party appealing an arbitration award who does not obtain a more favorable judgment shall, in addition to payment of costs and fees under that chapter, also pay the attorney's fees on appeal of the other party.

m. **Government Code Claims:** In addition to any and all contract requirements pertaining to notices of and requests for compensation or payment for extra work, disputed work, construction claims and/or changed conditions, the Contractor must comply with the claim procedures set forth in Government Code Sections 900, et seq. prior to filing any lawsuit against the District. Such Government Code claims and any subsequent lawsuit based upon the Government Code claims shall be limited to those matters that remain unresolved after all procedures pertaining to extra work, disputed work, construction claims, and/or changed conditions have been followed by Contractor. If no such Government Code claim is submitted, or if the prerequisite contractual requirements are not satisfied, no action against the District may be filed. **A Government Code claim must be filed no earlier than the date the work is completed or the date the Contractor last performs work on the Project, whichever occurs first. A Government Code claim shall be inclusive of all unresolved claims unless a new unrelated claim arises after the Government Code claim is submitted.**

n. The District's failure to respond to a claim from the Contractor within the time periods described in this Article or to otherwise meet the time requirements of this Article shall result in the claim being deemed rejected in its entirety.

ARTICLE 51. DISTRICT'S RIGHT TO TERMINATE CONTRACT

a. **Termination for Cause**: The District may, without prejudice to any other right or remedy, serve written notice upon Contractor of its intention to terminate this Contract if the Contractor: (i) refuses or fails to prosecute The Work or any part thereof with such diligence as will ensure its completion within the time required; (ii) fails to complete The Work within the required time; (iii) should file a bankruptcy petition or be adjudged a bankrupt; (iv) should make a general assignment for the benefit of its creditors; (v) should have a receiver appointed; (vi) should persistently or repeatedly refuse or fail to supply enough properly skilled workers or proper materials to complete the work; (vii) should fail to make prompt payment to subcontractors or for material or labor; (viii) persistently disregard Applicable Laws, ordinances, other requirements or instructions of the District; or (ix) should violate any of the provisions of the Contract Documents.

The notice of default and intent to terminate shall contain the reasons for termination. Unless within ten (10) Days after the service of such notice, Contractor resolves the circumstances giving rise to the notice of default to the District's satisfaction, or makes arrangements acceptable to the District for the required corrective action, this Contract shall terminate. In such case, Contractor shall not be entitled to receive any further payment until the Project has been finished. The District may take over and complete The Work by any method it may deem appropriate. Contractor and its surety shall be liable to the District for any excess costs or other damages incurred by the District to complete the Project. If the District takes over The Work, the District may, without liability for so doing, take possession of and utilize in completing The Work such materials, appliances, plant, and other property belonging to the Contractor as may be on the Project site.

b. **Termination For Convenience:** In addition to its right to terminate this Contract for default, the District may terminate the Contract, in whole or in part, at any time upon ten (10) Days written notice to Contractor. The Notice of Termination shall specify that the termination is for the convenience of the District, the extent of termination and the effective date of such termination.

After receipt of Notice of Termination, and except as directed by the District, the Contractor shall, regardless of any delay in determining or adjusting any amounts due under this Termination for Convenience clause, immediately proceed with the following obligations:

1) Stop Work as specified in the Notice.

2) Complete any Work specified in the Notice of Termination in a least cost/shortest time manner while still maintaining the quality called for under the Contract Documents.

3) Leave the Site and any other property upon which the Contractor was working and upon which the facility (or facilities) forming the basis of the Contract Documents is situated in a safe and sanitary manner such that it does not pose any threat to the public health or safety.

4) Terminate all subcontracts and purchase orders to the extent that they relate to the portions of The Work terminated.

5) Place no further subcontracts or orders, except as necessary to complete the remaining portion of The Work.

6) Submit to the District, within ten (10) Days from the effective date of the Notice of Termination, all of the documentation called for by the Contract Documents to substantiate all costs incurred by the Contractor for labor, materials and equipment through the Effective Date of the Notice of Termination. Any documentation substantiating costs incurred by the Contractor solely as a result of the District's exercise of its right to terminate this Contract pursuant to this clause,

which costs the Contractor is authorized under the Contract Documents to incur, shall: (i) be submitted to and received by the District no later than thirty (30) Days after the Effective Date of the Notice of Termination; (ii) describe the costs incurred with particularity; and (iii) be conspicuously identified as "Termination Costs Occasioned by the District's Termination for Convenience."

7) District's total liability to Contractor by reason of the termination shall be limited to the total (without duplication of any items) of:

i. The reasonable cost to the Contractor for all Work performed prior to the effective date of the termination, determined in accordance with the force account provisions of ARTICLE 46, including the Work done to secure the Project for termination. Reasonable cost may not exceed the applicable percentage completion values derived from the progress schedule and the Cost Breakdown. Deductions shall be made for cost of materials to be retained by the Contractor, cost of Work defectively performed, amounts realized by sale of materials, and for other appropriate credits or offsets against cost of Work as allowed by the Contract Documents. Reasonable cost will include reasonable allowance for Project overhead and general administrative overhead, not to exceed five percent (5%) of the cost. Contractor shall not be entitled to reimbursement under this section for Work for which Contractor has already received, or is eligible to receive, compensation under the terms of the Contract.

ii. When, in the District's opinion, the cost of any item of Work is excessively high due to costs incurred to remedy or replace defective or rejected Work, reasonable cost to be allowed will be the estimated reasonable cost of performing the Work in compliance with requirements of the Contract Documents and excessive actual cost shall be disallowed.

iii. A reasonable allowance for profit on cost of Work performed as determined in accordance with ARTICLE 46 provided that the Contractor establishes to the District's satisfaction that the Contractor would have made a profit had the Project been completed, and provided further that the profit allowed shall not exceed five percent (5%) percent of the cost. Contractor shall not be entitled to an allowance for profit on any work for which Contractor has received, or is eligible to receive, compensation under the terms of the Contract.

iv. Reasonable costs to the Contractor of handling material returned to vendors, delivered to the District or otherwise disposed of as directed by the District.

v. A reasonable allowance for the Contractor's internal administrative costs in preparing termination claim.

vi. Reasonable demobilization costs, and reasonable payments made to Subcontractors or suppliers on account of termination.

8) In no event shall the District be liable for unreasonable costs incurred by the Contractor or subcontractors after receipt of a notice of termination. Such non-recoverable costs include, but are not limited to, the cost of or anticipated profits on Work not performed as of the date of termination, post-termination employee salaries, unreasonable post-termination administrative expenses, post-termination overhead or unabsorbed overhead, surety costs of any type, costs of preparing and submitting the Contractor's termination claim, attorney fees of any type, and all other costs relating to prosecution of a claim or lawsuit.

9) The District shall have no obligation to pay the Contractor under this ARTICLE 51b (Termination for Convenience) unless and until the Contractor provides the District with updated and acceptable as-builts and Record Documents for Work completed prior to termination.

10) In arriving at the amount due the Contractor under this clause there shall be deducted in whole or in the appropriate part(s) if the termination is partial:

11) All unliquidated advances or other payments on account previously made to the Contractor, including without limitation all payments which are applicable to the terminated portion of the Contract Documents,

12) Any claim the District may have against the Contractor in connection with the Work, and

13) The agreed price for, or proceeds of sale of, any materials, supplies, or other things kept by the Contractor and not otherwise recovered by or credited to the District.

14) These provisions are in addition to and not in limitation of any other rights or remedies available to the District.

c. **Savings Clause**. If District terminates Contractor for cause, and if it is later determined that the termination was wrongful, such default termination shall automatically be converted to and treated as a termination for convenience. In such event, Contractor shall be entitled to receive only the amounts payable under this section, and Contractor specifically waives any claim for any other amounts or damages, including, but not limited to, any claim for consequential damages or lost profits.

d. **Exception.** Notwithstanding any other provision of this Article, when immediate action is necessary to protect life and safety or to reduce significant exposure or liability, the District may immediately order Contractor to cease Work until such safety or liability issues are addressed to the satisfaction of the District or the Contract is terminated.

ARTICLE 52. WARRANTY AND GUARANTEE

a. Contractor warrants that all materials and equipment furnished under this Contract shall be new unless otherwise specified in the Contract Documents; and that all Work conforms to the Contract Document requirements and is free of any defect whether performed by the Contractor or any subcontractor or supplier.

b. Unless otherwise stated, all warranty periods shall begin upon the filing of the Notice of Completion. Unless otherwise stated, the warranty period shall be for one year.

c. The Contractor shall remedy at its expense any damage to District-owned or controlled real or personal property.

d. Contractor shall furnish the District with all warranty and guarantee documents prior to final Acceptance of the Project by the District.

e. The District shall notify the Contractor, in writing, within a reasonable time after the discovery of any failure, defect, or damage. The Contractor shall within ten (10) Days after being notified commence and perform with due diligence all necessary Work to complete or correct the Work at issue. If the Contractor fails to promptly remedy any defect, or damage; the District shall have the right to replace, repair, or otherwise remedy the defect, or damage at the Contractor’s expense.

f. In the event of any emergency constituting an immediate hazard to health, safety, property, or licensees, when caused by Work of the Contractor not in accordance with the Contract requirements, the District may undertake at Contractor’s expense, and without prior notice, all actions necessary to correct such condition.

g. With respect to all warranties, express or implied, from subcontractors, manufacturers, or suppliers for Work performed and Materials furnished under this Contract, the Contractor shall:

1) Obtain for District all warranties that would be given in normal commercial practice or that are required in the Contract Documents;

2) Require all warranties to be executed, in writing, for the benefit of the District; and

3) Enforce all warranties for the benefit of the District, unless otherwise directed in writing by the District.

This Article shall not limit the District's rights under this Contract or with respect to latent defects, gross mistakes, or fraud. The District specifically reserves all rights related to defective work, including but not limited to the defect claims pursuant to California Code of Civil Procedure Section 337.15.

ARTICLE 53. DOCUMENT RETENTION & EXAMINATION

a. In accordance with Government Code Section 8546.7, records of both the District and the Contractor shall be subject to examination and audit by the State Auditor General for a period of three (3) years after final payment.

b. Contractor shall make available to the District any of the Contractor's other documents related to the Project immediately upon request of the District.

c. In addition to the State Auditor rights above, the District shall have the right to examine and audit all books, estimates, records, contracts, documents, bid documents, subcontracts, and other data of the Contractor (including electronic records, computations and projections) related to negotiating, pricing, or performing the modification in order to evaluate the accuracy and completeness of the cost or pricing data at no additional cost to the District, for a period of four (4) years after final payment.

ARTICLE 54. SOILS INVESTIGATIONS

When a soils investigation report for the Project site is available, such report shall not be a part of the Contract Documents. Any information obtained from such report as to subsurface soil condition, or to elevations of existing grades or elevations of underlying rock, is approximate only and is not guaranteed. Contractor acknowledges that any soils investigation report (including any borings) was prepared for purposes of design only and Contractor is required to examine the site before submitting its bid and must make whatever tests it deems appropriate to determine the underground condition of the soil.

ARTICLE 55. SEPARATE CONTRACTS

a. The District reserves the right to let other contracts in connection with this Work or on the Project site. Contractor shall cooperate with and permit other contractors reasonable access and storage of their materials and execution of their work and shall properly connect and coordinate its Work with theirs.

b. To ensure proper execution of its subsequent Work, Contractor shall immediately inspect work already in place and shall at once report to the Engineer any problems with the work in place or discrepancies with the Contract Documents.

c. Contractor shall ascertain to its own satisfaction the scope of the Project and nature of any other contracts that have been or may be awarded by the District in prosecution of the Project to the end that Contractor may perform this Contract in the light of such other contracts, if any. Nothing herein contained shall be interpreted as granting to Contractor exclusive occupancy at site of the Project. Contractor shall not cause any unnecessary hindrance or delay to any other contractor working on the Project. If simultaneous execution of any contract for the Project is likely to cause interference with performance of some other contract or contracts, the Engineer shall decide which Contractor shall cease Work temporarily and which contractor shall continue or whether work can be coordinated so that contractors may proceed simultaneously. The District shall not be responsible for any damages suffered or for extra costs incurred by Contractor resulting directly or indirectly from award, performance, or attempted performance of any other contract or contracts on the Project site.

ARTICLE 56. NOTICE AND SERVICE THEREOF

All notices shall be in writing and either served by personal delivery or mailed to the other party as designated in the Bid Forms. Written notice to the Contractor shall be addressed to Contractor's principal place of business unless Contractor designates another address in writing for service of notice. Notice to District shall be addressed to the District as designated in the Notice Inviting Bids unless District designates another address in writing for service of notice. Notice shall be effective upon receipt or five (5) Days after being sent by first class mail, whichever is earlier. Notice given by facsimile shall not be effective unless acknowledged in writing by the receiving party.

ARTICLE 57. NOTICE OF THIRD PARTY CLAIMS

Pursuant to Public Contract Code Section 9201, the District shall provide Contractor with timely notification of the receipt of any third-party claim relating to the Contract.

ARTICLE 58. STATE LICENSE BOARD NOTICE

Contractors are required by law to be licensed and regulated by the Contractors' State License Board which has jurisdiction to investigate complaints against contractors if a complaint regarding a patent act or omission is filed within four (4) years of the date of the alleged violation. A complaint regarding a latent act or omission pertaining to structural defects must be filed within ten (10) years of the date of the alleged violation.

Any questions concerning a contractor may be referred to the Registrar, Contractors' State License Board, P.O. Box 26000, Sacramento, California 95826.

ARTICLE 59. INTEGRATION

a. This Contract, together with its incorporated documents, contains the entire, integrated agreement of the parties hereto, and supersedes any and all other prior or contemporaneous negotiations, understandings and oral or written agreements between the parties hereto. Each party acknowledges that no representations, inducements, promises or agreements have been made by any person which are not incorporated herein, and that any other agreements shall be void.

b. Any modification of this Contract shall be effective in in writing signed by all parties hereto. No oral order, objection, direction, claim or notice by any party or person shall affect or modify any of the terms or obligations contained in the Contract Documents.

ARTICLE 60. ASSIGNMENT

Contractor shall not assign, transfer, convey, sublet, or otherwise dispose of this Contract or any part thereof including any claims, without prior written consent of the District. Any assignment without the written consent of the District shall be void. Any assignment of money due or to become due under this Contract shall be subject to a prior lien for services rendered or Material supplied for performance of Work called for under the Contract Documents in favor of all persons, firms, or corporations rendering such services or supplying such Materials to the extent that claims are filed pursuant to the Civil Code, the Code of Civil Procedure or the Government Code.

ARTICLE 61. CHANGE IN NAME AND NATURE OF CONTRACTOR'S LEGAL ENTITY

Should a change be contemplated in the name or nature of the Contractor's legal entity, the Contractor shall first notify the District in order that proper steps may be taken to have the change reflected on the Contract and all related documents. No change of Contractor's name or nature will affect District's rights under the Contract, including but not limited to the bonds.

ARTICLE 62. ASSIGNMENT OF ANTITRUST ACTIONS

Pursuant to Section 7103.5 of the Public Contract Code, in entering into a public works contract or subcontract to supply goods, services, or materials pursuant to a public works contract, Contractor or subcontractor offers and agrees to assign to the District all rights, title, and interest in and to all causes of action it may have under Section 4 of the Clayton Act (15 U.S.C. Section 15) or under the Cartwright Act (chapter 2 (commencing with Section 16700) of part 2 of division 7 of the Business and Professions Code), arising from the purchase of goods, services, or materials pursuant to this Contract or any subcontract.

This assignment shall be made and become effective at the time the District makes final payment to the Contractor, without further acknowledgment by the parties.

ARTICLE 63. PROHIBITED INTERESTS

No District official or representative who is authorized in such capacity and on behalf of the District to negotiate, supervise, make, accept, or approve, or to take part in negotiating, supervising, making, accepting or approving any engineering, inspection, construction or material supply contract or any subcontract in connection with construction of the project, shall be or become directly or indirectly interested financially in the Contract.

ARTICLE 64. LAWS AND REGULATIONS

a. Contractor shall give all notices and comply with all federal, state and local laws, ordinances, rules and regulations bearing on conduct of work as indicated and specified by their terms. References to specific laws, rules or regulations in the Contract Documents are for reference purposes only and shall not limit or affect the applicability of provisions not specifically mentioned. If Contractor observes that drawings and Specifications are at variance therewith, he shall promptly notify the Engineer in writing and any necessary changes shall be adjusted as provided for in this Contract for changes in work. If Contractor performs any work knowing it to be contrary to such laws, ordinances, rules and regulations, and without such notice to the Engineer, he shall bear all costs arising therefrom.

b. Contractor shall be responsible for familiarity with the Americans with Disabilities Act (“ADA”) (42 U.S.C. § 12101 et seq.). The Work will be performed in compliance with ADA laws, rules and regulations. Contractor shall comply with the Historic Building code, including but not limited to, as it relates to the ADA, whenever applicable.

c. Contractor acknowledges and understands that, pursuant to Public Contract Code section 20676, sellers of “mined material” must be on an approved list of sellers published pursuant to Public Resources Code section 2717(b) in order to supply mined material for this Contract.

ARTICLE 65. PATENT FEES OR ROYALTIES.

The Contractor shall include in its bid amount the patent fees or royalties on any patented article or process furnished or used in the Work. Contractor shall assume all liability and responsibility arising from the use of any patented, or allegedly patented, materials, equipment, devices or processes used in or incorporated with The Work, and shall defend, indemnify and hold harmless the District, its officials, officers, agents, employees and representatives from and against any and all liabilities, demands, claims, damages, losses, costs and expenses, of whatsoever kind or nature, arising from such use.

ARTICLE 66. OWNERSHIP OF DRAWING

All Contract Documents furnished by the District are District property. They are not to be used by Contractor or any subcontractor on other work nor shall Contractor claim any right to such documents. With exception of one complete set of Contract Documents, all documents shall be returned to the District on request at completion of the Work.

ARTICLE 67. NOTICE OF TAXABLE POSSESSORY INTEREST

In accordance with Revenue and Taxation Code Section 107.6, the Contract Documents may create a possessory interest subject to personal property taxation for which Contractor will be responsible.

END OF GENERAL CONDITIONS

SPECIAL CONDITIONS

SP – 1 DIFFERING SITE CONDITIONS

In the event that site conditions are materially different than shown on the plans or observed during the mandatory site visit, the Contractor shall promptly notify the Engineer in writing. The Engineer shall investigate the conditions, and if found that such conditions do materially differ and cause an increase or decrease in the Contractor's cost of, or the time required for, performance of any part of the Work under this Contract, the Engineer will recommend to the District that an equitable adjustment be made by modifying the Contract by Change Order to account for differing site conditions.

No Claim of the Contractor under this clause or any other shall be allowed unless the Contractor has given notice as indicated above..

No Claim of the Contractor for an equitable adjustment hereunder shall be allowed if asserted after final payment under this Contract.

SP – 2 USE OF STANDARDS

The District's Standard Technical Specifications and Standard Details (most recent edition) are considered a part of the Contract Documents and are the primary reference for technical Specifications for the construction of District projects. Any item of work not specified in the following Technical Specifications sections or not shown in the Bid Drawings shall be subject to the District's Standard Technical Specifications and Standard Details .

SP – 3 DESCRIPTION OF BID ITEMS

The Bid Items listed in Section 00400 Bid Form are described in further detail in Section 00900 – Measurement and Payment. The descriptions provided are intended as a guide for measurement and payment and may not include all items or work necessary to complete the Project. Any items not described, but necessary to complete the Project as specified within the Contract Documents shall be considered included in the appropriate Bid Item.

SP – 4 DAMAGE TO PAVEMENT AND CONCRETE

The Contractor shall provide all necessary protection to existing pavement and concrete so as to avoid scraping, gouging, imprinting, cracking edges or otherwise causing damage during the entire Project. The District shall direct the Contractor to repair any damage as deemed necessary by the District. The Contractor shall repair said damage using methods required by the District or the parties may agree to an alternative method in advance of said repairs. All costs of repairs to existing pavement and concrete due to damage caused by the Contractor shall be solely the responsibility of the Contractor.

END OF SPECIAL CONDITIONS

6700 MADISON AVENUE AT DEWEY DRIVE WATER MAIN PROJECT C21-105

The work described herein shall be performed according to the Citrus Heights Water District General Specifications as follows:

1. SCOPE OF WORK

The work shall include installing:

- 115 lineal feet of 8” Pressure Class 350 Ductile Iron Pipe (PC350 DIP)

The work includes all labor, materials, equipment, and incidentals, to completely install an operating facility in accordance with these Citrus Heights Water District General Specifications and the Contract Documents.

The Work shall be complete, and all work, materials, and services not expressly shown or called for in the Contract Documents which may be necessary for the complete and proper construction of the Work in good faith shall be performed, furnished, and installed by the Contractor as though originally so specified or shown, at no increase in cost to the District.

2. DISTRICT FURNISHED ITEMS

- The District shall furnish water for construction at no cost to the Contractor.
- The District shall provide for initial compaction testing as deemed necessary by the District at no cost to the Contractor.
- The District shall provide for bacteriological sampling of the water in the water main and services prior to reconnection of same at no cost to the Contractor.
- The District shall provide an Encroachment Permit approved by the County of Sacramento and pay all costs for fees and inspection at no cost to the Contractor.
- The District shall file and maintain a Notice of Exemption for the California Environmental Quality Act (CEQA).

3. CONTRACTOR FURNISHED ITEMS

- The Contractor shall furnish all other material including but not limited to pipeline and appurtenances, sand, 3/4” aggregate base, concrete for thrust blocks, temporary and final paving, and hauling and disposal of spoils. The Contractor is advised to order and acquire the specified materials well enough in advance so as not to cause the Project to be delayed or to necessitate substitutions. Additional work days will not be granted for failure to obtain materials in a timely manner.
- The Contractor shall be responsible for obtaining any necessary permit for the disposal of chlorinated water and coordinating with the proper agency. Any variation on this method will require approval in advance by Citrus Heights Water District. The discharge of chlorinated water into any surface water drainage system is strictly prohibited by law.
- The Contractor shall furnish a Traffic Control Plan approved by the County of Sacramento. The Traffic Control Plans shall comply with the Encroachment Permits.

4. ITEMS OF WORK, MEASUREMENT AND PAYMENT

Bid Item 1, Mobilization: Includes obtaining a temporary discharge permit as required. Includes preparatory work and operations, including, but not limited to, that necessary for the movement of personnel, equipment, supplies, and incidentals to the Project site; for the establishment of all work site offices, buildings, and other facilities necessary for the Project; and for all other work and operations which must be performed, including costs incurred, prior to beginning work on the various contract items at the work site.

The bid item for mobilization shall be no more than eight percent (8%) of the total contract amount. The first payment for mobilization shall be one hundred percent (100%) of the bid item amount. The Contractor shall submit an invoice to the District for payment of mobilization upon execution of the Agreement for Construction Services.

Bid Item 2, Sheeting, Shoring and Bracing: Consists of providing sheeting, shoring and bracing for below-grade excavations as is necessary to provide a safe work environment for the workers. The Contractor shall be responsible for the proper application of sheeting, shoring, and bracing as required at any trench depth. Furthermore, the Contractor shall comply with all requests by the District Inspector for applying of sheeting, shoring, and bracing at any trench depth.

The Contractor shall refer directly to Title 8 of the California Code of Regulations and the Labor Code, produced by the State of California Department of Industrial Relations and the Cal/OSHA Consultation Service Research and Education Unit, for detailed information regarding the regulation's scope, specifications, and exceptions and for other requirements that may be applicable to their operations.

The bid item for sheeting, shoring, and bracing shall be no more than one percent (1%) of the total contract amount. The first payment for sheeting, shoring, and bracing shall be one hundred percent (100%) of the bid item amount. The Contractor shall submit an invoice to the District for payment of sheeting, shoring, and bracing upon execution of the Agreement for Construction Services.

Bid Item 3, Traffic Control Plan and Implementation: Includes preparing and obtaining approval for a Traffic Control Plan, procurement and placement of all traffic control materials, equipment, and markings, and fulfillment of all other requirements as specified in the approved Traffic Control Plan. The Contractor shall coordinate required inspections with the County of Sacramento Encroachment Inspector. The Contractor shall comply with the approved County of Sacramento Encroachment Permits, and shall implement traffic control procedures as directed by the County Inspector and the District Inspector. The Contract lump sum price paid for Traffic Control Implementation includes compensation for all labor, materials, tools, equipment and incidentals and for all work involved with Traffic Control Implementation, including placement of surface mounted channelizers, electronic advance message boards, flashing arrow boards, construction area and stationary mounted signs, project information signs, flagging, removal of all traffic control materials, equipment, and markings from the site upon completion of work, complete in place, as shown on the Project Plans and as directed by the County Inspector. This bid item also includes any traffic control necessary for night time work, if necessary.

The bid item for the traffic control plan and implementation shall be no more than five percent (5%) of the total contract amount. The first payment for the traffic control plan and implementation shall be fifty percent (50%) of the bid item amount and shall be invoiced with the Contractor’s monthly payment request following receipt of the Notice to Proceed from the District. The remaining fifty percent (50%) of the bid item amount shall be invoiced by the Contractor with the following monthly payment request.

Bid Item 4, Storm Water Pollution Prevention Implementation: Includes procurement and placement of all storm water pollution protection materials and equipment, and fulfillment of all other requirements as specified in the Project Plan. The Contractor shall coordinate required inspections with the County of Sacramento Encroachment Inspector and the District Inspector. The Contractor shall comply with changes to the approved storm water pollution protection plans as required by the County of Sacramento Encroachment Inspector and the District Inspector. The contract lump sum price paid for Storm Water Pollution Prevention Implementation includes compensation for all labor, materials, tools, equipment and incidentals and for doing all work involved with Storm Water Pollution Prevention Implementation, including filter bags, gravel filled bags, geotextile fabric or erosion control blankets, staples, temporary fiber rolls, stakes, and removal of all storm water pollution protection materials and equipment from the site upon completion of work and as directed by the County and District Inspectors.

The bid item for the storm water pollution prevention plan and implementation shall be no more than one percent (1%) of the total contract amount. Payment for the storm water pollution prevention plan and implementation shall be one hundred percent (100%) of the bid item amount and shall be invoiced with the Contractor’s monthly payment request following receipt of the Notice to Proceed from the District.

Bid Item 5, Install 8” Pressure Class 350 Ductile Iron Pipe (PC350 DIP) Water Main: Includes construction saw cutting and removal of existing paving, excavation, all potholing prior to or during construction, and the installation of 8" Pressure Class 350 Ductile Iron Joint Pipe (PC350 DIP) water main, mechanically restrained with bolted external joints, as indicated on the Project Plan. Includes the installation of tees, elbows, caps, spools, and adaptors, flexible couplings, nuts, bolts, gaskets, insulated locator wire and non-detectable locator tape, thrust blocks, backfill, compaction, and temporary paving. Includes disinfection, hydrostatic pressure testing (150 PSI for two hours), flushing, and bacteriological testing of the new water mains prior to connecting to the existing water mains. Payment shall be at the contract unit price per each unit, complete.
See CONTRUCTION DETAILS “TREN_711” and “TREN_713SC”

Bid Item 6, 8” Connection to Existing 8” Water Main: Includes connecting newly constructed 8” water main to existing 8” water main as indicated on the Project Plan. Includes installing all materials and fittings, with the exception of water main, as necessary to obtain proper alignment with the existing water main as indicated on the Project Plan. Water main shall be invoiced at the linear footage price as part of the appropriate bid item. Includes potholing prior to construction, insulated locator wire and non-detectable locator tape, backfill, and compaction. Includes disinfection, flushing, and bacteriological testing. Includes removal of existing caps and blow-offs, valve boxes and risers, and thrust blocks regardless of size. Payment shall be at the contract unit price per each unit, complete.
See PROJECT PLANS, Sheet 4, Note 2 and 3.

Bid Item 7, 3” to 4” Max. Depth Asphaltic Concrete (AC) Paving Restoration: This work includes removal of temporary paving, surface preparation, subsurface compaction as necessary and installation of 1/2" aggregate Asphalt Concrete to a 3” to 4” Maximum depth (installed in 2" maximum lifts) in accordance with County of Sacramento Standard Construction Specifications. Spoils from demolition shall be properly disposed of by the Contractor outside County right -of-way. Includes replacement of pavement striping, lettering, and reflective buttons, disturbed during the project and as directed by the Inspector.

Final paving lift shall be applied using a paving finishing machine to provide an even surface with minor compaction. Hand raking of the final paving lift shall be minimal and only in areas where a paving finishing machine cannot be used. No disturbance of the paving shall be allowed until a pavement roller has adequately compacted the paving, and the paving has properly cooled. All paving not conforming to said specifications shall be removed and properly replaced by the Contractor at no cost to the District.

The contract unit price paid per square foot for 3” to 4” Max. Asphaltic Concrete (AC) Paving Restoration shall include compensation for all labor, materials, tools, equipment and incidentals and for doing all work involved in 3” to 4” Max. Asphaltic Concrete Paving Restoration, including all pavement striping, lettering, and reflective buttons, complete in place, as shown on the plans, as specified in these specifications, and as directed by the District Inspector. Payment shall be based upon the quantity of paving restoration, not the quantity of Slurry Seal.

See CONTRUCTION DETAIL “TREN _713SC”.

Bid Item 8, Concrete Planter Curb Restoration: This work includes construction and finish saw cutting, removal, subsurface recompaction with 4" minimum 3/4" aggregate base compacted to 95%, and replacement with six-sack concrete mix, and finish to match existing. The replaced curb shall be constructed in conformance with County of Sacramento Standard Construction Specifications. Spoils from demolition shall be properly disposed of by the Contractor outside County right of way.

The contract unit price paid per lineal foot for Concrete Planter Curb Restoration shall include compensation for all labor, materials, tools, equipment and incidentals and for doing all work involved in Concrete Planter Curb Restoration, including furnishing and placing aggregate base material, complete in place, as shown on the plans, as specified in these specifications, and as directed by the County and District Inspector.
See SPECIAL PROVISIONS, Concrete Restoration.

Bid Items 9, Landscape Restoration – Lawn or Planter Area: This work consists of restoring customer's lawn or planter area to its original or better condition prior to water installation. Includes sod removal and replacement or reinstallation, grading, mulching, irrigation and sprinkler systems, and a general site cleanup. Payment shall be at the contract price per each unit, complete.
See SPECIAL PROVISIONS, Landscape Restoration.

5. ORDER OF WORK

The order of work outlined below is to minimize public inconvenience and water service interruptions. The Contractor is to submit a more detailed written schedule of the order of work based on this outline.

1. Obtain approvals of submittals for the following items: Discharge permit if required, materials, pipeline and appurtenances, backfill material design, asphalt mix design, concrete design mix, and Construction Schedule.

2. Order and coordinate delivery of material and equipment, and request location services from Underground Service Alert (USA). Telephone: 1-800-642-2444 or 811.

3. Install new water mains with temporary caps with 2" blow-offs at points of connection to the existing system. Obtain approval from the District for installation and then backfill excavation.

4. Install temporary 2" Construction Water Service(s) as required by the District Inspector to allow pressurization of the old system and the new system simultaneously.
   See CONTRUCTION DETAILS, Construction Detail WS_290.

5. Flush and hydrostatically test water main. Disinfect (Chlorinate) and De-chlorinate water main. District performs bacteriological sampling.

6. Coordinate with District Inspector for connecting new water mains to existing water mains upon notification by District of satisfactory bacteriological sampling.

7. Restore sites to pre-construction conditions as required and obtain approval from the District and the County of Sacramento.

6. BACTERIOLOGICAL TESTING PROCEDURE AND TIMETABLE

Before project construction begins:

1. CHWD Water Quality personnel shall sample for both Coliform (Presence/Absence) and Heterotrophic Plate Count (HPC) on mains adjacent to the project. (SimPlate may be substituted for HPC)

During project:

2. CHWD Project Management personnel will provide a 24-hour notice to the Regional Water Quality Control Board for all flushing events.

3. The newly constructed mains shall be filled by the contractor and purged to remove any trapped air using the District-approved and tested backflow prevention device specification. All best management practices shall be followed to insure no sediment or chlorine reaches any drain inlet or creek.

4. The newly constructed mains shall pass the District pressure check requirements.

5. The mains shall be chlorinated at 100 ppm for a minimum of 24 hours by the contractor using an approved chlorination specialist.

6. The chlorine concentration shall be checked after 24 hours and a minimum residual of 25 ppm must be present throughout the new mains.

7. The mains shall be flushed by the contractor until the chlorine concentration matches the normal system residual. All best management practices shall be followed to insure no sediment or chlorine reaches any drain inlet or creek.

8. CHWD Project Management personnel shall submit a sampling plan to the Operations Manager for approval.

9. CHWD Water Quality personnel, when practical, will collect Coliform and HPC samples according to the approved sampling plan. The sampling schedule will be submitted to the Operations Manager and the Water Quality Supervisor with at least a 24-hour notice.

10. Samples shall be taken for both Coliform and Heterotrophic Plate Count (HPC) at 24 and 48 hour intervals after completion of flushing.

11. CHWD Project Management personnel shall submit negative sample documentation to Operations Manager for acceptance prior to the any connections

to the CHWD distribution system. Sample result documentation generally takes 3-5 business days after samples are delivered to lab.

12. CHWD Water Quality personnel will sample mains downstream of project for Coliform and HPC after the new main is connected to the CHWD distribution system.

The Contractor shall allow 8-10 business days for the Disinfection/Sampling Procedure prior to any connection to the District's distribution system. Larger systems will require additional time for chlorination and flushing. Bacteriological samples shall only be collected between 8:00am and 2:00pm Monday through Thursday. Any positive results on any sample taken shall require a repeat of the Disinfection/Sampling Procedure until all samples test negative. HPC samples require a plate count of less than 500 on any sample taken.

1. DAY 1 - Chlorinate new mains to 100 PPM and complete to allow flushing time on following day.

   ---24-hour chlorine detention period---

2. DAY 2 - Flush new mains to normal residual and complete before 2:00pm. (Similar to system residual)

   ---24-hour sampling detention period---

3. DAY 3 - Obtain first Coliform and HPC samples before 2:00pm.

   ---24-hour sampling detention Period---

4. DAY 4 - Obtain second Coliform and HPC samples before 2:00pm.

   ---3 to 5 business days for laboratory testing and review---

5. DAY 7-9 - Sample documentation provided to Operations Manager and customer notification of shut-down

   ---24-hour notification period---

6. DAY 8-10 - Connection to CHWD distribution system only after clearance from Operations Manager is received.

7. EXCAVATION AND POTHOLING

Prior to beginning any excavation, the Contractor shall call Underground Service Alert (USA) (800) 642-2444 or 811, at least two (2) working days in advance, to arrange for utility location. The Contractor shall be responsible for the location and protection of all existing utilities. **The Contractor shall expose and verify locations and elevations of existing utilities prior to construction as specified in the plans and specifications. The types, locations, sizes and/or depths of the existing underground utilities as shown on the plans were obtained from sources of varying reliability. The Contractor is cautioned that only actual excavation will reveal the types, extent, sizes, location, and depths of such underground utilities. If a utility is damaged, the Contractor shall contact the utility company immediately for repair.** The Contractor shall pay all costs for such repair if said damage is determined to be the responsibility of the Contractor. The Contractor shall receive no additional compensation for removing and reinstalling any pipe or appurtenances due to a lack of proper advance potholing.

Removal of soil, concrete, asphalt and other existing improvements shall be considered as excavation. Excavation shall also include exploration and/or "Potholing" to determine the location of existing underground facilities and obstructions, and shall be considered as a normal part of this work.

The Contractor shall immediately advise the District of inaccurate pothole data or any other pothole data which presents a conflict to the proposed water main alignment. The District shall provide direction in advance of any water main installation to resolve the conflict.

The District assumes no responsibility for the accuracy of utility markings other than water mains and appurtenances. Should the Contractor fail to locate any utility, the Contractor shall be solely responsible for contacting that utility to schedule a re-mark. The Contractor is advised that the District assumes no responsibility for additional costs for further excavation to locate a non-water related utility.
Furthermore, should the Contractor choose to abandon all attempts to locate a utility, the Contractor is hereby advised that they are proceeding with water main installation at their own risk. The District will not provide any written waiver of the requirement to locate in such case. Should the Contractor later encounter the utility during trenching operations, the District assumes no responsibility for cost of realignment of the new water main or repair for damage to the utility.

8. REMOVAL, RELOCATION OR PROTECTION OF EXISTING UTILITIES

In accordance with the provisions of Section 4215 of the California Government Code, any contract to which a public agency, as defined in Section 4402, is a party, the public agency shall assume the responsibility, between the parties to the contract, for the timely removal, relocation, or protection of existing main or trunk-line utility facilities located on the site of any construction project that is a subject of the contract, if such utilities are not identified by the public agency in the Project Plans and general specifications made a part of the Notice Inviting Bids. The agency shall compensate the Contractor for the costs of locating, repairing damage not due to the failure of the Contractor to exercise reasonable care, and removing or relocating such utility facilities not indicated in the plans and general specifications with reasonable accuracy, and for equipment on the Project necessarily idled during such work.

The Contractor shall not be assessed liquidated damages for delay in completion of the Project, when such delay was caused by the failure of the public agency or the owner of the utility to provide for removal or relocation of such utility facilities.

Nothing herein shall be deemed to require the public agency to indicate the presence of existing service laterals or appurtenances when the presence of such utilities on the site of the construction project can be inferred from the presence of other visible facilities, such as buildings, meter and junction boxes, on or adjacent to the site or construction; provided, however, nothing herein shall relieve the public agency from identifying main or trunk lines in the Project Plans and specifications.

If the Contractor, while performing the Contract, discovers utility facilities not identified by the public agency in the contract Documents it shall immediately notify the public agency and utility in writing.

The public utility, where they are the owners, shall have the sole discretion to perform such repairs or relocation work or permit the Contractor to do such repairs or relocation work at a negotiated price.

The Contractor shall cooperate fully with all utility forces of the District or forces of other public or private agencies engaged in the relocation, altering, or otherwise rearranging of any facilities which interfere with the progress of the work, and shall schedule the work so as to minimize interference with said relocation, altering, or other rearranging of facilities.

9. HOURS OF WORK

The Contractor shall schedule all work activities per the Encroachment Permits, Monday through Friday, with Saturdays, Sundays, and District Holidays being excluded. The Contractor shall indicate the need for non-normal work hours in the various schedules submitted during the progress of the Project.

Overtime work shall not entitle the Contractor to any compensation for any contract item in addition to that stipulated in the contract for the kind of work performed. In case of extra work ordered by the District, no additional payment shall be made to the Contractor because of the payment by him of overtime wage rates for such work, unless the use of overtime work in connection with such extra work is specifically ordered in writing by the District, and then only to such extent as extra payment is regularly being made by the Contractor to his personnel for overtime work of a similar nature in the same locality.

If, due to Contractor negligence, the District is called out after hours to restore water service, the Contractor shall be back-charged at a rate of $75 per hour per District employee for said restoration. All such charges shall be documented by the District and deducted by the District from retention monies due the Contractor.

10. MATERIAL SUBMITTALS

The Contractor shall submit the following items for District approval prior to the beginning of the Project:

Submittal List

Item Description	Submittal Summary
Pipe and Fittings	Product Data Sheets or other information
Sand	Gradation and Material Certification
Import Backfill	Gradation and Material certification
Asphalt Mix Design	Mix Design
Concrete Mix Design	Mix Design
Chlorination Specialist	Applicable State Contractors License Number

11. VARIATIONS FROM PLANS AND SPECIFICATIONS OR OTHER CONTRACT DOCUMENTS

Any portions of the work, which do not conform to the General Specifications, Special Provisions, Construction Details, Map and Project Plans, or other Contract Documents, shall be clearly identified by the Contractor in a written letter noting such variation. In the event of a conflict between the General Specifications and Special Provisions, the Special Provisions shall prevail.

The District reserves the right to make such modifications or alterations, reductions or omissions, extra or additional work to the General Specifications and Contract Documents, including the right to increase or decrease the quantity of any item or portion of the work or to omit any item or portion of the work, as may be deemed by the District as necessary or advisable, and to require such extra work as may be determined by the District to be required for the proper completion or construction of the whole work contemplated. All charges shall be considered a part hereof and subject to each and all of its terms and requirements.

Increases or decreases in the quantities shown in the bid schedule, regardless of the magnitude of the change, the percentage change from the bid schedule quantity or the elimination of a contract item of work does not constitute a change requiring a change order, a change in the scope of the work, or a change in the character of the work. Contractor shall be paid the unit price quoted in the Proposal for Construction Services for the actual quantities used.

No change or deviation from the Contract Documents or General Specifications shall be made by the Contractor without written authorization from the District setting forth a complete description of the change.

12. CALIFORNIA CONTRACTOR'S LICENSE CLASSIFICATION

In accordance with the provisions of California Public Contract Code Section 3300, the District has determined that the Contractor must possess a valid California State Class A - General Engineering Contractor Contractor's License at the time that the Contract is awarded and throughout the Contract's duration. Failure to possess the specified license shall render the bid as non-responsive, and shall act as a bar to award the Contract to any bidder not possessing said license at the time of award.

13. SUBCONTRACT DOCUMENTS

Subcontractor(s) shall possess a valid California State Contractor's License as applicable to the work performed. All subcontracts shall include provisions that the Contract between the District and Contractor is part of the subcontract, and that all terms and provisions of said Contract are incorporated in the subcontract. Copies of the subcontract shall be made available to the District upon written request and shall be provided to the District at the time any litigation is filed against the District concerning the Project. The Contractor shall pay subcontractor(s) for completed work within thirty (30) days of receipt of payment from the District.

14. PERMIT FOR CONSTRUCTION WATER

A Construction Water Permit, a fire hydrant meter, and a fire hydrant meter deposit is required for use of any District fire hydrant(s). The construction water fees are waived for the duration of the Contract and shall entitle the Contractor access to and reasonable use of water from assigned fire hydrants connected to the District's water distribution system.

15. SAFETY AND HEALTH PROVISIONS

Fixed or portable chemical toilets, properly obscured from public observance, shall be provided for the use of the employees of the Contractor. Toilets at the site shall conform with OSHA Safety and Health Standards for Construction. Toilets shall be serviced daily and shall be removed from the work site on Saturdays, Sundays, and District Holidays unless work is authorized for those days.

16. INJURY AND ILLNESS PREVENTION/HAZARD COMMUNICATION

The Contractor shall maintain written "Injury and Illness Prevention," "Confined Space Entry," and "Hazard Communications" programs and shall provide the District with documentation of same prior to the execution of the Agreement for Construction Services.

17. PRE-CONSTRUCTION CONFERENCE

A Pre-construction Conference shall be held at the office of the Project Manager (Citrus Heights Water District, 6230 Sylvan Road, Citrus Heights, CA 95610) for the purpose of discussing with the Contractor the Scope of Work, General Specifications, existing conditions, submittals, materials, construction equipment, and other essential matters relating to the satisfactory completion of the work. This conference shall be held prior to the issuance of the Notice to Proceed. The Contractor’s representatives shall include the Competent Person, Project on-Site Superintendent, other primary superintendents and may also include representative’s subcontractors, service providers and material suppliers if any.

18. PROJECT MEETINGS

The Contractor, the District Inspector, and Project Manager shall establish a routine meeting schedule throughout the course of the Project to discuss progress, changes, questions, and to update the Project Schedule. Meetings shall occur at two week intervals or more frequently if needed.

19. CONSTRUCTION SCHEDULE

A Construction Schedule shall be prepared and submitted by the Contractor to the District for review and approval prior to the issuance of the Notice to Proceed. Biweekly updates shall be provided thereafter and until completion of the project. Full compensation for preparing the Construction Schedule and biweekly updates thereto shall be considered as included in the contract prices paid for the various items of work, and no additional payment will be allowed therefor.

20. EMERGENT MATTERS AFTER HOURS

Matters requiring an emergent response after working hours include but are not limited to public safety and the protection of private property, such as; degradation of temporary paving, unsafe traffic plates, leaking piping, customers without water service, violations of storm water pollution prevention implementation and unsafe construction. The Contractor is advised that the District has the authority to determine what matters shall constitute an emergency, and the Contractor shall respond to all such emergencies until measures have been taken to remedy the matter to the District’s satisfaction.

21. EMERGENCY CONTACT AND CONTRACTOR RESPONSE

Prior to commencement of the Project, the Contractor shall designate a competent person to be responsible for responding to emergencies during non-work hours resulting from the Contractor’s work. Said person shall be available at all hours and shall be housed near the Project site. The maximum allowable response time shall be 30-minutes as determined by MapQuest. The District shall be provided with a cellular telephone number and other relevant contact information for said designated competent person. The Contractor is solely responsible for informing the District of any changes in designation of the responsible person or contact information during the course of the Project.

22. TRENCH AND EXCAVATION COMPETENT PERSON ASSIGNMENT AND RESPONSIBLITIES

The Contractor is hereby notified that a Trench and Excavation Competent Person shall be assigned to the Project at all times and shall be present on the Project during any and all work periods as specified in the Competent Person Assignment Form (see following page). The Trench and Excavation Competent Person shall be present at the Pre-Construction Conference and shall complete and sign this Form during the Conference. Should substitution of the assigned Trench and Excavation Competent Person be required, a new form shall be completed prior to initiating or continuing any work period, and that substituted Trench and Excavation Competent Person shall assume all responsibilities of the title.

Trench and Excavation "Competent Person" Assignment

PROJECT NAME: ____

(Name of individual)____
has been designated a "Competent Person" for Trenching & Excavation Operations by

(Name of employer)____
based on the individual's training, experience and demonstrated skills in the following:

1. Knowledge of Cal-OSHA Code of Regulations, Title 8, Article 6 Excavations (Section 1539-1547)
2. Soil classification
3. Use of protective systems and safe access to and from all work levels or surfaces

As such, the individual has the ability to detect:

1. Conditions that could result in cave-ins
2. Failures in protective systems
3. Potential hazardous atmospheres
4. Other hazards including those associated with confined spaces, and has
5. The authority to take prompt corrective measures to eliminate existing and predictable hazards and to stop work when required.

Inspections shall be made by the Competent Person and must be documented. The following specifies the frequency and conditions requiring inspections:

1. Daily and before the start of each shift
2. As dictated by the work being done in the trench
3. After every rainstorm or other events that could increase hazards, e.g. rain event, wind storm, thaw, earthquake, etc.
4. When fissures, tension cracks, sloughing, undercutting, water seepage, bulging of the trench, a change in soil types or other similar conditions that occur
5. When there is a change in the size, location, or placement of the spoil pile nearest the excavation
6. When there is any indication of change or movement in protective systems or adjacent structures

Designated by:

Signature: ________________________________Date______________

Name ________________________________Title______________________

________________________________ Title______________ Date________
Signature of individual assigned as Competent Person:

Office telephone number: (   ) ______________ Cellular number: (   ) ____________

After-hours telephone: (   ) ______________ Pager number: (   ) ____________

6700 MADISON AVENUE AT DEWEY DRIVE WATER MAIN PROJECT C21-105

1. Traffic Control Requirements

The following traffic control requirements shall be adhered to as a basis for bidding purposes. The County of Sacramento shall provide the traffic control requirements upon submittal of the encroachment permit by the contractor. Adjustments may be required in the field for the purposes of installing the water main and appurtenances.

DRIVEWAY ACCESS: The Contractor shall allow driveway access (ingress and egress) for all residential properties within the temporary traffic control zone unless special arrangements are approved by the property owner and the County of Sacramento.

PEDESTRIAN ACCESS: All temporary traffic controls shall incorporate measures to ensure full and safe access for pedestrians and shall be in full compliance with the Americans with Disabilities Act (ADA) and Title 24 of the California Code. Submittal of separate pedestrian signage and routing plans may be required by the County of Sacramento to ensure compliance with access requirements.

BICYCLE ACCESS: When the road shoulder or designated bike lane is blocked by work zone or temporary traffic control measures, temporary traffic controls shall be incorporated to provide safe passage for bicyclists through the work zone. “Share the Road” signs shall be placed at the beginning of the taper or closure and a minimum lane width of 12 feet shall be maintained in the lane shared by bicycles.

2. U.S.A. Markings and Tire Markings

The Contractor shall be responsible for removal of all U.S.A. markings and tire markings from construction equipment via power-washing or other approved method at no additional expense to the District.

3. Damage to Pavement and Concrete

The Contractor shall provide all necessary protection to existing pavement and concrete so as to avoid scraping, gouging, imprinting, cracking edges or otherwise causing damage during the entire Project. The Contractor shall exercise caution to avoid damaging pavement along the edge of pavement where the water main is to be installed on the shoulder of the roadway. The District Inspector or the County of Sacramento shall direct the contractor to repair any damage as deemed necessary. The Contractor shall repair said damage using methods required by the Inspector or shall agree to an alternative method in advance of said repairs. All costs of repairs to existing pavement and concrete due to damage caused by the Contractor shall be solely the responsibility of the Contractor.

4. Storage of Equipment and Materials

Storage of equipment and materials on the properties shall not be permitted without the written permission of the property owner. The Contractor shall contact the County of Sacramento to determine if any use permits are required and obtain same, if required, at no additional expense to the District.

Storage of equipment and materials within the County of Sacramento right-of-way shall require coordination with the District Inspector and County of Sacramento Encroachment Inspector. Requirements of the Encroachment Permit shall prevail.

5. Minimum Cover

Minimum cover on all main lines shall be 36” below finish grade unless otherwise shown on the plans or specifically approved by the District Inspector. Minimum cover on all service lines shall be 24” below finish grade unless otherwise specifically approved by the District Inspector. For the purposes of this contract “finish grade” shall be the grade of the completed trench, including restored surfaces. The restored surfaces shall match existing grade.

6. Backfill, Compaction, and Compaction Testing

Lawn, Planter, and Other Non-traffic Locations: Backfill around service piping, valves and fittings shall be #2 washed sand to a minimum of 3” below and 9” above. Backfill around water mains and service saddles shall be #2 washed sand to a minimum of 6” below and 12” above. Remaining backfill shall be 100% ¾” crushed rock to the bottom of the meter box. Above this level, backfill shall be native soil at optimum moisture content, placed in 3” lifts and hand-compacted to 90% minimum.

Roadway, Driveway, and Traffic Locations: Backfill around service piping, valves and fittings shall be #2 washed sand to a minimum of 3” below and 9” above. Backfill around water mains and service saddles shall be #2 washed sand to a minimum of 6” below and 12” above.

Proper haunching of the pipe shall be achieved by hand shovel slicing sand under the haunches of the pipe. With the pipe in place, the first lift of sand shall not exceed the springline of the pipe. No additional sand shall be added until the entire section of pipe has been properly haunched.

Compaction in the sanded pipe zone shall be 90% minimum. Remaining backfill shall be 100% ¾” crushed rock to the bottom of the meter box. Above this level, the remaining trench backfill shall be 100% import ¾" aggregate base compacted to 95% minimum.

Compaction at all paved locations shall be 95% minimum. Compaction at all other locations shall be 90% minimum unless otherwise specified by the District Inspector.

Initial compaction testing shall be performed at the discretion and expense of the District. Backfill not meeting compaction specifications shall be corrected by the Contractor at no additional expense to the District. Follow-up compaction testing shall be performed by the District at the expense of the Contractor. No extra time or payment shall be provided due to work delays for these tests.

Any surface settlement during the guarantee period shall be the responsibility of the Contractor.

7. Thrust Blocks

Thrust blocks shall be constructed of Type II six-sack Portland cement. Concrete shall conform to either the 1" or 1 ½" gradation at the option of the Contractor, unless otherwise specified in these Specifications or as required by the District Inspector. No backfill material shall be compacted above thrust blocks prior to a 24-hour period.

Trailers with "buggies" shall not be used to haul concrete. Concrete shall be hauled in cement mixing trucks or trailers only and shall be mechanically mixed at the site prior to placement.

8. Temporary Trench Restoration

Temporary paving (asphalt plant-mix cutback) shall be placed at locations and maintained at locations wherever excavation is made through pavement, sidewalk or driveways, as shown on the Project Plans, or as directed by the District. Temporary paving shall be placed as soon as the condition of the backfill is suitable to receive it and shall remain in place until the condition of the backfill is suitable for permanent resurfacing. Thickness of the temporary paving shall be one and one-half inches (1-½") unless otherwise shown on the Project Plans. Temporary paving shall be maintained at the same elevation as the existing surrounding surfaces until the permanent surfacing is placed. Temporary paving shall be placed using a hand powered compaction device.

Trench plates and their installation shall comply with the Encroachment Permit. Trench plates shall be pinned prior to subjecting them to public traffic. The edges of the trench plates shall be lined with temporary paving wedges. The 2" Construction Water Service (See Exhibit G, Construction Detail WS_290) and all temporary blow-offs shall be plumbed below the roadway surface and installed in traffic-rated valve boxes for the duration of the Project.

9. Resilient Wedge Gate Valves

The resilient wedge gate valves shall fully comply with the latest revision of AWWA C509, and shall also be UL listed and FM approved. The valves shall be tested and certified to ANSI/NSF 61.

The valve shall have a 250 psig working pressure.

The valve type shall be NRS (non-rising stem).

The valve shall have an arrow cast on the operating nut or handwheel showing opening direction. The direction of opening shall be counterclockwise (left).

The NRS valves shall be provided with a 2” square operating nut. The bolt that attaches the operating nut to the stem shall be recessed into the operating nut so as not to interfere with valve wrench operation.

The valve body, bonnet, stuffing box, and disc shall be composed of ASTM A-126 Class B grey iron or ASTM A395 or A536 ductile iron. The body and bonnet shall also adhere to the minimum wall thickness as set forth in Table 2, section 4.3.1 of AWWA C509. Wall thickness less than those in Table 2 are not acceptable.

The valve disc and guide lugs must be fully (100%) encapsulated in SBR ASTM D2000 rubber material. The peel strength shall not be less than 75 pounds per inch.

The valves shall have all internal and external ferrous surfaces coated with a fusion bonded thermosetting powder epoxy coating of ten (10) mils nominal thickness. The coating shall conform to AWWA C550.

10. Chlorination and Flushing

The Contractor shall use a licensed Chlorination Specialist for the process of introducing a chlorine solution into the new water system. Said specialist shall maintain an Active C36 (Plumbing) and C55 (Water Conditioning) license with the California State Licensing Board.

Chlorine shall be introduced into the system at a minimum of 50 PPM and a maximum of 100 PPM. The Inspector shall be provided with proof of uniform chlorination throughout the system within the stated range using an approved test procedure. All requirements of American Water Works Association standard C651-05 (Disinfecting Water Mains) shall be followed.

Chlorinated water shall be properly disposed of using dechlorination procedures outlined in American Water Works Association standard C651-05 (Disinfecting Water Mains) and shall comply with all regulations. The Inspector shall be provided with proof of uniform dechlorination at a minimum of 10 minute intervals during disposal using an approved test procedure. Dechlorination shall be maintained at 0.0 PPM at all times during any disposal of any water into a drainage system.

11. Sprinklers

The properties may have underground sprinkler systems. It is the Contractor's responsibility to locate the system piping, and if disturbed, repair or replace it to its original condition at no cost to the District or property owner. Sprinkler system repairs and reconnections shall be made using Schedule 40 PVC pipe w/Schedule 40 fittings or better. Full compensation for restoration of existing sprinkler systems shall be considered as included in the contract unit prices paid for the various items of work, and no additional payment will be allowed therefor.

12. Concrete Restoration

- **Materials**

  Class A-2 Concrete – Shall contain six (6) sacks (564 pounds) of Portland cement per cubic yard and shall have a maximum size of course aggregate of three-quarter inch (3/4")

  Concrete shall be hauled in cement mixing trucks or a trailer mounted barrel mixer only and shall be mechanically mixed at the site prior to placement. All ingredients are to be thoroughly intermingled during mixing, and all aggregate particles are to be completely coated with cement paste.

  Note: Transporting or use of concrete in non-mixing trucks or trailers ("buggies") is not permitted.

- **Installation**

  All new concrete shall be installed within thirty (30) calendar days of removal. All concrete construction shall conform to existing finishes. Thickness shall be 4" minimum and 6" maximum. Temporary "cut-back" asphalt shall be placed in sidewalks and other pedestrian traffic areas, until the final restored concrete can be placed.

Restored concrete surfaces shall be installed per County of Sacramento Standard Construction Specifications Plan 4-30 and Section 27.

Doweling and restored concrete surfaces shall comply with County of Sacramento Specifications as required.

♦ **Saw-cutting**

Double saw cutting is required for all locations in the concrete. An initial construction saw-cut is required to facilitate the locating and excavating of existing water distribution facilities or other utilities and to permit the installation of the proposed facilities. After facility installation, backfill and compaction, a second final saw-cut 6” beyond the excavation is required immediately prior to restoration of the surface. Saw cutting to the nearest expansion or control joint is required if within 18” of a proposed facility or at the direction of the District. Saw cut shall be for full depth of the slab. Edges remaining after removal shall be square, uniform, and with no chips or spalling.

♦ **Placement**

Replaced portions of concrete shall be finished to match existing surfaces.

♦ **Vandalism**

Contractor shall take all reasonable precautions to protect wet concrete from damage or vandalism.

13. Landscape Restoration

Landscape restoration work shall be performed by the Contractor. If the Contractor is unable to satisfactorily restore the landscaping, a Landscape Contractor shall be retained. The Landscape Contractor to be used shall be provided in Exhibit A, List of Subcontractors if work exceeds one percent (1.00%) of total amount of bid.

Provide all labor, materials, services and equipment necessary to complete all landscape restoration work, including but not limited to the following:

1. Sod removal and replacement
2. Ground Cover removal and replacement

3. Shrub removal and replacement
4. Pruning
5. Grading
6. Mulching – Shredded Bark
7. Weed Retardant Fabric replacement
8. Cleanup
9. Restoration of Sprinkler Systems

♦ **Sod Removal and Replacement**

All lawn areas disturbed by the work shall be re-sod according to the following procedures: The grass shall be cut to a height of 2". The sod shall be removed with an appropriate tool, cutting a minimum of 1 1/2" below the surface of the soil. The sod shall be stockpiled and maintained in a healthy condition, and shall be replaced within three (3) days of the time it was cut.

If the sod removed is not healthy when it is to be relayed, it shall be replaced with new sod. New sod shall be installed when and where required, within fourteen (14) days of the completion of the trench or excavation. It shall be the responsibility of the Contractor to notify the property occupant in writing to water the newly replaced sod on a regular basis as required.

Areas to be planted shall be cultivated until the soil is mixed thoroughly and in a loose and fine textured condition. The top 2” shall be cleared of all stones, stumps, dirt clods, debris, etcetera, larger than ¼” in diameter, that are brought to the surface as a result of cultivation.

♦ **Ground Cover Removal and Replacement**

Ground cover disturbance shall be kept to a minimum and removal confined to an immediate area of required excavation. Replacement shall be with healthy new plant material of a like variety, installed in conformance with the recommendations of the Sunset Western Garden Book.

New ground cover shall be installed where required within fourteen (14) days of completion of the trench or excavation. It shall be the Contractor’s responsibility to notify the property occupant in writing to water the newly replaced ground on a regular basis as required.

♦ **Shrub Removal and Replacement**

Any shrubbery, which must be removed, as directed by the District, shall be removed by the Contractor so as not to damage it. If any damage is done to the shrubbery, the Contractor at no cost to the District or property owner shall replace it. Replacement shrubs shall be 5-gallon minimum size and shall match the size of the removed shrub.

- **Pruning**

Pruning of any shrubbery or trees shall be conducted under the direction of the District and follow sound horticultural practice. Pruning shall be limited to the minimum necessary to provide access to work, to remove injured twigs and branches and to compensate for loss of roots during a transplant.

- **Grading**

Planting beds shall be graded to drain with uniform levels or slopes between finished elevations and existing elevations.

Remove debris, roots, stones, etcetera, in excess of 2” in size.

Fine grade all planting areas to a smooth, loose, and a uniform surface.

- **Mulching**

The Contractor shall replace mulch that has been disturbed by the operation. Minimum depth of mulch will be 2”.

- **Weed Retardant Fabric Replacement**

The Contractor shall replace fabric used to retard weed growth that has been disturbed by the operation. The replaced fabric shall be of similar quality and character of the existing fabric disturbed.

- **Cleanup**

Any excess soil, imported fill, prunes, or other debris shall be removed daily from the work zone and disposed of in a lawful manner at the Contractor’s expense.

- **Guarantee and Replacement**

All plant material and sod installed, new or reused, under this Contract shall be guaranteed for thirty (30) days from time of installation against any and all poor, inadequate, or inferior materials and/or workmanship or improper maintenance, as determined by the District.

14. Maintaining Traffic, Public Convenience and Safety

The Contractor shall be responsible for the safety of traffic within the Project limits and on the approaches to the Project. The Contractor shall be responsible for maintaining local property access and access to the existing public cross-streets within the limits of this contract. The Contractor shall provide adequate steel plating to protect driveways and provide access to properties.

Temporary paving shall be used when trenching occurs across a driveway. The Contractor shall make a reasonable effort to reduce durations of the driveway closures by scheduling and coordinating work accordingly.

The Contractor shall provide 72 hour advance notification to the occupants of property to which the existing access or frontage parking will be closed for a period of time exceeding two (2) hours. Notification will be by written notice placed on or near the building entrance or the property access point to be closed. The Contractor shall be responsible for making access available into the existing driveways at any time during their work day to emergency type vehicles such as fire, ambulance, police, and etcetera.

Personal vehicles of the Contractor's employees shall not be parked within the right of way.

Minor deviations from the requirements of this section concerning hours of work which do not significantly change the cost of the work may be permitted upon the written request of the Contractor if in the opinion of the District Inspector, public traffic and convenience will be better served and the work expedited. These deviations shall not be adopted by the Contractor until the County of Sacramento and District have approved them in writing.

Pedestrian access facilities shall be provided through construction areas within the right-of-way as specified herein. Access shall be American's with Disabilities Act (ADA) compliant. Pedestrian walkways shall be provided with surfacing of asphalt concrete, Portland cement concrete or timber. Surface shall be skid resistant and free of irregularities.

Paved pedestrian access to sidewalks and signals and signal push buttons shall be maintained during all stages of construction. Walkways shall be maintained in good condition by the Contractor. Walkways shall be kept clear of obstructions.

Full compensation for providing said pedestrian facilities shall be considered as included in the prices paid for the various contract items of work involved and no additional compensation will be allowed therefor.

Any closure or detour of pedestrian access for Contractor's convenience shall be approved in writing by the County of Sacramento and District prior to scheduling work in the area under question. Any request for temporary closure or detour of pedestrians shall be made in writing and include plans and information showing requested duration, days of the week, routes, signing and safety measures. Approval or rejection of requests will be at the sole discretion of the County of Sacramento and District. Additional signing and safety measures for pedestrians approved as part of a pedestrian access modification shall be considered as included in the prices paid for the various contract items of work involved and no additional payment shall be made therefor.

15. Public Notification

The District will be responsible for notifying the public, local residents, local businesses, local public, Regional Transit Route Scheduling Unit, local law enforcement agencies, local fire districts, local public and private ambulance and paramedic service providers, local utility companies and any other persons or agencies affected by this Project. The District will be responsible for coordinating with the Contractor to ensure the proper timing and information is provided to the public.

16. Construction Layout and Staking

The District will provide construction staking for the water line as described below:

- Offset stakes will be provided at 50 foot intervals along waterline, grade breaks and two stakes will be placed at each waterline angle point along the route. Offset stakes will provide centerline of the water main and cut elevation to flowline of pipe.
- Staking Waterline Tees or Service Laterals
- Staking Water Meters or other waterline appurtenances

<u>The following staking items will not be provided by the District:</u>

- Staking Saw Cut Line
- Staking Construction Area Signs
- Traffic control except as noted below

<u>Contractor Responsibilities:</u>

- Discuss scheduling of staking needs for Contractor operations and time estimates of staking operations with the District Inspector. Staking needs shall be included on the biweekly schedule updates.

- Request construction stakes a minimum of three (3) working days in advance of starting an operation that will use the stakes (i.e. if stakes are to be used Thursday, the staking request shall be submitted on Monday). Weekends and holidays are not considered working days.

- Submit suitable requests for construction stakes, ensuring that the requested staking area is ready for stakes and that the stakes will begin to be used within five (5) days of staking.

- Coordinate construction operations so that areas to receive stakes are relatively clear of construction equipment activity, in order that stakes can be set in safe and expeditious manner to the satisfaction of the District Inspector.

- Contractor shall provide a safe working environment for the survey crews.

- Contractor shall establish priorities for requested construction stakes and note the priorities on the staking request.

- Contractor shall preserve all construction stakes. Replacement of stakes will be completed at the expense of the Contractor.

- The Contractor will coordinate with the District Inspector regarding the location and placement of Fire Hydrants, Valves, Tees, Crosses, Water Services, ARVs and related appurtenances. The final location of these facilities will require approval from the District Inspector.

If the area or facility is not prepared satisfactorily for the stakes, as determined by the District Inspector, the staking request will be voided by the District Inspector and the Contractor shall submit a new request for the stakes when the area or facility has been properly prepared. If survey crews have been mobilized to an area that is not ready for stakes, the District will provide written documentation and charge the Contractor with re-staking charges for the survey crew's time.

Full compensation for coordinating construction layout and staking with the District Inspector and the District's staking agents shall be considered as included in the various contract items of work and no additional payment will be allowed therefor.

END OF SPECIAL PROVISIONS

<u>6700 MADISON AVENUE AT DEWEY DRIVE WATER MAIN PROJECT C21-105</u>

The following Project Plans pertain to Citrus Heights Water District's 6700 Madison Avenue at Dewey Drive Water Main Project C21-105:

6 Sheets	Project Plans are 22" x 34" and shall be purchased as a portion of the Bid Package

6700 MADISON AVENUE AT DEWEY DRIVE WATER MAIN PROJECT C21-105

The following Encroachment Permit Documents pertain to Citrus Heights Water District's 6700 Madison Avenue at Dewey Drive Water Main Project C21-105:

County of Sacramento Encroachment Permit

Encroachment Permit and Attachments (21 Pages)

ENCROACHMENT PERMIT

SACRAMENTO COUNTY MUNICIPAL SERVICES AGENCY
827 - 7TH STREET, ROOM 105, SACRAMENTO, CA 95814
PHONE (916) 874-6544

Encroachment Inspection Area: 02

U.S.A. TICKET NO. ______________
Phone (800) 227-2600

ENUC2022-00399

1. Permit Type: Utility
2. Application is made for permissions to excavate, construct and/or otherwise encroach on County right-of-way by performing the work described below on:

   6700 Madison Avenue at Dewey Drive

   Project Location

3. Scope of Work:

   CITRUS HEIGHTS WATER DISTRICT
   CONSTRUCT I I 5 LINEAR FEET OF NEW 8" WATER MAIN IN SEPTEMBER AND OCTOBER 2022 PER A TT ACHED PROPOSED PLANS . ALL CONSTRUCTION WILL OCCUR ON SITE AT 6700 MADISON A VENUE. THIS PERMIT APPLICATION IS FOR USING THE RIGHT-TURN LANE ON DEWEY DRIVE FOR POSITIONING EQUIPMENT AND MATERIALS DURING APPROVED WORKING HOURS. NO MATERIAL OR EQUIPMENT WILL STORED IN THE RIGHT-OF-WAY DURING NON-WORKING HOURS.

4. **Except for Annual Permits: Permittee shall schedule a pre-construction meeting to activate this permit by calling CMID at (916) 875-2707.**
5. Before starting work, the Permittee shall notify Sacramento County Construction Management at (916) 875-2707,24 hours in advance of the date work is to begin.
   a) For emergency work, notification shall be provided within 1 hour of dispatch as defined in Section 7-8.03 of the County Standard Construction Specifications
   b) No notification required for work that does not involve excavation and does not obstruct or modify pedestrian, bicycle or vehicular traffic patterns.
6. **Permittee shall contact the County Survey Section at (916) 874-6546 for potential location of survey monuments.**
7. Applicant must check with all Utility Companies serving the area covered by this permit, for location of existing underground pipes, conduits or cables. Underground Service Alert (U.S.A.) does not locate non-pressurized sewer and drainage facilities.
8. Attention is directed to teh General Provisions attached hereto and to any specific conditions made a part of hereof.

In consideration of the granting of this application, it is agreed by the applicant that the County of Sacramento and any officer or employee thereof shall be saved harmless by the applicant from any liability or responsibility for any accident, loss or damage to persons or property, happening or occuring as the proximate result of any of the work undertaken under the terms of this application and the permit or permits which may be granted in response to thereto, and that all of said liabilities are hereby assumed by the applicant. It is further agreed that if any part of this installation interferes with future use of the highway, it must be removed or relocated, as designated by the Director of County Engineering, at the expense ofthe applicant or their successor in interest.

FOR USE BY UTILITY COMPANIES			
District:		Division:	
Engineer:		Job No:	C21-105

Contact Person: PAUL DIETRICH
Phone (916) 735-7723
Applicant Signature: ______________

Applicant: CITRUS HEIGHTS WATER DISTRICT PAUL DIETRICH Phone: (916) 735-7723

Address: PO BOX 286 CITRUS HEIGHTS CA 95611 - 5611

Invoice #	Fee Item	Fee Due	Fee Paid	Date Paid
1473520	IT Recovery Fee Billable	$15.75	$0.00	
1473520	Permit Fee - Utility Company	$350.00	$0.00	

Fees Due: $365.75 **Fees Paid:** $0.00 **Current Balance** **$365.75**

DEPARTMENTAL REVIEW	APPROVED	DATE	DEPARTMENTAL REVIEW	APPROVED	DATE
WATER SUPPLY	N/A		WATER QUALITY	YES	7/8/2022
TRANSPORTATION	YES	7/20/2022	TECHNICAL RESOURCES	YES	7/20/2022
WATER RESOURCES	YES	6/23/2022	Sub. Order Number:	90014131	
			Customer Number:	1000000602	

Approved application is subject to payment of fees, pre-construction meeting with CMID, Attachment A, and is revocable at any time. This permit is nontransferable and EXPIRES ONE YEAR from date issued.

***ANNUAL Permits expire December 31 of the year permit is issued.**

On Behalf of the Director of County Engineering

By: ______________
CMID INSPECTOR Date

Plan Submittal Date: 6/22/2022

"ASBUILT" Inspector Approval ______________
Name Date

<u>Department of Transportation Specific Comments</u>

DESCRIPTION:

Permit No. ENUC2022-00399
Description of Work: **Citrus Heights Water Dist**, install 115ft of new 8inch water main, along Dewey Dr just S/O Madison Ave

SPECIFIC REQUIREMENTS FOR ALL ENCROACHMENT PERMITS

- A mandatory preconstruction meeting is required prior to beginning any work on site. This permit is not activated and therefore not approved until a preconstruction meeting held.
- Site specific notification must be given to Sacramento County Construction Management and Inspection Division at (916) 875-2707 a minimum of 24-hours prior to any work.
- The deposit may be released 180 days after the acceptance of the work provided all inspection costs have been paid in full where applicable.
- Applicant is aware that permit fees DO NOT include inspection charges. Inspection charges will be billed separately at a later date.
- All work covered under this encroachment permit shall comply with the provisions of the revised January 2016 edition of the County of Sacramento Standard Construction Specifications (SCS) and the Standard Requirements for Encroachment Permits (attachment "A"). Prior to the start of any work, it is the responsibility of the applicant to be sure that all requirements including those indicated on "Attachment A" and the SCS are fully understood. Any failure to comply with any of the requirements indicated on attachment A, the SCS or any requirements indicated below may result in work stoppage, fines and/or penalties, or both. This permit is issued in accordance with Division 2, Chapter 5.5 of the Streets and Highways Code of the State of California and Chapter 12.08 of the Sacramento County Code as amended on January 6, 1998.
- Specific attention is directed to the "BACKFILL AND PAVEMENT RESTORATION REQUIREMENTS**"** section of attachment "A". All work covered under this permit shall conform to these requirements. Deviations from these requirements shall be reviewed and approved (if appropriate) in writing separately from this encroachment review process.

POSSIBLE CONFLICTING PROJECTS

- No projects are proposed at this location which will conflict with the work covered under this permit.

TRAFFIC CONTROL REQUIREMENTS

- An approved traffic control plan will be required prior to beginning work.

- Pedestrian and disabled traffic mitigation to be in compliance with 2016 Sacramento County Standard Construction Specifications Section 12. These provisions shall be shown on TCP.

- Closure of a paved shoulder (or outside lane) requires deployment of "Share the Road" signage (W16-1, W11-1) and 25mph speed limit signage (C17/25).

  Tentative work hours: 8:00 am to 3:30 pm
  (Note: Work hours subject to change based on submitted TCP)
  Refer to California MUTCD typical applications for TCP requirements.

TRENCH CUT FEES:

- Trench cut fees if any, will be determined at the conclusion of the project.

PAVEMENT MORATORIUM RESTRICTIONS:

- No roadways included under this permit are subject to the pavement moratorium

HOLIDAY MORATORIUM:

- Madison Ave & Dewey Dr is included as a Holiday Moratorium Street. All construction work on Madison Ave & Dewey Dr will be suspended and no activities that interfere with public traffic shall be conducted on designated streets (as identified above) during the holiday season (defined as the four-day Thanksgiving weekend and December 8 through January 1). SCSCS 7-8.06

Reviewed by BL on 07/19/22 – Sac County ROW Management Section

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-ATTACHMENT A-

STANDARD REQUIREMENTS
FOR
SACRAMENTO COUNTY ENCROACHMENT PROJECTS

REQUIREMENTS AND STANDARDS

Provisions of the most recent editions of the County of Sacramento Standard Construction Specifications (SCS) and the County of Sacramento Improvement Standards shall apply to all work covered under this encroachment permit. This permit is issued in accordance with Division 2, Chapter 5.5 of the Streets and Highways Code of the State of California and Chapter 12.08 of the Sacramento County Code as amended on January 6, 1998. The following requirements shall also apply to this work.

ACCEPTANCE OF PROVISIONS

It is understood and agreed by the Permittee that performing any work under this permit shall constitute an acceptance of the general and specific conditions hereof.

WORK AND MATERIALS

Work and materials shall be in accordance with the current edition of the County of Sacramento "Standard Construction Specifications." All work shall be in compliance with the Americans with Disabilities Act.

VALID PERMIT KEPT ON SITE

This permit is valid only for work done in the unincorporated Sacramento County area. Any use of private property for storage of materials, trenching and/or placement of signage (other than traffic control devices) shall be approved by the property owner of the land parcel or acting agent thereof. This permit shall be kept on the worksite and must be shown to any authorized representative of the Agency or any law enforcement officer upon demand. Fines for failing to provide a valid permit may be accessed in accordance with Chapter 12.08 of the Sacramento County Code.

GENERAL DEPOSIT

Applicant shall post a $2,500.00 deposit as specified in Chapter 12.08 of the Sacramento County Code. The deposit may be released 180 days after acceptance of the work provided all inspection costs have been paid in full where applicable.

GUARANTEE

Should any failure of the work occur within a period of one year after completion and acceptance by the Agency, (i.e., sign off of permit), including the refilled excavation settling or if the resurfacing or restoration of the roadway disintegrates or develops ruts or holes or if found that materials used were not in compliance with County Standard Specifications, the permittee shall repair and/or resurface the work to the satisfaction of the Agency. If the permittee fails or refuses to do such corrective work, the County may elect to complete the corrective work and collect the cost of the work from the permittee, or to pursue such other remedies as may be available to complete the corrective work at the permittee's expense.

PROSECUTION OF WORK

Any work authorized by this permit shall be performed in a workmanlike, diligent and expeditious manner to the satisfaction of the Agency. The Permittee shall submit a schedule prior to beginning work for any project lasting more than 5 working days.

U.S.A. NOTIFICATION REQUIRED

The Permittee shall notify Underground Service Alert two working days in advance of performing excavation work by calling the toll-free number (800) 227-2600. U.S.A. notification to be renewed at not more than 14 calendar day intervals.

Disregard for or destruction of underground utilities may be cause for revocation of this permit and/or denial of future permits at the discretion of the Agency. Any utility so damaged shall be immediately reported to the owner and the Agency.

ADDITIONAL NOTIFICATION REQUIREMENTS

This permit is for work within the County Right of Way only. Applicant is responsible for coordinating and obtaining all other permits, permission, rights, etc. necessary for work both within the County Right of Way and beyond the limits covered under this permit.

Work performed within the former McClellan Air Force Base must be coordinated with Paul Bernheisel (916) 997-1798 or Mike Swart at (916) 643-0830, ext. 230. A McClellan Facility Encroachment permit is required through these contacts prior to obtaining a County Permit.

Work performed within the former Mather Air Force Base must be coordinated with Clark Whitten at (916) 874-2555. Address: 700 H Street, Ste. 7650, Sacramento, CA 95814

STORAGE OF EQUIPMENT OR MATERIALS WITHIN THE RIGHT-OF-WAY

No equipment of materials shall be parked or stored within any traffic lane or within the public right-of-way at any time of day or night, including holidays and weekends without written consent from the Department of Transportation.

TREES

Unless specifically approved on the face of this permit, the removal or trimming of a tree(s) requires a separate tree permit per County Ordinance, call (916) 874-6291.

TRAFFIC CONTROL REQUIREMENTS AND HOURS OF WORK

A traffic control plan (or plans) shall be submitted for review and approval for any work requiring modifications to existing traffic patterns. The traffic control plan (or plans) shall include provisions for vehicular, pedestrian and bicycle access. Additionally, the traffic control plans (or plans) shall address traffic signal operations for any work performed within 200 feet of a signalized intersection.

Contractor shall contact schools affected by construction to determine if school is in session. If school is in session, no construction activities shall take place 30 minutes before and 30 minutes after the arrival (am) or departure (pm) bell. Contractor shall also be responsible for providing notification to any fire station that could potentially be affected by construction activities.

Transportation routes involving a river crossing over the American River have been identified as being critical for traffic circulation between areas north and south of the river. In order to maintain traffic flow across these critical corridors, no lane or road closures are permitted from 7:00 am to 9:00 pm at the following locations:

Watt Avenue	Between Folsom Boulevard and Fair Oaks Boulevard
Sunrise Boulevard	Between Folsom Boulevard and Fair Oaks Boulevard
Hazel Avenue	Between Folsom Boulevard and Winding Way

Lane or road closures at these locations during the times indicated will only be allowed in emergency situations or with the written approval of the Director of the Department of Transportation or his designee.

ROAD CLOSURE

No highway or street may be closed without first obtaining approval in writing from the Agency. If permission is granted, it shall be the Permittee's responsibility to notify the Highway Patrol and Fire Department prior to closing the street.

LANE/ROAD CLOSURE DURING NOVEMBER/DECEMBER HOLIDAY SEASON

Unless specifically approved by the Agency, construction will be suspended and no activities that interfere with public traffic shall be conducted on designated streets during the holiday season (defined as the four-day Thanksgiving weekend and December 8 through January 1). All existing pits, excavations, trenches, and openings in the road surface shall be backfilled and paved to produce a level and smooth surface. All barricades and barriers shall be removed from all traffic lanes, unless authorized by the Agency as long-term traffic controls. SCC 7-8.06

MAINTAINING AND PROTECTING TRAFFIC CONTROL FACILITIES

Metal objects (such as manhole frames and lids, valve boxes, bore casings, etc.) shall not be installed within 72 inches of a traffic detector loop. Any traffic signal or detector operation disruption shall be repaired and the system made operational within eight hours of the damage. Should the County elect to provide repair or replacement services, the Permittee shall be required to reimburse the County for all costs involved.

EXISTING SPEED TABLES:

If work requires excavating into existing speed tables, one half of the speed table shall be removed and reconstructed in accordance with current County speed table requirements. If the remaining half of the speed table does not meet current standards, the entire speed table shall be removed and reconstructed in accordance with current standards. If excavation is cored and no greater than 1 sq. ft. in area, in lieu of removing the speed table, pavement restoration may be as specified in Attachment A for "backfilling of potholes and borings within pavement areas".

DIRECTIONAL BORE REQUIREMENTS

Prior to beginning work, the contractor must submit to the Agency (County of Sacramento Inspector) a general work plan. Verify all underground utilities in accordance with Government Code 4216 (SCS sec. 6-16). Before drilling, prepare a directional bore profile showing all verified utility depths with utility required clearances and the projected bore path (elevation). Contractor shall provide directional bore profile to the Agency (County of Sacramento Inspector) prior to drilling. Directional bore depths to be a minimum of 42 inches below pavement grade. Directional bore profile, log of boring operation and a guidance system log shall be kept onsite with the permit. Surface incisions on project streets shall not exceed industry bore pit standards. In the event surface incision dimensions (i.e., length and width) exceed industry bore pit standards (as determined by the Agency), additional pavement restoration will be required. Additional pavement restoration shall include a slurry seal placed over the entire width of the roadway (or to the roadway centerline if disturbances are isolated to one half of the roadway) to encompass the area of restored pavement. Surface incisions located within 50 feet shall be included in the same slurry seal area. Slurry seal shall extend 4 feet beyond the outermost surface incisions.

TUNNELING

No tunneling will be permitted except on major work as may be specifically approved and set forth on the permit thereof. Tunneling under sidewalks are also not allowed.

PROTECTION OF EXISTING SURFACES

The permittee's contractor shall use appropriate equipment, construction methods and effort/care to prevent damage to existing pavement. The permittee shall also document the pre-existing pavement conditions in a manner that will allow construction damage to be identified. The permittee shall make a post construction evaluation of the pavement surface upon completion of the work and will be responsible for repairing all damage to the pavement surface resulting from construction activities. The permittee will also be responsible for repairing any damaged pavement that cannot be identified as pre-existing.

Excavations within sidewalk areas, when not active, must be covered with a material suitable for pedestrian use and secured to avoid shifting. The excavation shall be covered for no more than 7 days (i.e., the excavation must be backfilled and the surface restored within 7 days of initial excavation). Sidewalk repairs shall conform to Sacramento County Details 4-25 and 4-43.

MAINTENANCE

The permittee agrees to exercise reasonable care to properly maintain any encroachment placed by it in the County right-of-way. The permittee further agrees to repair any damage to portions of the right-of-way which occurs as a result of the maintenance of the encroachment.

TRENCHING

Not more than one-half of the width of a traveled way shall be disturbed at one time and the remaining width shall be kept open to traffic by bridging or backfilling. Pedestrian and bicycle facilities shall be maintained through the work site at all times unless provisions have been shown on an approved traffic control plan.

TEMPORARY BRIDGING OF EXCAVATIONS AND TRENCHES

The use of steel plates shall be approved by the Agency prior to installation. Steel plates used in the roadway, shall have the name and 24 hour emergency telephone number of the contractor responsible for maintaining the plates stenciled on the roadway pavement adjacent to the plates. Painted text shall be in white lettering. The text shall be neatly stenciled lettering, a minimum five inches (5") in height and shall be maintained in a neat and legible condition for the duration of plate placement. Steel plates shall conform to the following width and thickness requirements:

Steel Plate Width	Min. Thickness
18" or less	¾"
18" to 72"	1"
Width greater than 72"	per analysis by engineer

When steel plates are used to cover excavations on roadways with two or more lanes in each direction or posted 45 mph or greater posted speed or where the related work is to take place for longer than two (2) weeks, the steel plates shall be inlayed or recessed into the existing pavement. Existing pavement surface shall be milled out to ensure that the top of plate elevation matches the existing elevations of the adjacent pavement surface. Steel plates must be large enough to allow a minimum of one foot (1') of bearing on all sides of the trench.

When steel plates are used to cover excavations on all other roadways, they maybe placed on top of the asphalt with transitional ramps of MC250 asphalt mix (cutback) against all vertical edges of the plates. All ramping must be accomplished to provide a minimum angle of approach of twelve to one (12:1), providing a smooth, gradual transition between the pavement and the plate. Steel plates shall be anchored to the roadway surface with pins or spikes on the four (4) outermost corners. Additional pins shall be placed as necessary to assure the steel plates are secured. Pins shall be installed such that they do not protrude above the plate surface anymore than is necessary to anchor the plate and shall not create a hazard for the motoring or pedestrian public. Steel plates should be welded together to prevent shifting/bouncing where necessary. Where the Street surface is uneven, plates shall be bedded on MC250 asphalt mix (cutback). The steel plates shall extend beyond the edge of the trench a minimum of 18", but no more than 30" on all sides. No corner of any steel plate shall protrude into the traveled way as to create a hazard to the motoring public.

Steel plates shall have a nonskid surface static coefficient of friction of 0.35 per California Test 342 for all steel plates within traveled roadway, and 0.50 per ASTM C 1028 for those steel plates in pedestrian crosswalks or accessible areas. When required by the Agency, the Contractor shall certify in writing to the Agency that steel plates to be used in the Work meet the required static coefficient of friction.

The length of a series of plates running parallel to traffic wheel paths shall not exceed 30' unless approved by the agency or noted in the TCP or contract drawings. Steel plates shall not remain on the roadway for longer than seven (7) calendar days, unless otherwise approved by the Agency

Trench walls and adjacent soils shall be sufficiently stabilized prior to the use of steel plates for bridging. For conditions that require a support structure (wide excavation with multiple plates), the system must be designed by a registered professional engineer and submitted to the Agency for approval before use.

Steel plates shall be installed to operate with minimum noise levels as indicated in Sacramento County Code, Section 6.68, "Noise Control". All steel plates within the right-of-way, whether used in or out of the traveled way, shall be without deformation (e.g., chains, attachments, weldments, or irregularities that can constitute a hazard). BUMP (W8-1) warning signs shall be properly posted and maintained in advance of all roadway plates placed on the surface of the pavement. The Contractor is responsible to maintain the steel plates in a proper condition until the roadway is properly back-filled and patched to allow for the safe passage of vehicles. The Contractor shall be responsible for any damages or injuries which may occur as a result of the plates being placed in the roadway. The Contractor must reimburse to the Agency any cost for emergency repairs.

In sidewalk areas, one and one-eighths inch (1-1/8") plywood with a nonskid surface static coefficient of friction of 0.50 per ASTM C 1028 may be substituted for steel plating where the excavation is less than two (2) feet deep and when authorized by the Agency. Transitional ramps of MC250 asphalt mix (cutback) shall be installed against vertical edges in the direction of pedestrian traffic (both up and down-stream). All ramping must be accomplished to provide a minimum angle of approach of twelve to one (12:1), providing a smooth, gradual transition between the sidewalk and the plate. Plywood shall extend beyond the edge of the trench and any overlap shall be a minimum of 18". Plywood shall not be placed such that it protrudes past the sidewalk edge.

REMOVAL OF USA MARKINGS

Before the project is accepted as complete, all USA and other construction related markings shall be removed to the satisfaction of the Agency**.** Removal shall occur within 30 days of the date the markings are no longer needed, or upon completion of the work, whichever is sooner. The Agency will accept natural weathering of markings if the markings disappear within the 30 day period. If the markings are in brick paver or concrete areas and if by natural weathering or other approved removal methods the markings still remain, the contractor must replace the concrete or the brick pavers in-kind, unless the utility operator has failed to use chalk-based paint or other non-permanent marking materials. Excavators and utility operators are encouraged to avoid marking in these areas by using offset markings. Removal methods shall be non-destructive and residual shadowing shall not remain.

Removal of markings shall comply with the federal, state and local requirements of the National Pollutant Discharge Elimination System (NPDES) and the Regional Water Quality Control Board.

U.S.A. markings not removed by the required time lines may be removed and the sidewalk or street repaired/replaced by the Agency at its discretion. The Agency will charge the excavator a service fee equal to the actual costs of removal plus an administrative fee of 20% for removing the markings and making any repairs and/or replacements. This fee will include the cost to comply with NPDES.

DAMAGE TO EXISTING IRRIGATION SYSTEMS

Irrigation systems owned or operated by the County of Sacramento are located within the right-of-way and on dedicated property outside the right-of-way. In the event the irrigation systems are damaged due the permittee's activities, it shall be repaired under the supervision of the Department of Transportation, Contract Landscape Section staff (916-875-5123). The system shall be repaired in accordance with the current County Standards. Care shall be taken to eliminate any debris from entering the system. Any damage resulting from repairs or contamination into the irrigation system will be the responsibility of the permittee. A contractor working in the Landscape construction or maintenance field shall be required for all necessary repairs to the landscape system.

Any permittee working in the right-of-way shall verify the location of the utilities with regards to easements. It shall be the permittee's onus to verify they are not encroaching on dedicated properties such as Assessment District parcels along the right-of-way. In the event a utility has been installed on dedicated property outside of the right-of-way or utility easements, or is planned to be placed on dedicated property, a utility easement must be acquired.

DRIVEWAYS

Portland cement concrete is not allowed for private driveway approaches within County right-of-way unless specifically approved by the Director of the Department of Transportation.

CLEANUP

All roadside drainage ditches shall be restored to a true grade and intake and outlet ends of all culverts shall be left free from all excess material and debris.

RECORD DRAWING

Upon completion of underground or surface work of consequence, the Permittee shall furnish record drawings to CMID showing location and details of work performed.

FUTURE MOVING OF INSTALLATION

The installation authorized herein shall, upon demand of the Agency, be relocated in a timely manner by, and at the sole expense of the Permittee whenever construction, reconstruction, maintenance, or traffic conditions on the highway may require such relocation. The permittee must commence such relocation within the time specified in said demand and thereafter diligently prosecute the same to completion.

BACKFILLING OF POTHOLES AND BORINGS WITHIN PAVEMENT AREAS

Backfilling of potholes or similar types of minor excavations shall be with native or aggregate base materials compacted to 95%. In lieu of using compacted materials, controlled density fill (CDF) conforming to section 50-15 of the SCS may be used.

Backfilling of borings for soil or ground water sampling shall be in accordance with Sacramento County Environmental Health Requirements and County Standards. Backfilling of borings within pavement areas shall utilize cementitious grout materials regardless of the depth of encountered ground water. Backfilling of the upper one foot of borings/monitoring wells located in pavement areas shall consist of either high strength non-shrink grout or fast-setting concrete (minimum compressive strength of 4000 psi). The grout/concrete shall be uniformly color stained black to match surrounding asphalt surfaces (surface staining of placed concrete is prohibited). Placement of material shall utilize hand-rodding methods to facilitate consolidation. Once placed and rodded the surface shall be finished smooth using hand-trowel or other methods.

In the event that consolidation of backfill materials occurs within the first 24-hours of placement resulting in settlements within the boring/monitoring well hole greater than ¼-inch, the hole shall be subsequently refilled with high strength non-shrink grout as required to reestablish a smooth surface. Additionally, if separation/shrinkage of the placed concrete is greater than 1/8-inch occurs along the outer perimeter of the filled hole, a flexible sealant shall be placed such that it uniformly fills associated gaps/voids. If the above criteria are not satisfactorily met, the County Inspector may require cutting/grinding within affected areas and subsequently repave in accordance with County Drawing 4-64.

TEMPORARY PAVEMENT REQUIREMENTS

Vehicular travel over backfilled but unpaved excavations will not be allowed. The Contractor shall provide a temporary surface suitable for driving consisting of at least one and one half inches (1-1/2") of plant mix type "A" asphalt concrete on all roadways with two or more marked traffic lanes in each direction or 45 mph or greater posted speed. Plant mix type "A" or asphalt plant mix cutback maybe used on all other roadways.

All temporary paving shall be identified by painting the words "TEMPORARY PAVEMENT" along with the name of the contractor responsible for maintaining the temporary paving material and the date in which the material was placed. Painted text shall be in white lettering at the beginning, ending and along the length of the temporary paving at a spacing not to exceed 500 ft. The TEMPORARY PAVING and the contractor or utility's name shall be neatly stenciled 5 inches minimum in height and shall be maintained in a neat and legible condition. The date in which the material was place may be painted free hand without the use of a stencil, but must be legible.

Temporary pavement and/or portions of temporary pavement totaling 1000 ft or greater in length shall also be identified with a construction sign placed along the edge of the roadway and constructed in accordance with section 34 of the SCS. Temporary pavement signs shall be 30" X 30" in a diamond configuration and shall be orange with 5 inch black lettering. Signs shall be installed at the beginning, ending and at a spacing not to exceed 1000 ft. and shall be installed within the road right of way whenever possible. Signs shall not be installed in a location that would obstruct visibility or create an obstacle for pedestrians. Property owner's permission must be obtained if sign is placed on private property.

In no case shall temporary pavement be allowed to remain for a period greater than 30 calendar days unless specifically approved by the Department of Transportation Right-of-Way Management Section.

RESTORATION OF SURFACES

(Note: Requirements for Trench Restoration are currently in the process of being revised. New requirements may be enforced on this project if final paving has not been completed prior to implementation of new requirements.)

Replace section 14-3 STREET AND PARKING LOTS and Section 14-4 CONCRETE of the County Standard Construction Specifications with the following:

14-3 STREETS AND PARKING LOTS

14-3.01 Trench Restoration

Edges of trench restoration shall be cut/grind so that edges are parallel or perpendicular to the centerline of the roadway. All required sand/slurry seal must be placed so that edges are parallel or perpendicular to the centerline of the roadway. Edges of existing pavement that are broken or damaged shall be removed and neatly trimmed back to stable and undisturbed base and surface materials. For locations where the existing pavement is severely fractured, remove loose asphalt to the nearest crack beyond the specified restoration limits.
Repaving of trenched areas shall be in accordance with Standard Drawing 4-64 (including Shallow Trench, Deep Trench and Earth Saw Trench Details) with the following exceptions:

<u>Roadways less than 3 years old</u>
Cuts in pavement that have been constructed or overlaid within the last three (3) years are not generally allowed. County Code section 12.09.120 prohibits excavations in newly constructed or overlaid roadways for a period of three (3) years. In circumstances such as emergency repair work where no other feasible options exist, the Sacramento County Dept. of Transportation may grant a waiver to this restriction. In the event that a waiver is granted, the applicant should be prepared to meet more stringent restoration requirements than those specified in these specifications.

<u>Roadways with pavement 3 to 5 year old</u>
Cuts in pavement that have been constructed or overlaid within three (3) to five (5) years shall receive a minimum 1-1/2 inch deep grind from lane line to lane line or edge of pavement and overlaid with asphalt concrete in conformance with these specifications. At roadway intersections and cul-de-sac bulbs, minimum grind and overlay shall extend to include the entire ¼ quadrant of the roadway affected by the work. 1-1/2 inch grind depth shall be considered a minimum and shall be adjusted as necessary to produce a stable surface for new pavement material. A seal coat will not be required.
For Earth Saw Trench Section, delete "is within 20" of lip of gutter, otherwise 6" minimum" and replace with "edge of pavement or lane line". A seal coat will not be required

<u>Roadways with pavement greater than 5 years old</u>

<u>Minor Roadways:</u>

Alternate 1 – Comply with requirements of Drawing 4-64 except eliminate tee portion of asphalt restoration by limiting the extent of paving to the projected area above the trench. Follow the trench paving with a minimum 1-1/2 inch grind and overlay from center of roadway to edge of pavement.

Alternate 2 – Comply with requirements of Drawing 4-64. Slurry seal or sand seal from edge of pavement to centerline of roadway and a minimum of two (2) feet beyond the trench paving limits. At roadway intersections and cul-de-sac bulbs, minimum slurry seal or sand seal shall be placed on the entire ¼ quadrant of the roadway affected by the work. Sand seal applications shall be limited to 250 sq. ft. or less or as directed by the County **(Black sand shall be used for this application)**.

<u>Roadways with 2 or more lanes in each direction or 45 mph or greater posted speed:</u>

Add: Arterial and thoroughfares shall receive a minimum 1-1/2 inch deep grind from lane line to lane line or edge of pavement and overlay with asphalt concrete in conformance with these specifications. 1-1/2 inch grind depth shall be considered a minimum and shall be adjusted as necessary to produce a stable surface for new pavement material. A seal coat will not be required

Limits for "Seal Coats" specified in section 49-2.02 which is referenced in the "Earth Saw Trench Section" detail shall be revised to comply with the limits indicated above.

14-3.01 Repair to areas damaged by Contractor's Operations
Areas of existing asphalt surfaces damaged during construction shall be removed and the top four inches (4") of base material shall be re-compacted to a minimum relative compaction of ninety-five percent (95%). Base or underlying material that is wet, loose, or otherwise unsuitable for supporting new paving shall be removed to a maximum depth of twelve inches (12") below the bottom surface of the new asphalt pavement section and replaced with aggregate base material per the requirements of Section 22, "Base Material", of the County Standard Construction Specifications. Aggregate base material shall be compacted in layers not exceeding six inches (6") in depth to a minimum relative compaction of ninety-five percent (95%). If unsuitable materials exist below this depth, an approved geotextile fabric shall be installed prior to placing the aggregate base materials.

14-3.02 Asphalt Concrete
The asphalt concrete shall conform to requirements specified in Section 23, "Asphalt Concrete", of the Sacramento County Standard Construction Specifications. If the existing pavement surfacing is rubberized asphalt, top layer of new asphalt surfacing shall match the existing. Special attention should be noted that section 23-3.02 "Binders" specifies that "Conventional dense graded asphalt used on on-ramps, off-ramps, arterial streets and thoroughfare streets shall use PG70-10 binder."

Contractor is responsible for developing and providing appropriate placing and compacting techniques for producing asphalt concrete in conformance with these specifications including the determination of minimum acceptable paving temperatures for the specific mix to be used.
In no case however shall any layer of asphalt concrete be placed when the atmospheric temperature is below 50°F, during raining weather or when the roadway is moist or damp. For the purpose of this provision, "raining" shall mean any weather condition that causes the roadway to become moist or damp. In the case of sudden precipitation, all paving work must stop immediately, all asphalt concrete on site not yet placed and all asphalt concrete in transit from the plant shall be rejected. Asphalt concrete shall be delivered to the site in a thoroughly blended condition and spread by a self-propelled asphalt paving machine in such a manner as to avoid segregation during the placing operations and placed in such a manner as to achieve a density of not less than 92%, nor greater than 97% (CTM 309). Prior to placing asphalt concrete pavement, the vertical edges of any existing pavement, curbs, and gutters adjoining the area to be paved shall be clean and given a tack coat of asphaltic emulsion. Horizontal surfaces of asphalt (new and/or existing) shall also receive a tack coat prior to placing new asphalt. Asphaltic emulsion shall be of the high viscosity type subject to the approval of the Agency, and shall conform to Sections 39 and 94 of the State Specifications. Asphalt paving machine shall be used for placing the finish lift of asphalt concrete paving on all trench restorations. Limited areas inaccessible to mechanical spreading and compaction equipment or where irregularities or unavoidable obstacles exists may be spread, raked and luted by hand tools or other methods approved by the Agency. Asphalt paving machines shall be mechanical spreading and finishing equipment provided with a screed or strike-off assembly capable of distributing the material to not less than the full width of the trench. Screed action shall include any cutting, crowding or other practical action which is effective on the mixture without tearing, shoving or gouging and which produces a surface texture of uniform appearance. The screed shall be adjustable to the required section and thickness. The paver shall operate independently of the vehicle being unloaded.

Final pavement surface for trenches greater than 3 feet in width and which are mostly parallel to the centerline of the street shall not vary from the edge of a 10 foot straight edge (placed parallel and perpendicular to the trench) by more than 3/8-inch, except at intersections or changes in grade.

Final pavement surface for trenches 3 feet or less in width, bore holes having an area less than 50 square feet, and trenches of any width not mostly parallel to the centerline of the street shall match the smoothness of the existing pavement, except final pavement surface grade shall not exceed 3/8-inch above a line between the existing pavement surface at each edge of the excavation. Final pavement below this line is not acceptable.

Pavement not meeting the above requirements shall be removed and replaced. Such pavement shall be removed to a minimum depth of 1-1/2 inches for the full width of the trench. The minimum length of removal along the trench shall extend for 4 feet beyond the ends of the non-conforming areas, but in no case exceed the limits of the original pavement repair.

14-3.02A Density requirements

The County may require testing of the asphalt concrete used in pavement restoration to verify that the materials being place conforms to these specifications. Density of asphalt concrete for quality control purposes may be determined by nuclear gage testing or other approved nondestructive testing method. At the County's request, the Contractor shall provide quality assurance testing based on sampling of the asphalt on a lot basis defined as each five hundred (500) linear feet of trench. Compaction results shall be from comparing the average of density of cores taken from the compacted pavement to the Maximum Theoretical Density (Rice) as determined by California Test 309 (CT 309) taken from randomly sampled material on a lot basis. A minimum of two (2) cores per lot shall be sampled with half of the cores taken at the joint between the newly placed and the existing asphalt concrete (not more than 1 ft away from existing asphalt concrete). Contractor shall meet with the inspector and mutually agree on the sampling location. The density of each core shall be determined per CTM 308. The core samples shall be four inches (4") in diameter. Samples shall be neatly cut with a saw, core drill, or other approved equipment. If the density does not fall within the specified density range, the Contractor may test at two additional locations within the same 500 linear feet of trench area and average the results of all three tests. This averaged result shall fall within the above-specified range. The Contractor shall notify the County inspector prior to paving and provide contact information for Contractor's testing personnel. The Agency reserves the right to conduct parallel quality assurance testing at its discretion in accordance with Caltrans test methods, 308, 309, and 375. Asphalt not meeting the above specified compaction requirements will be rejected on a lot basis.

14-3.03 Seal Coats

Specified seal coat treatment shall conform to the following requirements and shall not be placed until at least seventy-two (72) hours after the placement of the final paving lift.

Slurry Seal (type 2)

Slurry seal shall be furnished and placed as specified in Section 37-2 for Slurry Seal, of the State Specifications, with the exception that the fifth paragraph of Section 37-2.06, "Placing", shall be modified to provide that the thickness of application of slurry seal shall be adjusted to provide one (1) layer not less than one eighth inch (1/8") thick nor greater than one-quarter inch (1/4") thick. The requirement for wetting surface prior to placement of slurry seal is waived.

Sand Seal

Sand seal shall be furnished and placed as specified in Section 37-1, "Seal Coats", of the State Specifications with the exception of the requirements for the asphaltic binder and aggregate. Asphaltic binder and aggregate shall be as follows:

- The asphaltic materials for sand seal shall conform to the requirements in Section 50-17, “Asphalt, Liquid Asphalt, and Asphaltic Emulsion”, of these Specifications. The asphaltic materials shall be CRS 1.
- The rate of application of CRS 1 shall vary between 0.08 and 0.15 gallons per square yard as directed by the Agency, depending upon the surface condition and weather.
- Aggregate for sand seal shall conform to Section 37-2.02C, “Aggregate”, of the State Specifications and shall be spread at the rate of six (6) to ten (10) pounds per square yard, or as directed by the Agency. Preparation of seal coat, applying bituminous binder, spreading, and finishing shall be in accordance with Section 37, “Bituminous Seals”, of the State Specifications, with the exception that steel wheeled rollers for sand seal may be eliminated and the pneumatic roller used for all seal operations. Asphaltic emulsion shall be applied by a distributor truck.
- Black sand shall be used for this application.

14-3.04 Shoulders
Surface restoration of trenches located in a shoulder within six feet (6’) of the traveled way shall consist of a structural section equal to the original, or as shown on the Plans, but having a minimum of five inches (5”) of aggregate base compacted to a relative compaction of ninety-five percent (95%).

14-4 CONCRETE

Repairs to concrete curbs, gutters, sidewalks, driveways and other concrete surfaces shall be made by removing and replacing the entire portions between joints or scores, except as follows:

- Curb and gutter shall be replaced between saw cuts so that the remaining or new curb and gutter will not be less than four feet (4’) in length, measured from the saw cut to the nearest score mark, expansion joint, construction joint or weaken plane joint.
- The entire width of sidewalk shall be replaced between saw cuts for a length of not less than four feet (4’) in length, measured from the saw cut to the nearest score mark, expansion joint, construction joint or weaken plane joint.
- Driveways shall be replaced as directed by the Agency, either completely or partially by saw cutting in the middle of the driveway.
- Existing driveways not in conformance with current ADA requirements shall be completely removed and replaced to conform to current requirements.
- In accordance with section 4-18 of the County of Sacramento Improvement Standards and the American with Disabilities Act (ADA), California Code of Regulations, Title 24 and the California Manual on Uniform Traffic Control Devices, any modification of any portion of an intersection shall require access improvements to all corners of that intersection. Re-construction of existing sidewalk ramps as a result of damage to the sidewalk ramp shall be considered a modification to a portion of the intersection. All existing corners of an intersection where sidewalk ramps are not in conformance with current ADA requirements shall be completely removed and replaced to conform to current requirements.
- Curb dowels and reinforcing shall be provided and shall be installed in accordance with Section 27-6 of the County Standard Construction Specifications.

Replacement shall be in accordance with the applicable requirements, including the placement of Aggregate Base Class 2 under the new concrete as specified in Section 27, “Curb, Gutter, Sidewalk, and Drainage Structures” of the County Standard Construction Specifications. Pedestrian access shall be maintained in accordance with Section 12-12.02, “Pedestrian and Bicycle Access’ of the County Standard Construction Specifications.

14-5 PAVEMENT MARKINGS

Replace entire section with the following:

Except where specified otherwise in these Specifications or the Special Provisions, the Contractor shall replace all crosswalks, legends and other permanent pavement markings and raised markers that have been disturbed, destroyed or covered by the Work. Damaged pavement legends shall be completely removed and crosswalks shall be removed from edge of road to centerline in accordance with section 13-2.09 “Removal of Traffic Stripes and Pavement Markings” and a sand seal or slurry seal conforming to section 14-3.04 “Seal Coat” shall be applied. Seal coat shall cover the entire pavement surface and extend a minimum of 6 inches past the areas where the legend has been removed. All edges of seal coat shall be perpendicular or parallel to the centerline of the roadway. Pavement markings shall then be replaced in accordance with section 48-2 “Thermoplastic Traffic Stripes and Pavement Markings”.

P:\Shared Folders\R-O-W Management\Templates\Encroachment permits\Attachment A Comments - January 3, 2018.docx

DWR STANDARD REQUIREMENTS FOR ENCROCHMENT PERMITS

Show all County storm drain facilities within the vicinity of the project site and denote with SD.

If project disturbs one acre or more, project owner must determine if coverage under the Construction General Permit (CGP) or a waiver of coverage must be obtained. Include Waste Discharge Identification (WDID) number on construction drawings.

<u>NOTES TO BE INCLUDED ON CONSTRUCTION DRAWINGS:</u>

1. For locations where tunneling/trenching occurs under existing storm drain pipe, control density backfill shall be used consistent with Section 50-15 of the Sacramento County Standard Construction Specifications (September 2001 Revised March 2004, Revised January 2008 and Revised January 1, 2016).
2. Sacramento County Department of Water Resources requires a minimum horizontal separation of 36 inches and a minimum vertical separation of 12 inches from nearest side of storm drain facility. All drainage facilities shall be field verified prior to any construction activity.
3. All drain inlets within the project limits and any downstream inlets that may be affected shall be protected using Sacramento County Standard Construction Specifications (September 2001 Revised March 2004, Revised January 2008 and Revised January 1, 2016).
4. If during construction, the drainage system is damaged or found to be damaged, immediately contact the Drainage Maintenance Engineering Office by calling 311 and the inspector. Repairs shall adhere to the current Sacramento County Standard Construction Specifications.

<u>POTHOLE NOTE:</u>

Prior to beginning construction, the contractor shall pothole   all drainage locations on these plans and allow utility company appointed surveys to locate the Utilities within l/10 (0.10') of a foot. After surveys have located the utilities, the contractor shall backfill the potholed areas in accordance with Sacramento County Standard Construction Specifications. Utility companies shall review the information provided by surveys and revise the alignment of the utility lines as necessary.

DWR ENCROACHMENT PERMIT STORM WATER CONDITION OF APPROVAL

1. Contractor shall inspect on a daily basis all immediate access roads and gutters. At a minimum daily (or when deemed necessary by the inspector) and prior to any rain event, the discharger shall remove sediment or other construction activity related materials that are deposited on the roads and gutters (by vacuuming or sweeping).
2. A haul route plan and soil export destination locations shall be part of this permit. Grading permit/s may be required for soil disposal locations.

STANDARD CONSTRUCTION SPECIFICATIONS 10-4.03 STORMWATER QUALITY

Contractors performing construction in the County of Sacramento are required to develop and implement a Water Pollution Control Program (WPCP).

Unless specifically authorized in writing by the Agency, activities that could create water pollution (like potholing, clearing, grubbing, directional drilling, boring, or similar ground-disturbing activities) must not be performed without a written program to control water pollution.

WATER POLLUTION CONTROL PROGRAM (WPCP)

The Permit holder must prepare a Water Pollution Control Program (WPCP) detailing the following:

1. A map showing:
   a. Locations of storm drain system.
   b. Locations of water lines with owner contact information.
   c. Locations of soil stockpiles and solid waste containers.
   d. Locations of Vehicle and equipment fueling, servicing, cleaning and storage areas.
   e. Locations of Material storage areas.
   f. Locations of erosion and sediment control Best Management Practices (BMPs).
   g. Site drainage (flow arrows) during execution of the Work.
   h. Locations of stabilized vehicle accesses.
   i. Locations of concrete clean out areas.
2. List of chemicals, potential pollutants, and hazardous materials to be used. For example: drilling fluids, marking paint removal solutions, etc.
3. Methods for (include copies of BMP: drawings, details, and/or descriptions):
   a. Storm Water and Non-Storm Water dewatering.
   b. Street cleaning.
   c. Managing run-on and run off.
   d. Frack-out prevention and control.
   e. Spill prevention and control.
   f. Handling and disposal of solid waste.
   g. Methods for safekeeping and secondary containment of chemicals, potential pollutants, and hazardous materials.
   h. Storage and dispensing of fuel and lubricants.
   i. Clean out and disposal of concrete.
   j. Construction BMP maintenance, inspection, and repair.
   k. Sanitation provisions.
4. Methods of site stabilization after completion of the work.
5. Construction BMP implementation and removal schedule.

The program must be available on-site and is subject to review by County personnel.

Failure to implement the program may subject the permit holder to formal enforcement actions including but not limited to stop work notification.

Review drawing attached to this permit. For lower lateral location contact U.S.A. 1-800-227-2600. In the event of damage and or broken SASD (sewer) facilities, contact SASD Radio room at (916) 875-6730 and provide location of damage line, a SASD representative will document and evaluate the damage.

We are enforcing County Standard .Please plot public utilities with offset dimensions relative to other facilities, utilities; center line & right of way, and write adjacent Assessor's Parcel Number (see Encroachment Review application form). Please request Plan & Profile of the sewer facilities in your project area in writing and or visit us from 1:00 PM to 4:30 PM at:

10060 Goethe Rd.

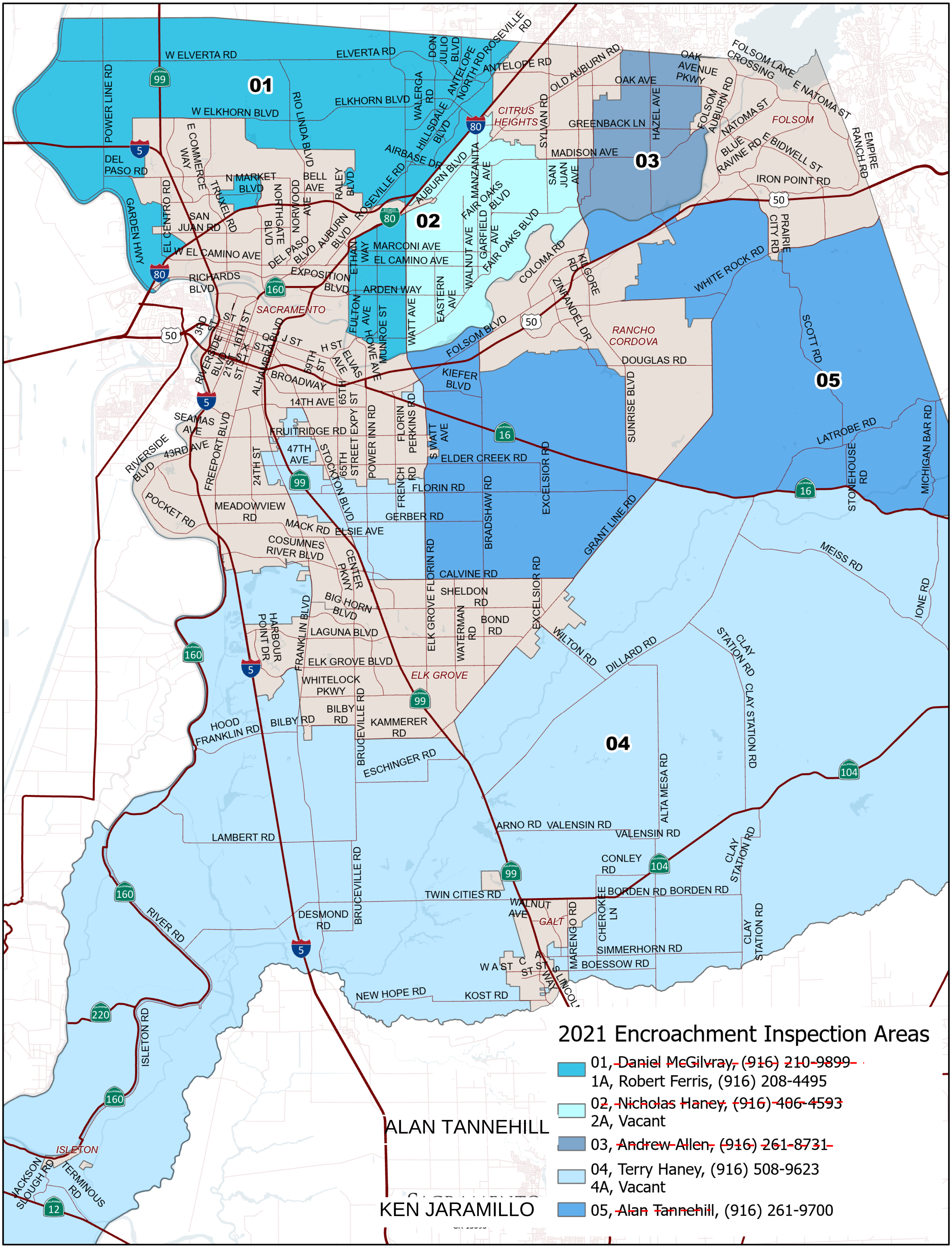
Sacramento Ca. 95827

Maintain 5' Min. Horizontal clearance to Sewer facilities. Except Water Main per State Health & Safety code requires 10' min Horizontal clearance.

Maintain 1' Min. Vertical clearance to Sewer facilities on all crossings.

To access any SASD sewer:

An approved Access Permit is required. Access Permit is available on SASD website www.sacsewer.com , please allow 10 days for approval.


2021 Encroachment Inspection Areas
01, ~~Daniel McGilvray, (916) 210-9899~~
1A, Robert Ferris, (916) 208-4495
02, ~~Nicholas Haney, (916) 406-4593~~
2A, Vacant
03, ~~Andrew Allen, (916) 261-8731~~
04, Terry Haney, (916) 508-9623
4A, Vacant
05, ~~Alan Tannehill~~, (916) 261-9700
ALAN TANNEHILL
KEN JARAMILLO
01
02
03
04
05
CITRUS HEIGHTS
FOLSOM
SACRAMENTO
RANCHO CORDOVA
ELK GROVE
GALT
ISLETON

U.S.A. TICKET NO. ____________

Phone (800) 227-2600

SACRAMENTO COUNTY MUNICIPAL SERVICES
827 – 7TH STREET, ROOM 105, SACRAMENTO, CA. 95814
PHONE (916) 874-6544

PERMIT NO. ENUC2022-00399

MAP NUMBER
COORDINATES

APPLICATION FOR ENCROACHMENT PERMIT

1. Permit Type:

2. Application is made for permission to excavate, construct and/or otherwise encroach on County right-of-way by performing the work described below on:

6700 Madison Avenue at Dewey Drive

Project Location

3. Scope of Work:

CITRUS HEIGHTS WATER DISTRICT
CONSTRUCT 115 LINEAR FEET OF NEW 8" WATER MAIN IN SEPTEMBER AND OCTOBER 2022 PER ATTACHED PROPOSED PLANS. ALL CONSTRUCTION WILL OCCUR ON SITE AT 6700 MADISON AVENUE. THIS PERMIT APPLICATION IS FOR USING THE RIGHT-TURN LANE ON DEWEY DRIVE FOR POSITIONING EQUIPMENT AND MATERIALS DURING APPROVED WORKING HOURS. NO MATERIAL OR EQUIPMENT WILL STORED IN THE RIGHT-OF-WAY DURING NON-WORKING HOURS.

4. **Permittee shall schedule a pre-construction meeting to activate this permit by calling CMID at (916) 875-2707.**
5. **Permittee shall notify Construction Management and Inspection Division (CMID) at (916) 875-2707, at least 24 hours in advance prior to commencing work.**
6. **Permittee shall contact the County Survey Section at (916) 876-5829 for potential location of survey monuments.**
7. Applicant must check with all Utility Companies serving the area covered by this permit, for location of existing underground pipes, conduits or cables. Underground Service Alert (U.S.A.) does not locate non-pressurized sewer and drainage facilities.
8. Attention is directed to the General Provisions attached hereto and to any specific conditions made a part of hereof.

In consideration of the granting of this application, it is agreed by the applicant that the County of Sacramento and any officer or employee thereof shall be saved harmless by the applicant from any liability or responsibility for any accident, loss or damage to persons or property, happening or occurring as the proximate result of any of the work undertaken under the terms of this application and the permit or permits which may be granted in response to thereto, and that all of said liabilities are hereby assumed by the applicant. It is further agreed that if any part of this installation interferes with the future use of the highway, it must be removed or relocated, as designated by the Chief Deputy County Executive of Municipal Services, at the expense of the applicant or their successor in interest.

FOR USE BY UTILITY COMPANIES			
District	Citrus Heights Water District	Division:	Engineering
Engineer	Missy Pieri	Job No:	C21-105

Contact Person: PAUL DIETRICH

Applicant Signature: Paul Dietrich

Applicant: CITRUS HEIGHTS WATER DISTRICT, PAUL DIETRICH Phone: 916 735-7723

Address: PO BOX 286 City: CITRUS HEIGHTS State: CA ZIP: 95611

DEPARTMENTAL REVIEW	APPROVED	DATE			VALIDATION:
			Bond / Deposit:		
WATER SUPPLY			Code: 077C-0772982-5500000		
TRANSPORTATION			PERMIT FEE:		
WATER RESOURCES			Code: 005A-2900000-92925800		
WATER QUALITY			Sub. Order Number:		
TECHNICAL RESOURCES			Customer Number:		

Approved applications subject to payment of fees, pre-construction meeting with CMID, Attachment A, and is revocable at any time. This permit is nontransferable and EXPIRES **ONE YEAR** from date issued. ***ANNUAL Permits expire December 31 of the year permit is issued.**

***RON E. VICARI*, Road Commissioner**

By: ______________________ Date: ________

CMID INSPECTOR

Plan Submittal Date:

"ASBUILT" Inspector Approval: ______________ ________
Name Date

Traffic control plans templates:
http://www.sacdot.com/Pages/TrafficControlPlansandDetourPlans.aspx

Sacramento County General Map Viewer e-Map-It
http://generalmap.gis.saccounty.net/Default.aspx

STATEMENT OF APPLICANTS RESPONSIBILITY

Encroachment Permit

Dear Applicant:

Please read the following statement outlining your responsibilities regarding the checking and approval of your Encroachment Permit.

California Government Code Section 66451.2 authorizes cities & counties to charge a fee for the actual cost of review. Sacramento County has implemented this fee in Section 22.20.016 of Sacramento County Code. In submitting your plan for review and signing this form, you are agreeing to take responsibility for the costs generated by the County related to plan review, material testing, and construction inspections. An application fee of $365.75 ($350.00 + $15.75 I.T. Recovery Fee) is to accompany this encroachment permit submittal. Upon receipt, a unique account will be established in your name. You will receive a statement on a monthly basis, and all charges must be paid in full prior to final inspection approvals of your permit. If you are the owner of the affected land please sign on the line below. If you are an authorized agent of the owner please sign below and present a copy of your power of attorney for this project. Failure to keep your account current may result in delays of permit approval and final inspection approvals.

I hereby confirm that I understand my financial responsibility for this plan. If I sell or option this property, I will disclose the terms of this statement, and if I fail to do so, I will be jointly responsible.

Property Address/Project Name:	6700 Madison Avenue at Dewey Drive		
Assessor's Parcel No.:	239-0070-001		
FOR UTILITY ENCROACHMENT PERMITS ONLY IDENTIFY UTILITY PURVEYOR WHO OWNS FACILITIES:	Citrus Heights Water District		
Applicant's Name:	Paul Dietrich		
Title:	Project Manager		
Company Name:			
Contractor's License No.:		Business License:	
Address:			
Telephone No.:		E-mail Address:	
SECURITY DEPOSIT			
☐ Bond — Bond Number:		Bond Amount:	
Bond Exp. Date:		Bonding Company:	
☐ Cash			
Refund Cash Deposit To:			
Name:			
Address:			
Signature:		Date:	

AGENDA ITEM: B-1

CITRUS HEIGHTS WATER DISTRICT

DISTRICT STAFF REPORT TO BOARD OF DIRECTORS
SEPTEMBER 28, 2022 REGULAR MEETING

SUBJECT	: ADVANCED WATER METER REPLACEMENT PLANNING STUDY UPDATE
STATUS	: Action Item
REPORT DATE	: September 7, 2022
PREPARED BY	: Rebecca Scott, Director of Operations

OBJECTIVE:

1. Receive and file the Study's Technical Memos.
2. Provide direction to Staff to return to the Board in Q2 of 2023 with an update on CHWD's meter program and the Regional Program.

BACKGROUND AND ANALYSIS:

Background

In 2019, the Carmichael Water District, Citrus Heights Water District (CHWD), City of Folsom, City of Sacramento, Fair Oaks Water District, Golden State Water Company, Orange Vale Water Company, RWA, Sacramento County Water Agency, Sacramento Suburban Water District, and San Juan Water District (SJWD) executed a Memorandum of Understanding establishing a flexible framework for agencies to participate in a Regional Water Meter Replacement Program (Program). The idea of the consortium was to explore potential economies of scale and build collaborative relationships in the region.

Subsequently, the District awarded a contract to Harris & Associates for an initial planning study (Study) to develop six technical memos encompassing the following:

1. An inventory and assessment of the current meter fleet
2. An evaluation of potential replacement meter technology options and specifications, including their applicability to Consortium agencies and an evaluation of potential technology sharing opportunities
3. A summary and assessment of current meter testing programs and options for optimizing performance
4. An evaluation of potential replacement meter procurement programs and financing models
5. An implementation strategy for each agency, including budgeting, staffing and a regional collaboration plan
6. A final report summarizing prior results and recommending a regional meter assistance program

The Study is now complete, and each participating Consortium member has an agency-specific implementation plan to help inform decisions moving forward. In CHWD's implementation plan, Harris recommended that the District complete a pilot project to assess new meter technologies (specifically the Sensus endpoints). CHWD recently completed an eight-month pilot program using Sensus technology at Mitchell Village. Ultimately, staff decided to decommission the project due to a variety of factors.

Staff is now working with Neptune to start another pilot project at Mitchell Village using their trailer-mounted meter reading tower. Staff has also been working with Neptune to complete a propagation study to assess the District's need for data collectors if the District were to convert to an AMI (automated) meter reading system.

The Study also recommended that the District implement a meter testing program, in which several hundred meters would be targeted for testing annually. As the District does not have the equipment or staffing to accommodate this, the Study recommended that the District partner with other agencies with large test benches, such as the City of Sacramento, City of Folsom or Placer County Water Agency. CHWD has reached out to these agencies and is in discussions with the City of Sacramento regarding potential testing in the future.

Once the District has at least one year of better meter testing data (as a result of testing a larger number of meters in 2023), staff will refine a meter replacement strategy for the District. The test data will allow the District to better determine the District's replacement cycle duration and determine which meters to prioritize for replacement. Typically, meter accuracy loss correlates to the flow rate rather than age, and the District's test data will likely confirm this for CHWD meters.

Regional meter asset management program collaborations will be explored further through a joint purchasing committee established by the Regional Water Authority (RWA), and chaired by Citrus Heights Water District Director of Operations Rebecca Scott. Staff will update the Board periodically on the Committee's discussions and progress.

RECOMMENDATION:

1. Receive and file the Study's Technical Memos.
2. Provide direction to Staff to return to the Board in Q2 of 2023 with an update on CHWD's meter program and the Regional Program.

ATTACHMENT:

Meter Replacement Program Planning Study Final Report

ACTION:

Moved by Director _________________, Seconded by Director _________________, Carried __________

SUBMITTAL DRAFT

Meter Replacement Program Planning Study

Technical Memorandum No. 6
Final Report

July 2022

Prepared for:

Prepared by:

3620 American River Drive, Suite 175
Sacramento, California 95864
(916) 970-8001
Contact: Tom West

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Acknowledgements

Participating Consortium Agencies

Carmichael Water District
Citrus Heights Water District
City of Folsom
City of Sacramento
Fair Oaks Water District
Golden State Water Company
Orange Vale Water Company
Placer County Water Agency
Regional Water Authority
Sacramento County Water Agency
Sacramento Suburban Water District
San Juan Water District

Technical Advisory Committee Members

Rebecca Scott, Citrus Heights Water District
Todd Eising, City of Folsom
Robb Lane, City of Folsom
Jon Conover, City of Sacramento
Craig Stevens, City of Sacramento
Deanne Neighbours, City of Sacramento
Dalton Lee, City of Sacramento
Linda Higgins, Placer County Water Agency
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Kellie Eng, Sacramento County Water Agency
Carlos Smith, Sacramento County Water Agency
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Andrew MacDonald
Tom West
Brian Spindor

M.E. Simpson

John Van Arsdel
Steve Davis

Isle Utilities

Nicole Kaiser

AMI	**Advanced Metering Infrastructure** is a collection of wireless communication equipment that enables a utility to remotely collect meter data at regular intervals.
CHWD	**Citrus Heights Water District**
Consortium	**Water Meter Replacement Program Consortium** includes Carmichael Water District, Citrus Heights Water District, City of Folsom, City of Sacramento, Fair Oaks Water District, Golden State Water Company, Orange Vale Water Company, Placer County Water Agency, the Regional Water Authority, Sacramento County Water Agency, Sacramento Suburban Water District, and San Juan Water District.
CoS	**City of Sacramento**
Folsom	**City of Folsom**
Harris	**Harris & Associates**
Intermediate Meters	**Intermediate Meters** are meters that have a 1.5-inch or two-inch water flow capacity.
Large Meters	**Large Meters** are meters that have a three-inch flow capacity or larger.
MG	**Million Gallons**
MRP	**Meter Replacement Program**
NaaS	**Network as a Service**
O&M	**Operations and Maintenance**
PCWA	**Placer County Water Agency**
R-MAP	**Regional Meter Asset Management Program**
RWA	**Regional Water Authority**
SaaS	**Software as a Service**
SCWA	**Sacramento County Water Agency**
SJWD	**San Juan Water District**

Small Meters	**Small Meters** are meters that can have a one-inch water flow capacity or smaller.
SSWD	**Sacramento Suburban Water District**
Study	**MRP Planning Study**

Section 1 Introduction

The Meter Replacement Program (MRP) Planning Study (Study) has presented a unique opportunity for neighboring water agencies in the greater Sacramento area to explore potential benefits of working together. Water MRP Consortium (Consortium) agencies understand that the utilities of the future will operate in a different paradigm—one that is largely built on public and stakeholder trust, along with cooperation and collaboration with adjoining entities with common interests and economic benefits.

Agencies participating in the Study included CarmichaelWater District, Citrus Heights Water District (CHWD), City of Folsom (Folsom), City of Sacramento (CoS), Fair Oaks Water District, Golden State Water Company, Orange Vale Water Company, Placer County Water Agency (PCWA), Sacramento County Water Agency (SCWA), Sacramento Suburban Water District (SSWD), and San Juan Water District (SJWD). The Regional Water Authority (RWA) also participated in developing the approaches for sensible integration.

1.1 Study Purpose

The purpose of the Study was to develop water meter replacement strategies for each participating water agency that included, where feasible, a strategy for the sensible integration of elements of the MRPs between participating water agencies.

Drivers behind conducting the Study and doing so as a consortium included the following:

- Aging water meter infrastructure
- Meter accuracy
- Individual agency resource limitation
- Significant investment – participating agencies are projected to spend over $100 million over the next 15 years on water meter infrastructure
- Emphasis on data-driven decision-making with available technology
- State requirement for monthly consumption reporting starting in 2028

The Study explored several specific opportunities, including the following, for sensible meter program integration:

- **Capital –** sharing large capital investments, such as communications towers
- **Common software platforms –** greater potential for collaboration
- **Equipment –** sharing testing or other high-value items
- **Lessons learned –** higher performance at the regional level
- **Redundancy –** increased collaboration, making it easier to react and respond to risk

- **Shared inventory –** cost savings and quicker access to inventory
- **Staffing –** a deeper and more consistent pool of relevantly skilled staff in the greater Sacramento area

Meter programs are composed of a collection of hardware, software, and skilled professionals organized into an integrated set of systems (i.e., data collection, meter reading, billing, operations, and maintenance). Fundamentally, water meters are used to obtain information on the flow of water at particular locations in a water distribution system. Historically, the purpose of this information has been to support customer billing. Thus, the water meter is often considered to be the "cash register" of the water utility. In recent years, this data has come to serve additional important purposes, including leak reduction, water auditing, regulatory compliance, demand management, and operational efficiency. Water meter programs have evolved over time to serve these various functions. Methods for collecting and using meter data have become more advanced and automated. These changes require skill sets to evolve with them.

The meter program for any agency will be unique because of the specific context, priorities, and needs of the community it serves. First, the Study provided guidance on opportunities to match technologies and business models with the specific context of each agency. Second, the Study looked across agencies to identify where contexts and interests align. These were the areas in which the Study explored specific opportunities for collaboration between agencies. Some possible areas of meter program collaboration investigated over the course of the Study included operations and maintenance (O&M) of different hardware and software; installation; testing; customer service; leak detection; and compliance monitoring systems (Figure 1, Elements of a Meter Program).

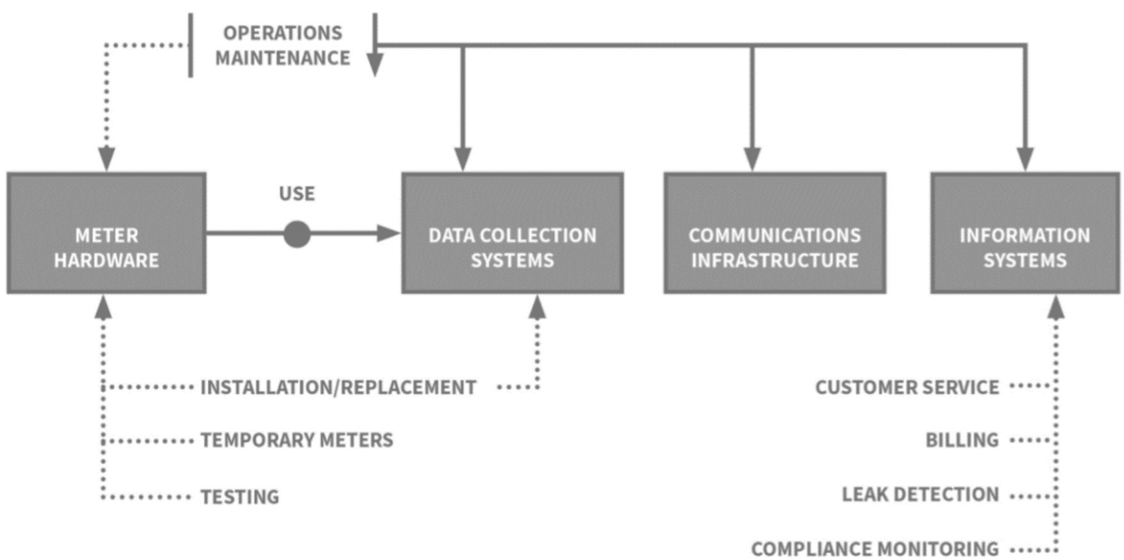

Figure 1. Elements of a meter program, including the efforts required to operate, maintain, and optimize the systems and ancillary efforts, such as customer service, billing, and compliance monitoring.

1.2 Study Organization

The Study was comprised of seven specific tasks as illustrated on Figure 2, Overall Meter Study Activities. Each task concluded with a technical memorandum that can be found in Appendices A–E of this Final Report. A summary of the findings and conclusions from each task are provided in Section 2, Summary and Conclusions.

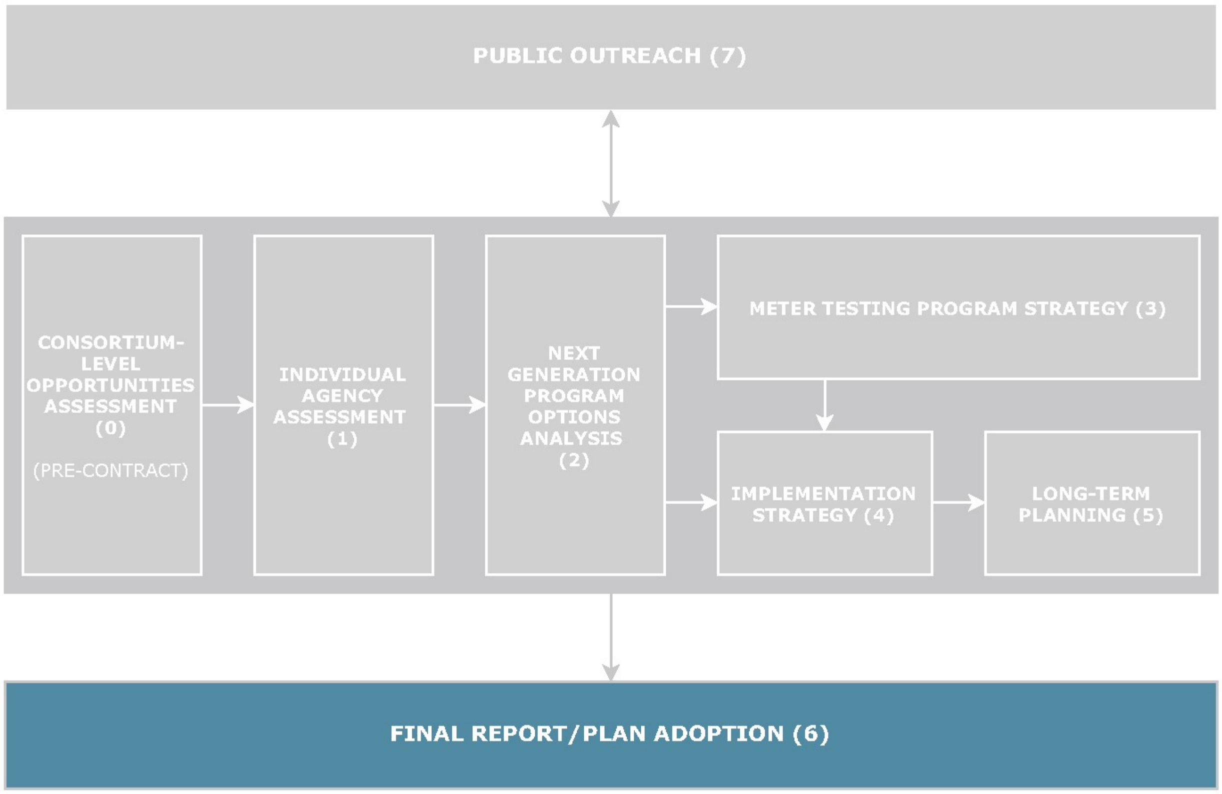

Figure 2. Overall Meter Study Activities

Phase 0 – A pre-contract process for soliciting Study participation by Consortium agencies by understanding the needs and priorities of each participating agency's meter program.

Phase 1 – An investigation of each participating agency's current inventory and a financial assessment for each participating agencies' deployed meter fleet. Data collection/presentation was assembled into a standardized format developed by the consultant for participating agencies.

Phase 2 – An investigation of different options in meter technology, vendors, and accompanying meter specifications. This included a detailed evaluation of the top three to five meter vendors according to criteria set forth by participating agencies.

Phase 3 – A review of each agency's current water meter testing program and available water meter testing facilities (in-house and regional). Opportunities for Consortium-level collaboration were researched in this phase to identify the feasibility of joint meter testing options.

Phase 4 – A blueprint for actions that participating agencies can employ to guide policies, programs, projects, and tasks associated with a shift toward meter program collaboration. The implementation strategy was developed as a "to-do list" for policy leaders and program managers to follow and implement the recommendations of the Study.

Phase 5 – Development of tools and a strategy for planning for future generations of meter replacements both at the individual agency level and at the Consortium level. This includes replacement timing/phasing, financial implications, and best practices.

Phase 6 – A compilation of the entire set of Technical Memoranda (No. 1–5) and an executive summary.

Phase 7 – Ongoing support for public engagement over the course of the Study.

Consortium members provided input on the Study in several ways, including:

- Providing agency-specific data regarding current meter assets and programs, as well as plans for the future
- Sharing knowledge and experience with various meter-related technologies, vendors and pricing
- Brainstorming potential bench and field-testing collaboration and resource-sharing
- Reviewing deliverables
- Developing individual-level and consortium-level implementation plans and strategies
- Participating in several Technical Advisory Committee (TAC) meetings

Section 2 Phase Summary and Conclusions

Section 2 summarizes the findings and conclusions of each of the Study's major phases. Each phase concluded with a technical memorandum, which are appended to this Final Report (Appendices A–E).

2.1 Agency Assessment (Technical Memorandum No. 1)

The purpose of Phase 1 was to collect detailed information as a basis for subsequent phases of the Study. The Harris team collected information related to each participating Consortium agency's meter program and organized it in terms of each agency's current meter inventory, meter reading platform(s), software and data systems, and cost information.

2.1.1 Approach Overview

The approach for Phase 1 consisted of five steps:

- Assemble a meter inventory for each agency
- Assess the condition of each agency's deployed meter inventory
- Assemble an inventory of meter software and data systems for each agency
- Inventory the cost data for each agency's meter system
- Conduct one-on-one interviews

Once data was compiled, Harris organized and analyzed the information using the following categories:

- Meter Inventory
- Count
- Age
- Use
- Type
- Reading Platform
- Manufacturer
- Register
- Lids

2.1.2 Conclusions

The primary conclusions derived from the quantitative and qualitative information compiled in Phase 1 included the following:

- Participating agencies can be grouped into four categories in terms of their meter reading platforms:
  - The CHWD and SJWD primarily have manual or touch-read meters. CHWD has not yet decided to invest in an advanced metering infrastructure (AMI) platform. SJWD is now developing its AMR platform (July 2022).
  - The PCWA and SCWA have selected AMI solutions but still have a significant percentage of their meters on manual/touch or automatic meter reading platforms.

- The SSWD has selected and partially converted its deployed meter inventory to AMI platforms.
- Folsom and the CoS have both selected and fully converted to AMI platforms.

- Average meter age varies across participating agencies. Folsom has the youngest inventory with an average age of 7.5 years. The CHWD and SJWD have the oldest inventories with an average age of 14.8 years and 14.6 years, respectively.
- Participating agencies generally prefer positive displacement (mechanical) meters for their small size applications (less than two inches). Meters are generally purchased from three vendors: Neptune, Badger, and Sensus.
- To date, participating agencies have largely selected fixed-network AMI systems. One exception is the SSWD, which has 33 percent of its deployed meter inventory on a cellular platform. The CoS and PCWA also have a small subset of meters on cellular platforms. The most common platforms are Badger ORION (CoS, PCWA, and SSWD) and Sensus FlexNet (SCWA and SSWD).
- Participating agencies do not employ an expansive small meter testing program but do test these small meters when they are replaced due to failure of some sort or when a customer challenges their meter's accuracy. Most but not all agencies have a schedule for testing or replacing large meters (three inches or greater). As a result, most agencies employ age-based replacement criteria for small meters.

2.2 Next Generation Program Options Analysis (Technical Memorandum No. 2)

Meter and meter reading technologies have become increasingly digital and more complex to provide advanced functionality in terms of performance, accuracy, and efficiency. Automatic meter reading platforms offer improved access to data with fewer inconsistencies and greater granularity. Consortium agencies must have confidence that these technologies will function dependably and cost effectively in the field before they unseat the proven technologies that the Consortium agencies depend on to provide reliable and affordable water service.

The purpose of Phase 2 was to support the Consortium agencies in their evaluation of different meter and meter reading technologies. In addition to offering insight into technology trends and differences between AMI solution offerings, this phase gave Consortium agencies the opportunity to share feedback regarding their experience with meters, meter reading, and meter data management products and solution providers.

2.2.1 Approach Overview

Phase 2 began with an overview of the advanced meter technology landscape, including trends in meter reading technologies, supporting software, and major solution providers. A comparative evaluation of well-positioned vendors was conducted to help participating agencies consider opportunities to maximize investments in equipment, capital, software, and staffing through a more collaborative approach to meter program decision-making.

The Phase 2 scope of work included the following activities:

- Reviewing trends in meter technology, including meter reading systems and software solutions.
- Identifying the predominant solution providers of meter technology in the U.S. market.
- Comparing a subset of vendors against performance criteria of interest to the Consortium. Six over-arching categories of priority metering solution characteristics were defined:
  - **Accuracy –** Refers to the degree to which the water meter can correctly convey the quantity of water that flows through it. This topic is discussed in detail in Section 3, Meter Technologies, in Technical Memorandum No. 2.
  - **Simplicity –** Covers the ability of a solution to operate with minimal required infrastructure and O&M while still delivering a reliable system. This includes the ability to provide flexible business models, such as network as a service (NaaS) and software as a service (SaaS) agreements, which require less upfront investment. Additionally, the ability to update endpoints and data collection units remotely minimizes required field maintenance.

- **Reliability –** Covers the ability of a solution to ensure proper functioning and to decrease single points of failure. This includes long-life components, secure data storage protocols, and data loss prevention.
- **Responsiveness –** Encompasses the ability of a solution to include analytics or instrumentation as turnkey features that support the monitoring of the AMI system. This may include leak detection, high-flow detection, remote shutoff or turn-on, pressure monitoring, reverse flow alarms, and tampering detection and alerts.
- **Flexibility –** Comprises the capabilities and limitations of a solution to integrate with other components and information systems. Given the variety of components in an AMI system, the ability for a vendor to be compatible and able to complement an existing AMI system is advantageous. This includes physical components, like meters, and information and data management systems (e.g., customer portals, billing software).
- **Redundancy –** Covers the ability of a solution to ensure the communication and transmission to and from network devices (i.e., endpoint, data collection unit) with multiple communication pathways, providing alternatives or backup options so that information is preserved and transmitted in any event or case of failure.

2.2.2 Recommendations

2.2.2.1 Meter Technologies

Based on the evaluation of meter technologies, the following recommendations were made to leverage the Consortium agencies' participation in the Study:

- **Recommendation 1:** Develop and employ a joint Request for Proposals for Consortium-level small meter purchasing
- **Recommendation 2:** Establish a consistent meter database across Consortium agencies
- **Recommendation 3:** Establish a Consortium-wide meter pilot program

2.2.2.2 Meter Reading Technologies

Based on the evaluation of meter reading technologies, two recommendations were made to evaluate meter reading technologies, and a third recommendation was made to share data compiled from meter reading technologies:

- **Recommendation 4:** Conduct a Consortium-level propagation study
- **Recommendation 5:** Conduct a Consortium approach to piloting emerging technologies
- **Recommendation 6:** Develop a Consortium-wide analytics program

Currently, the advantages that static meters (with no moving parts) have do not offer a sufficiently clear net benefit to Consortium agencies. **Consortium agencies are recommended to continue deploying mechanical meters for sizing up to two inches and compound, combination, or**

turbo meters for two-inch meters. Consortium agencies are also recommended to continue piloting new meter technologies. If Consortium agencies follow the meter data management recommendations in the Study, particularly the recommendation to connect meter attribute data with related life-cycle cost information, then they will be better positioned to more effectively evaluate new technologies within several years. For more information, see Technical Memorandum No. 2.

2.3 Meter Testing (Technical Memorandum No. 3)

Meter testing is an integral part of water meter asset management because it helps water agencies better understand real water losses by both volume and value (costs) and make informed decisions about when to replace deployed meters. Changes in meter accuracy over time are influenced by several factors, including the type of meter, volumetric throughput, and water quality. Changes in meter accuracy will differ by agency, but there can be regional trends (e.g., meter type or water quality).

The purpose of Phase 3 was to provide Consortium agencies with recommended improvements to their meter testing programs. Opportunities for Consortium-level collaboration, including the feasibility of joint meter testing options, are presented. Meter testing standards and methods are discussed, and recommended region-wide procedures are provided.

2.3.1 Conclusions and Recommendations

2.3.1.1 Small Meter Testing (One-Inch and Smaller)

Consortium agencies do not currently have well-defined schedules for small meter testing but should prioritize doing so. The CoS, Folsom, PCWA, and SJWD have in-house testing capabilities for small meters. The CoS, Folsom, PCWA, SSWD, and SJWD have bench tested small meters in recent years. Existing data provides these agencies with insight into how the performance of their deployed meters changes over time. However, all agencies need to collect additional data to develop statistically significant relationships between accuracy, age, and total registered flow. The cost of small meter testing is justified through the ability of Consortium agencies to track meter accuracy degradation over time and to use this information to replace meters at the most appropriate time. The investment will enable agencies to develop and demonstrate efficient small meter replacement schedules that minimize revenue lost through meter inaccuracy relative to both the cost of meter testing and meter replacement.

Recommendation 1 – Conduct accuracy testing consistent with American Water Works Association standards of randomly selected deployed meters at 95 percent confidence levels with an initial focus on meters in the 10- to 25-year age range and two- to six-million gallon (MG) total registered flow range. Within the next five years, each agency should aim to develop statistically significant accuracy estimates for 11- to 15-, 16- to 20-, and 21- to 25-year age intervals. Agencies should also aim to develop statistically significant accuracy estimates for two to three, three to four, four to five, and five to six MG total registered flow intervals. This will enable agencies to establish more accurate and statistically defensible small meter replacement criteria and water loss estimates.

2.3.1.2 Intermediate Meter Testing (1.5- and Two-Inch)

Most Consortium agencies do not have testing schedules for intermediate testing. Although it is possible to bench test intermediate meters, on-site testing is the recommended method so that all deployed intermediate meters can be tested on a four- or five-year rotation. Because many of the Consortium's deployed intermediate meters are older positive displacement models without test ports, currently, it is difficult to implement on-site testing. The cost of intermediate meter testing is justified through its role in enabling Consortium agencies to maintain the accuracy of their deployed meters. The test results will demonstrate if agencies are recovering the cost of testing in terms of recovering potentially lost revenue from inaccurate intermediate meters. With this information, agencies will be able to adjust their testing rotation moving forward to balance the costs of meter testing compared to the potential revenue recovery it provides.

Recommendation 2 – Agencies are recommended to place intermediate meters on a four- or five-year testing rotation. The meters should then be rebuilt or replaced based on the test results. If, in the first couple years, the cost justification for annual testing shows that the meter can be shifted to a different schedule, then agencies can adjust accordingly. The methods described here can be used to determine if more or less frequent intervals can be adopted.

2.3.1.3 Large Meter Testing (Three-Inch and Larger)

The SSWD, Folsom, PCWA, and SJWD currently test large meters on fixed schedules. The SSWD, Folsom, PCWA and CoS currently own and operate large meter test equipment (July 2022). Only the SJWD currently tests all meters on an annual basis. The cost of large meter testing is justified through its role in enabling Consortium agencies to maintain the accuracy of their deployed meters. Agency data indicates that deployed meters generate sufficient revenue (on average) to justify annual testing.

Recommendation 3 – Large meters should be selected for annual testing per a recommended standard operating procedure provided in this Final Report. If, in the first couple years, the cost justification for annual testing shows that the meter can be shifted to a bi-annual program, then agencies can adjust accordingly. Conversely, if agencies elect to use more infrequent test intervals (i.e., three years or more), then the methods described here can be used to determine if more frequent intervals (such as one or two years) should be adopted as recommended here.

2.3.2 Consortium Opportunities

There are two test benches among Consortium agencies that are recommended for joint meter testing. The CoS facility can test up to 12 small meters in parallel and larger meters up to 16 inches in size. They can also test up to five 1.5- or two-inch meters at a time. The Folsom facility can test up to eight meters in parallel and larger meters up to two inches in size. Given its size and capabilities, the CoS test facility would be a good option for the CHWD, SCWA, and SSWD to test their small and intermediate meters.

As of July 2022, CoS now offers meter testing for outside water agencies using its Mars meter test bench at South Area Corporation Yard. The testing fee is based on size and type of meter.

On-site testing can be performed either by agency staff or a third-party contractor. Several Consortium agencies employ the use of third-party contractors for meter testing. It is recommended that the Consortium develop a qualified vendor list and employ the on-site testing standard operating procedure provided in this memorandum. This will provide agencies with consistent testing and possibly better pricing.

Consistent information management processes for meter test data and deployed inventory will also enable agencies to share and benefit from one another's data. A consistent database is recommended among Consortium agencies that could potentially be linked together for comparison of meter accuracy test results associated with age, total registered flow, model, type, and other factors.

Consortium agencies are recommended to establish annual meter testing programs to better understand real water losses by both volume and value (costs) and to make informed decisions about when to replace deployed meters (Table 1, Annual Meter Testing Quantities and Costs by Agency for Recommended Sampling). All agencies need to collect additional data to develop statistically significant relationships between accuracy, age, and total registered flow. This will enable agencies to develop and demonstrate efficient small meter replacement schedules that minimize revenue lost through meter inaccuracy relative to both the cost of meter testing and meter replacement. For more information, see Technical Memorandum No. 3.

Table 1. Annual Meter Testing Quantities and Costs by Agency for Recommended Sampling

Agency	Small Meters		Intermediate Meters		Large Meters	
	Annual Test Count	Estimated Annual Cost	Annual Test Count	Estimated Annual Cost	Annual Test Count	Estimated Annual Cost
CoS	383	$5,021.56	1,799	$242,540.57	1,211	$286,678.00
SSWD	381	$5,046.13	607	$116,196.16	224	$142,086.40
SCWA	383	$7,021.67	762	$95,762.86	167	$73,480.00
Folsom	378	$6,930.00	214	$26,902.86	86	$37,840.00
CHWD	377	$6,911.67	297	$37,274.29	43	$18,920.00
PCWA	381	$6,832.60	244	$30,005.03	58	$24,748.00
SJWD	371	$6,618.64	84	$10,184.09	14	$5,994.24

Notes: CHWD = Citrus Heights Water District; CoS = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA = Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

2.4 Long-Term Planning (Technical Memorandum No. 4)

Long-term planning helps water agencies effectively allocate the resources they need to monitor, assess, replace, operate, and maintain their meters and associated components in an efficient and cost-effective manner. The purpose of Phase 4 was to provide recommended meter replacement strategies, meter reading strategies, and financial forecasts for Consortium agencies.

2.4.1 Meter Replacement Conclusions

A meter replacement strategy informs long-term utility asset and business planning. It provides a basis for anticipating and quantifying the timing and amount of meter investments needed to meet an agency's desired level of service. Meter replacement criteria serve as a tool to identify meters for replacement and when replacement should occur. Meter test data provided primarily by the CoS was analyzed to develop recommendations for Consortium small meter replacement criteria. Intermediate and large meters are recommended to be replaced based on the results of a scheduled test rotation (see Technical Memorandum No. 3).

The results indicate that small (mechanical) meter accuracy decreases primarily at low-flow rates with minimal changes at intermediate- and high-flow rates as meters age. The analysis also indicates that total registered consumption is a more significant determinant of changes in accuracy than its deployed age. Consortium agencies are recommended to replace between four and five percent of small meters per year, prioritizing (1) meters that have more than five MG of total registered consumption or (2) meters that are more than 25 years old. Consortium agencies are recommended to replace or rebuild 10 percent of intermediate meters per year. Large meters should be rebuilt based on the results of regularly scheduled testing (see Technical Memorandum No. 3) (Table 2, Annual Meter Rebuild/Replacement Summary).

Table 2. Annual Meter Rebuild/Replacement Summary

Meter Type	Replacement Factors	CHWD	CoS	PCWA	SCWA	SJWD	SSWD	Total
Small (1-inch and smaller)	Target Annual Replacement (4%–5%)	798–998	4,876–6,095	1,433–1,791	2,003–2,504	412–515	1,466–1,832	**10,988–13,735**
Intermediate (1.5- and 2-inch)	Estimated Annual Rebuild/Replacement (10%)	119	719	97	304	27	244	**1,510**
Large (3-inch and larger)	Estimated Annual Rebuild/Replacement (7.5%)	7	182	9	26	2	32	**258**

Notes: CHWD = Citrus Heights Water District; CoS = City of Sacramento; PCWA = Placer County Water Agency; SCWA = Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

2.4.2 Meter Reading Conclusions

Consortium members are recommended to evolve their meter reading systems collaboratively moving forward to potentially secure economy-of-scale pricing for hardware and to share the O&M of network hardware. Currently, Consortium agencies employ several different meter reading systems. Propagation studies were requested from multiple AMI vendors based on the information provided in Technical Memorandum No. 2. Badger, Neptune, Sensus, and Zenner submitted propagation studies, which revealed that the Badger ORION cellular and Sensus FlexNet systems are capable of providing benefits at the Consortium level and within a relatively short time frame (because they are already widely deployed across the Consortium). Both systems offer comparable capabilities for their managed networks (including customer portals and data analytic platforms). It is also important to clarify that each agency's final decision on the lowest cost alternative will depend on formal bid processes. For more information, see Technical Memorandum No. 4 and the list below:

- The **Sensus FlexNet platform** can cover the Consortium-wide service area with fewer data collection units than the other evaluated systems. The advantage of a Consortium-level network configuration is that the endpoints have a greater range and, therefore, require less infrastructure to cover multiple agencies, which could provide a less costly and more redundant network compared with alternative systems.
- The **Badger ORION platform** offers flexibility in the speed at which agencies can deploy the system. This is because it employs existing commercial cellular networks for collecting meter data and does not require additional investments in network data collection hardware. This flexibility is an important advantage of this system over the alternatives. For example, it can be deployed for a portion of an agency's meters. It should be noted that a cellular solution has annual costs for cellular service that can be significant depending on the system size

2.4.2.1 Financial Analysis Conclusions

Agency-specific financial scenarios were developed for a 15-year planning period. The analysis estimates the annual capital and O&M costs for meter hardware replacement and meter reading. Badger ORION cellular, Sensus FlexNet (NaaS), and Sensus (SaaS) meter reading scenarios were compared with business-as-usual scenarios for each agency.

Table 3, Estimated Annualized Meter and Endpoint Replacement Costs, shows projected annualized hardware costs for each agency over the 15-year planning period, assuming best-case unit pricing as a result of joint (Consortium) purchasing arrangements. The key assumption for meters is that, collectively, agencies will be able to secure at least the same pricing that has already been quoted to at least one Consortium member without minimum purchase requirements. However, this should be considered a conservative estimate. Potential Consortium pricing for endpoints was provided by the vendors for the purpose of the Study. The results of a bulk public bidding process may provide better cost savings than what is indicated in Table 3.

Table 3. Estimated Annualized Meter and Endpoint Replacement Costs (2019 dollars)

Item	CHWD	CoS	PCWA	SCWA	SJWD	SSWD
Meters	$274,865	$2,011,466	$485,815	$1,127,830	$171,301	$537,785
Endpoints	$275,647	$1,289,429	$326,687	$798,693	$119,438	$223,616
Sales Tax	$24,256	$151,384	$25,716	$69,298	$14,284	$35,549
Material Recycling Fee	$7,918	$75,276	$7,608	$26,392	$3,295	—[1]
Total Hardware Costs	**$582,686**	**$3,527,555**	**$845,826**	**$2,022,213**	**$308,318**	**$796,950**
Potential Cost Savings	**$324,126**	**$0**	**$12,670**	**$596,567**	**$92,410**	**$33,544**

Notes: CHWD = Citrus Heights Water District; CoS = City of Sacramento; PCWA = Placer County Water Agency; SCWA = Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

1 The SSWD has incorporated the material recycling fees into its contracted hardware purchase price.

2.5 Implementation (Technical Memorandum No. 5)

The purpose of Phase 5 of the Study was to use conclusions and recommendations from prior phases to develop Implementation Plans for each participating Consortium member.

2.5.1 Individual Agency Plans

Harris worked with support agency staff to evaluate the tradeoffs for different meter replacement phasing strategies and to determine an optimal time frame to phase in next generation meter technologies. The evaluation incorporated findings from the previous phases, including both technical and financial factors. Additionally, the phasing strategy incorporated financing options and the organizational changes required.

A Phase 4 Implementation Plan for each individual participating agency was created for distribution, discussion, and review/comment before finalization. Contents of each Implementation Plan include the following:

- A detailed description of the key elements that underpin the implementation strategy, including all relevant hardware, software, staffing, and financial elements
- A detailed meter replacement and meter reading implementation strategy, including piloting, for each agency and the Consortium
- A full analysis of Consortium-level opportunities for efficiency and the policies, programs, and tasks necessary to implement them
- A full assessment and Implementation Plan for meter replacement phasing at the individual agency and Consortium level
- An implementation schedule and funding program for each participating agency and consideration of individual agency metering needs, wants, internal capabilities, available staff, financial resources, Consortium opportunities, and plan risks and unknowns

Each Implementation Plan provides analysis and recommendations for the following activities:

- Meter testing
- Meter rebuilding or replacement
- Meter reading
- Meter data management

2.5.2 Consortium-Level Plans

The Study has identified numerous opportunities for closer collaboration between Consortium agencies. These opportunities can be realized and honed programmatically over time. Consortium agencies are recommended to co-develop a subscription fee-based Regional Meter Asset Management Program (R-MAP) through the RWA, of which they are already members. Other (non-Consortium) RWA members should be encouraged to join as well to secure greater economy-of-scale pricing for both bulk hardware purchases, as well as lower subscription fees. The R-MAP program will offer the following three areas of collaboration at start-up; however, the program is intended to evolve over time and provide additional benefits as it matures:

- **Regional Bulk Purchasing –** The RWA will establish and maintain a joint meter specification and carry out a public bidding process for the bulk purchase of meters, meter repair parts, accessories, and meters. The RWA will act on behalf of agencies for the bulk purchase of meters, endpoints, meter repair parts, or other types of hardware typically used on a municipal water supply system and meeting the established joint specification(s).
- **Meter Testing Agreement Assistance –** Willing member agencies (such as the CoS) with in-house bench testing facilities and capabilities (provider) will provide bench testing as a fee-based service to other member agencies that lack these capabilities in-house (recipient). It is expected that providers will offer bench testing services "at cost" to recipients so that they may recover the labor and facility expenditures related to the testing that it provides as a service. The RWA anticipates that these bilateral arrangements will be developed per the specific procurement processes in place for each provider. The purpose of this effort is to provide member agencies with a scoping document that includes a set of parameters for bilateral bench testing services to be used by member agencies. A single set of parameters will offer consistency to member agencies across the region.
- **Technical Assistance –** The RWA will establish and maintain a list of qualified vendors for field-based meter asset management activities, including (1) in-place meter testing (meters 1.5-inches and larger), (2) meter and meter box maintenance/rebuilds, (3) meter replacements, and (4) endpoint replacements. Participating agencies will be provided a list of approved vendors.

2.5.3 Implementation Conclusions

The results from Phase 4 of the Study illustrate that several Consortium members expect to significantly expand their meter programs within the next five years. Many agencies will embark on significant replacement of existing water meters and installation of new or next generation data endpoints to improve data collection. Meanwhile, as agencies make significant metering investments, meter testing should be expanded by many of the Consortium members to improve data analysis and decision-making regarding meter precision and replacement.

Given the expanded volume of meter-related coordination, purchasing, testing, and technical assistance needed, analysis shows that consolidating and coordinating efforts among participating agencies could lead to significant cost savings while also reducing burden on individual agency staff performing duplicative activities.

The recommendation from Phase 4 is for the Consortium to establish a regional meter program to realize these cost saving and coordination benefits. The RWA appears to provide an excellent forum for implementing such a program.

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Section 3 Consortium-Level Implementation Program

Based on the implementation guidance developed for the Consortium members, several opportunities to collaborate are apparent. Three broad areas for further focus and development are as follows:

- **Bulk purchasing:** Coordinated and pooled purchasing of like metering products, such as meters, endpoints, and accessories or spare parts, to obtain volume discounts from supplier.
- **Bench testing:** Use of bench testing equipment and available capacity of some Consortium members to assist those lacking such bench testing equipment.
- **Technical assistance:** Provision of meter support services that can be shared among Consortium members to reduce agencies having to perform the same work for themselves.

In early 2021, a survey of Consortium members found that they are most interested in participating in several Consortium-level activities as summarized in Table 4, Consortium Member Interest in Regional Meter Program Support.

Table 4. Consortium Member Interest in Regional Meter Program Support

	Bulk Purchasing			Bench Testing	Technical Assistance	
	Meters	Endpoints	Accessories		Qualified Vendors	Standard Operating Procedures
CHWD	X	X	X	X	X	X
CoS	X[1]	—	X	X	—	X
Folsom	X	—	X	X	—	X
PCWA	X	—	X	X	X	X
SCWA	—	X	X	X	X	X
SJWD	X	X	X	X	X	X
SSWD	X	X[2]	X	X	—	X

Notes: CHWD = Citrus Heights Water District; CoS = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA = Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Based on survey and discussions from December 2020 to March 2021.

[1] CoS: Currently under purchasing contract through 2027.

[2] SSWD: Currently under purchasing contract through 2028.

3.1.1 Potential Consortium Member Benefits

As part of the Implementation Plan development for each participating Consortium member, the potential benefit of using Consortium-level support and resources was estimated. Table 5, Benefits of Consortium-Level Meter Services, lists the range of benefits that could be realized through these Consortium-level services. An estimated $17 million could be saved through bulk purchasing by at least four of the Consortium members, averaging approximately $1 million per year over 15 years. Meanwhile, regional support to help Consortium members handle more than 2,000 recommended additional meter tests per year could help reduce testing costs and coordination, thus promoting more testing (and greater accuracy). Lastly, technical assistance coordinated regionally could reduce potential duplicative efforts rather than each agency performing its own vendor qualification and developing its own standard operating procedures.

Table 5. Benefits of Consortium-Level Meter Services

Types of Support	Estimated Benefits
Bulk Purchasing	**Cost savings over 15 years:** CHWD: ~$3 million PCWA: ~$2 million SCWA: ~$9 million SJWD: ~$1.4 million **Total: ~$15.4 million**
Bench Testing	**Additional meter tests planned per year:** CHWD: >600 PCWA: >200 SCWA: >1,000 SJWD: >400 **Total: >2,200**
Technical Assistance	Save agency staff time (undetermined) qualifying vendors and preparing standard operating procedures for testing and maintenance.

Notes: CHWD = Citrus Heights Water District; PCWA = Placer County Water Agency; SCWA = Sacramento County Water Agency; SJWD = San Juan Water District

The actual benefits of these services will need to be evaluated on an ongoing basis, especially in light of exponential price increases in nearly all purchasing categories in 2021 and 2022.

3.1.2 Proposed Consortium-Level Program Elements

Based on interest from Consortium members, the following four elements are proposed to form the basis of a regional program: (1) coordination, (2) purchasing, (3) testing, and (4) technical assistance. Given that the potential cost savings of joint purchasing is the most significant benefit of the program, it is recommended that the program first start with purchasing and then follow with testing and technical assistance.

3.1.2.1 Coordination

Coordination would occur through execution of a project agreement by RWA member agencies that wish to participate in the program. The project agreement will describe the support services to be provided, the estimated cost for the RWA to provide these services, and the subsequent cost share for each participating agency.

Each committed agency will participate on a regional water meter committee that will oversee the planning and execution of and budgeting for the regional meter program. The committee will also be responsible for proposing recommendations for improvements, additions, and/or modifications to the regional meter program over time.

3.1.2.2 Purchasing

At this time, the assumption is that material to be purchased jointly will include meters, endpoints, meter accessories, and spare parts. Purchasing support will entail ongoing tracking of member agencies' purchasing needs and upcoming plans. With this information, program staff will recommend joint purchasing opportunities, prepare specifications and purchasing documentation, and negotiate pricing with vendors. Program staff will also coordinate material deliveries with participating agencies along with payment and invoicing.

3.1.2.3 Testing

Based on the findings of the Study, meter testing for several Consortium members should be expanded significantly to provide a greater degree of confidence in meter data and to improve timing for replacement of aging meters. Testing support provided by the regional program will entail working with participating agencies to review their proposed testing programs, determine volume and timing of additional testing, coordinate available bench testing capacity with regional partners (e.g., CoS and Folsom), develop/confirm bench testing protocols and standards, and facilitate testing agreements between agencies.

3.1.2.4 Technical Assistance

As the meter replacement and testing programs of several Consortium members are expanded, each agency will have a greater need for technical assistance. This assistance may include meter replacement and repair, endpoint installation and data integration, and field testing. The regional program will survey participating agencies regarding their upcoming technical needs and develop a technical assistance program to provide support. For example, support may include the coordination and development of standard operating procedures or vendor pre-qualification and price negotiation.

Section 4 Overall Study Conclusions

As this Final Report marks the completion of the MRP Study, valuable outcomes and conclusions can be highlighted regarding both water meter technology and infrastructure and the value of a collaborative approach to water meter implementation at the regional scale. Three of particular note are:

- **Structured approach promoted more effective knowledge sharing and opportunity creation.** While agencies frequently collaborate with each other in "one-off" transactions or opportunities, a structured approach like the MRP Study allowed more agencies to collaborate and go deeper in their evaluation, creating greater benefit for each as well as the region as a whole. An ongoing structured approach should continue as the value of "best practices" in water meter implementation only grow in importance.
- **Shared contributions have led to enhanced mutual accountability.** The sharing of water meter technical information and processes among consortium members has contributed to building and sustaining relationships between both individuals and water agencies.
- **Support best practices in agency economics.** The MRP Study not only illustrated, but calculated, the potential cost savings associated when efforts are combined to procure meter equipment, testing capabilities, and other services common to each consortium members.

Appendix A. Technical Memorandum No. 1 – Agency Assessment

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METER REPLACEMENT PROGRAM PLANNING STUDY

TECHNICAL MEMORANDUM 1, INDIVIDUAL AGENCY ASSESSMENT

December 13, 2019, Submission Version

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1. STUDY OVERVIEW

1.1 Introduction

The Meter Replacement Program Planning Study (The Study) presents a unique opportunity for neighboring water agencies in the greater Sacramento area to explore potential benefits of working together. Consortium agencies understand that the utility of the future will operate in a different paradigm; one that is largely built on public and stakeholder trust, along with cooperation and collaboration with adjoining entities with common interests. The purpose of The Study is to:

1. Develop a strategy for the replacement of the first generation of water meters for some participating water agencies or next generation for others, and
2. Determine the feasibility and a strategy, as appropriate, for long-term, full or partial integration of meter replacement programs for participating water agencies.

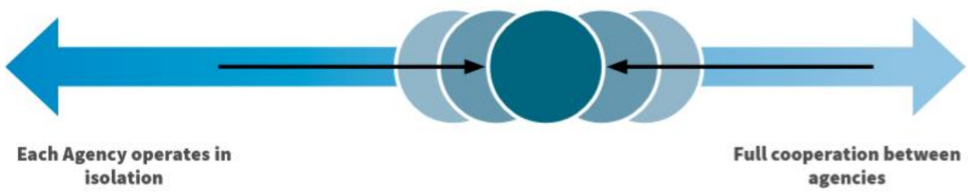


Figure 1.1, The purpose of The Study is to determine how participating agencies can sensibly integrate their meter programs over time

Agencies participating in The Study include:

- Citrus Heights Water District (CHWD)
- City of Folsom (Folsom)
- Placer County Water Agency (PCWA)
- City of Sacramento (City of Sac)
- Sacramento County Water Agency (SCWA)
- San Juan Water District (SJWD)
- Sacramento Suburban Water District (SSWD)

Agencies that are members of the Water Meter Replacement Program Consortium but are not directly participating in The Study include:

- Carmichael Water District (CWD)
- Golden State Water Company (GSWC)
- Orange Vale Water Company (OVWC)
- Regional Water Authority (RWA)

Meter programs are comprised of a collection of hardware, software, and skilled professionals that are organized into an integrated set of systems (i.e. data collection, meter reading, billing, operations, and maintenance). Fundamentally, water meters are used to obtain information on the flow of water at some location in a water distribution system. The purpose of this information has historically been to support customer billing. Thus, the water meter is often considered to be ‘the cash register’ of the water utility. In recent years, this data has come to serve additional important purposes, including leak reduction, water auditing, regulatory compliance, demand management, and operational efficiency. Water meter programs have evolved over time to serve these various functions. The methods for collecting and using meter data have become more advanced and automated. These changes require skill sets to evolve with them.

The meter program for any individual agency will be unique as a result of the specific context, priorities, and needs of the community it serves. First, The Study will first provide guidance on opportunities to match technologies and business models with the specific context of each agency. Secondly, The Study will look across agencies to identify where contexts and interests align. These will be the areas in which The Study will explore specific opportunities for collaboration between agencies. Some possible areas of meter program collaboration that will be investigated over the course of The Study include operations and maintenance of different hardware and software, installation, testing, customer service, leak detection, and compliance monitoring systems.

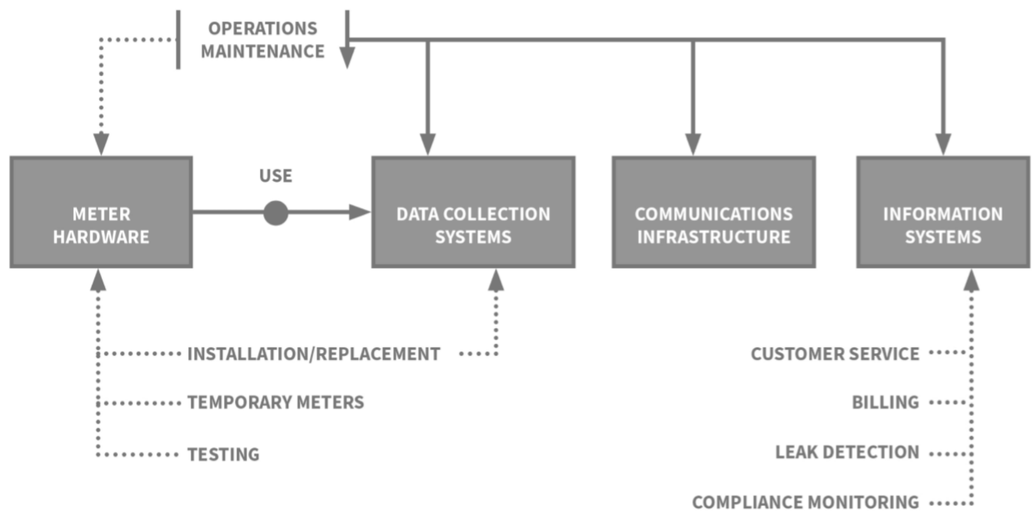


Figure 1.2, Elements of a meter program, including the efforts required to operate, maintain, and optimize the systems as well as ancillary efforts such as customer service, billing, and compliance monitoring.

The Study will explore several specific opportunities for sensible meter program integration, including:

- Equipment – sharing testing or other high-value items
- Staffing – a deeper and more consistent pool of relevantly skilled staff in the Sacramento area
- Capital – sharing large capital investments such as communications towers
- Common software platforms – greater potential for collaboration
- Lessons learned – higher performance at the regional scale
- Redundancy – increased collaboration making it easier to react and respond to risk
- Shared inventory – cost savings and quicker access to inventory

The consulting team is comprised of the following firms:

- Harris and Associates – The team lead with project management and financial analysis responsibilities
- M.E. Simpson and Company – Providing water meter hardware, software, and testing expertise
- Isle Utilities – Providing meter technology expertise
- Laura Mason Smith – Providing public outreach expertise for CHWD customer engagement

1.2 Overview of Study Phases

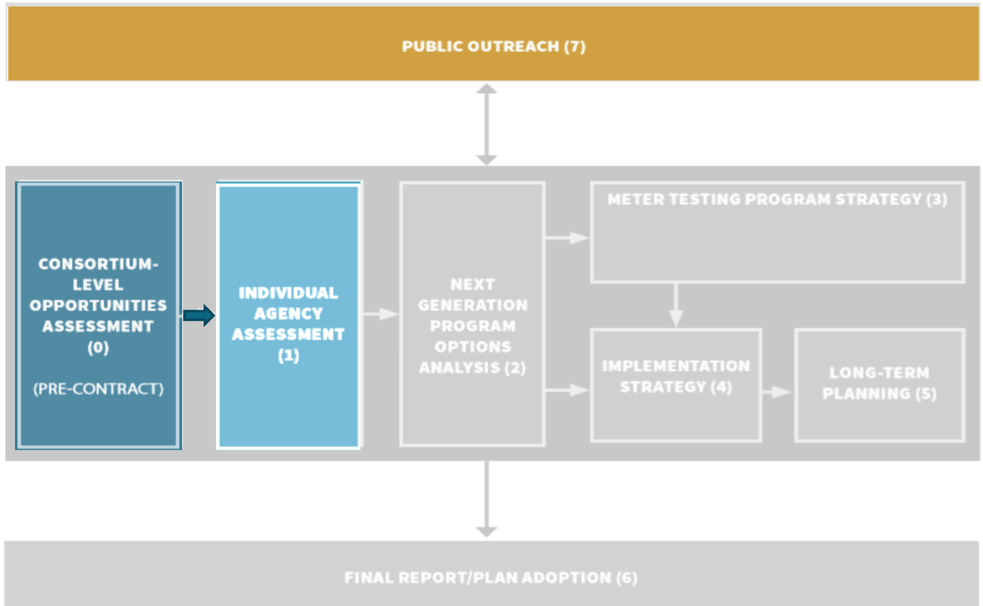


Figure 1.3, The Study is comprised of seven phases. As shown above, this technical memo (#1) pertains to work completed under Phase 1: Individual Agency Assessment.

The Study is organized as follows, with a technical memo accompanying each of the first six phases:

Phase 0 – A pre-contract process for soliciting Study participation by consortium agencies by understanding the needs and priorities of each participating agency's meter program.

Phase 1 - An investigation of each participating agency's current inventory and a financial assessment for each participating agencies' deployed meter fleet. Data collection/presentation will be assembled into a standardized format developed by the consultant for participating agencies.

Phase 2 - An investigation of different options in meter technology, vendors, and accompanying meter specifications. This will include a detailed evaluation of the top 3 to 5 meter vendors according to criteria set forth by participating agencies.

Phase 3 – A review of each agency's current water meter testing program and available water testing facilities (in-house and regional). Opportunities for consortium-level collaboration will be researched in this phase to identify the feasibility of joint meter testing options.

Phase 4 - A blueprint for action that participating agencies will employ to guide policies, programs, projects, and tasks associated with a shift towards meter program collaboration. The Implementation Strategy will be developed as a "To-Do List" for policy leaders and program managers to follow and implement the recommendations of The Study.

Phase 5 – Development of tools and a strategy for planning for future generations of meter replacements, both at the individual agency level and at a Consortium level. This will include replacement timing/phasing, financial implications, and best practices.

Phase 6 – A compilation of the entire set of Technical Memorandums (1-5) plus an executive summary.

Phase 7 – Ongoing support for public engagement over the course of The Study.

2. PHASE 1 INTRODUCTION

2.1 Purpose

The purpose of Phase 1 was to collect detailed information as a basis for subsequent phases of The Study. The Harris Team (The Team) collected information related to each participating consortium agency's meter program and organized it in terms of each agency's current meter inventory, meter reading platforms, software and data systems, and cost information.

2.2 Overview

The Phase 1 Scope of Work included the following sets of activities:

The Team evaluated each participating agency's meter program. A data request was submitted to consortium agencies on August 13, 2019. Initial sets of data were provided to the Team by participating agencies between August 23 and September 13. Data analysis was initially performed between August 23 and September 16. Additional revisions were performed between September 23 and October 4 based on one-on-one interviews with participating agencies. This information was used to complete the following:

A. ***Assemble a meter inventory for each agency***
B. ***Assess the condition of each agency's deployed meter inventory***
C. ***Assemble an inventory of meter software and data systems for each agency***

The Team also investigated the cost basis of each agency's meter program. Cost information was incorporated into the data request described for Tasks A-C.

D. ***Inventory the cost data for each agency's meter system***

The Team conducted individual meetings with each participating agency in order to verify submitted data and collect additional qualitative information. Interviews were conducted between September 23 and October 10.

E. ***Conduct one-on-one interviews***

The Team developed written documentation of all Phase 1 activities, data, and findings as a basis for subsequent phases of The Study. The first draft was submitted to participating agencies for review on October 25. Feedback was provided by participating agencies from October 28 through November 8. A second draft was circulated for review from November 25 to December 6. The final draft was submitted to participating agencies on December 13, 2019.

2.3 Methodology

Meter Inventories

The Team prepared an Excel spreadsheet template, which was provided to participating agencies for completing individual, agency-specific deployed meter inventories. This request was for a single electronic spreadsheet file of individual water meter attributes. Each water meter had an individual spreadsheet row, and each attribute was provided in a specifically labeled column. The requested format is indicated below. As shown, no customer specific information was included in the data.

Deployed Meter Inventory Template Headers (Appendix A)

Meter ID	Manuf.	Model	Type	Size	Install Year	Units of Use	No. Reg. Digits	AMR/ AMI	Cust. Class	2016 Use	2017 Use	2018 Use	2019 Use	Total Use Since Install

Meter Condition

In addition, available meter accuracy test data was collected in an Excel spreadsheet template in order to provide additional information regarding the condition of each agency's deployed meter inventory. Each test has an individual spreadsheet row, and each attribute was provided in a specifically labeled column. Data was requested for small and large meters in two separate electronic files. The requested format is indicated below.

Meter Accuracy Test Template Headers (Appendix A)

Meter ID	Manufacturer	Model	Type	Size	Test Date	Low Flow ACCUR.	Int. Flow ACCUR.	High Flow ACCUR.	Flow Distribution	Weighted ACCUR.	Notes

The process followed by the Team in evaluating the provided deployed meter inventory information included the following steps:

1. Compute 2018 Usage by Size (CCF, GAL)
2. Compute Typical Meter Accuracy by Size for Small Meters
3. Tabulate Consortium Level Summary for All Agencies
4. Analyze Data and Discuss Findings

Meter Cost

The Team developed an inventory of costs associated with each agency's meter program in order to compile a baseline cost per meter for each agency that would be used to assess future meter program investments. The methodology included the preparation of an Excel-based cost data template that collected available cost and other meter-related data from each agency historically (last 3 years) and prospectively (budget and next 3 years). Key assumptions in this approach were that staffing related costs were the most significant driver of meter-related costs and the organization of meter resources, i.e. staff, was impacted by the choice of meter technology. Therefore, efforts in this phase were focused on understanding the current (2019) and to some degree, historical, meter related functions, organization and associated costs.

A copy of the template can be found in Appendix A. The following information was requested:

1. Number of meters by year
2. Meter functions and organizational information
3. Number of staff working on meter-related tasks
4. Staff and benefit costs for these staff
5. Meter purchase costs
6. Meter testing costs
7. Meter billing costs

8. Meter reading costs
9. Other meter-related costs as specified by agency
10. Meter cost funding sources
11. Meters installed and replaced annually
12. Most recent rate study

Data responses were provided by all agencies and the costs were reviewed in order to provide a preliminary comparison of various cost categories.

Using the provided data responses, preliminary cost ratios were developed for each agency for 2019 including:

1. Monthly cost per meter
2. Monthly cost (less meter purchases) per meter
3. Annual cost (salary and benefits) per staff
4. Cost per meter compared to monthly fixed charge

There were challenges to this approach in that comparison of these preliminary meter cost ratios across the agencies yielded a wide range of values. The range of differences can be attributed to several factors including:

1. **Meter Technology** - The differences in meter technology among agencies, ranging from manual reads to Automatic Meter Reading (AMR) to Advanced Metering Infrastructure (AMI), led to differences in staffing and related operations costs. Developing "apples to apples" performance and cost metrics was difficult given the high-level nature of the analysis. The data used to develop ratios did not have the needed level of detail to normalize data. Therefore, it was determined that more data will be collected in the subsequent phases.
2. **Meter Resources Organization** - Meter resources in the form of staff organization were reviewed through organization charts provided by some agencies and FTE meter related staffing analyses provided by other agencies. The organizations also reflected decisions around the use of contract operations mainly in the areas of meter reading and meter testing. These two areas will be further investigated in subsequent phases and the data collected in those phases will allow for a more detailed analysis of performance and cost metrics.
3. **Indirect Costs** - Indirect costs were reported depending on the agency's organization either as a stand-alone water district or a department in a city or county. Agencies that were part of a larger organization tended to report indirect costs that supported their water departments such as HR, IT and legal costs. These costs were generally not reported by stand-alone water districts. Depending on how subsequent data analyses proceed with the collection of detailed data, the Team will decide whether indirect costs need to be looked at further.
4. **Timing of Meter Purchases** – 2019 data was the most complete for all agencies and therefore was used to develop the baseline. Further, some of the meter purchase data included other costs such as meter installation and consultant costs which could not be extracted from the data provided. As with the other cost categories, The Study will be focusing on specific cost-related elements in subsequent phases and will determine at that time how to address this cost element. For example, another cost element that will likely impact meter purchase is each agency's procurement policy which has not yet been explored.

It was determined that further analyses and refinement of the data was needed before updates to these cost ratios could be prepared. For this technical memo, the focus of the cost inventory reporting is to capture the agency-specific cost elements for analysis in other phases of The Study.

3. DEPLOYED METER INVENTORY

The following tables are presented to portray data submitted by the seven consortium agencies by specific category. Categories of data are presented by meter size and include meter count, average meter age, meter age groups, 2018 usage, meter manufacturer, meter type, meter register number of digits, and calculated small meter accuracy using Utah State University (Utah State) research equations for meter age.

3.1 Meter Count

Table 3.1 indicates the existing meter inventory by size for each of the consortium agencies. Meter population varies from about 10,000 services for SJWD to over 130,000 for the City of Sacramento. The predominant meter size for the consortium members is 1-inch, primarily driven by the State of California requirement to install fire sprinklers in new single-family residences. Combined fire sprinkler and peak domestic water demand warrant a one-inch water meter due to its Safe Maximum Operating Capacity (SMOC) of 50 gallons per minute (gpm). Prior to that, the common meter size for residential connections was 5/8 or 3/4-inch, with a SMOC of 20 gpm. This smaller flow capacity is sufficient to provide typical single-family residential peak domestic use as well as variable land irrigation use. Two participating agencies have predominant meter sizes below 1-inch. PCWA has a predominant meter size of 5/8-inch and SSWD has a predominant meter size of 3/4-inch. To satisfy current state fire flow requirements, both agencies install a minimum of 1-inch meters for new single family residences.

One issue that the fire sprinkler requirements have created is flow requirements for fire protection and the proper sizing of water meters for usage. For example, the amount of customer water passing through a meter impacts the meter accuracy and the amount of unmeasured flow. Low flow accuracy is very different for a 1-inch meter compared to a smaller meter, where the 1-inch will likely be less accurate at low flows. Further detail on this topic is explained in Appendix D. A 1-inch mechanical water meter is likely to have more unmeasured flow than smaller sizes in that the meter is designed to be accurate in accordance with American Water Works Association (AWWA) guidance at 3/4 gpm (the 1-inch low flow accuracy test rate). AWWA guidance for meter accuracy testing is in Manual M6 *Water Meters-Selection, Installation, Testing, and Maintenance,* Fifth Edition (2012).

Table 3.1. Meter Count by Size and Agency

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
0.625"	66	4,598	185	29,154		2,442	40
0.75"	1,828	236	213	2,129		33,697	2,396
1"	16,789	15,620	121,494	4,819	50,073	3,649	7,657
1.5"	573	228	3,415	606	1,687	1,026	301
2"	613	704	3,779	370	1,360	1,411	164
3"	42	101	1,123	83	249	310	24
4"	21	53	886	19	64	104	4
6"	12	7	266	12	18	27	
8"	10	4	131	1	3	5	
10"	1	6	15			1	
12"		1					
TOTAL	19,955	21,562	131,507	37,202	53,454	42,675	10,586

Note: The highlighted fields indicate the predominant meter size for each agency

3.2 Meter Age

Table 3.2 indicates the average ages of water meters by size for the participating agencies. The City of Folsom has the youngest meter inventory average age at 7.5 years. The oldest inventories are found in CHWD, SJWD, and SCWA. Age is often a criterion for meter replacement, as is cumulative volume through the meter, since manufacturer warranties for meter accuracy are based on these two factors. The age data below are averages for each size and do not indicate the meter count by size. Average meter age varies by size, as does manufacturer warranty. Smaller sizes have longer meter accuracy warranties. Attention should be given to the average age of the predominant meter size (which is highlighted for each agency using the data from Table 3.1). For example, CHWD should focus on the 1-inch meters, and PCWA should focus on 5/8-inch meters. Since only averages are indicated, numerous meters exist with many more years in service. The electronic databases these data are derived from allow sorting by age for each meter size. See further discussion of meter accuracy and age relationships in Appendix D.

Table 3.2. Average Age of Meters for Each Meter Size (inches) by Agency

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
0.625"	10.8	13	21	11.8		6.1	23.3
0.75"	15.6	7	18.5	11.2		8.8	20.7
1"	16.8	9	6.6	5.6	13.3	10.3	14.4
1.5"	20.7	4	5.7	12.8	10.1	12.8	17.9
2"	20.3	1.5	6.7	11	14.3	15	17
3"	9	1	8	10.4	13.8	9.9	11.1
4"	14	9	7.1	9.2	13.6	9.7	11.3
6"	13.4	9	8.3	12.3	15.9	5.1	1
8"	17.4	16	5.9	11	18	11.2	
10"	10	3	8.1			12	
12"		3					
AVERAGE	14.8	7.5	9.6	11.0	14.1	9.2	14.6

Note – The highlighted fields indicate the predominant meter size for each agency

3.3 Meter Use

Consortium agencies provided multiple years of individual meter use information. The latest complete year of 12-month usage is 2018. For 2018, total water usage was provided and analyzed for each meter size and each agency. Total water usage for 2018 and use per service connection for all agencies are shown and compared below in Table 3.3.1.

Table 3.3.1. Meter Use (2018) by Agency

	2018 Use (1000 Gal)	Total Meter Count	Use per Connection (Gal/Year)
CHWD	3,063,070	19,955	153,499
FOLSOM	5,099,634	21,562	190,819
CITY OF SAC	33,215,840	131,507	252,578
PCWA	11,770,007	37,202	316,381
SCWA	8,691,555	53,454	203,669
SSWD	8,760,224	42,675	205,278
SJWD	3,302,917	10,586	312,008

The agency with the lowest 2018 water use per connection is CHWD. The agency with the highest 2018 water use per connection is City of Sacramento. Usage per connection is shown to characterize type of development and differentiate large lot residential irrigation use. Higher use per connection indicates a greater number of high-demand customers. This is an increasingly important metric to track in California as a result of evolving water conservation standards. It is also important for determining water loss estimates (real and apparent).

Table 3.3.2 presents a summary of predominant meter size with the portion of total 2018 usage for each agency. Five of the agencies indicate primary water usage by single family residents, represented by small, residential-sized meters. The City of Sacramento and SSWD have the broadest range of use by meter size and a lesser percentage of smaller meter sizes, indicating a higher portion of commercial demand and multi-family residential demand. For instance, the smaller gal/connection for CHWD reflects their smaller parcel size compared to SJWD and PCWA, which have larger parcels and increased residential irrigation demand. Understanding how total water use is distributed across different types of users (and meter sizes) has implications for how agencies will manage demand and respond to water conservation regulations.

Table 3.3.2. Percentage of Total Use (2018) by Predominant Meter Size by Agency

	Predominant Meter Size	Percent of Total Use
CHWD	1-inch	79.8
FOLSOM	1-inch	65.0
CITY OF SAC	1-inch	34.6
PCWA	5/8-inch	52.7
SCWA	1-inch	69.6
SSWD	3/4-inch	48.5
SJWD	1-inch	72.3

Distribution of 2018 water usage by meter size may be used to determine a system-wide meter accuracy for auditing purposes if estimates of accuracy are provided for all meter sizes.

3.4 Meter Type

Table 3.4 indicates the agency-specific meter type for all meter sizes. This information was downloaded from the agency billing system. For example, Positive Displacement (PD) meters are not manufactured in sizes larger than 2 inches. The following types of meters are included in the inventories of participating agencies:

- Positive Displacement (PD) – A mechanical meter type consists of either a nutating disc or oscillating piston to measure flow. A nutating disc meter has a disc mounted to a central ball. When fluid enters the chamber, it causes the disc to wobble (nutate). An oscillating piston meter uses a precision-machined chamber containing a cylindrical piston that oscillates as liquid flows through it. The nutations and oscillations are directly transferred to the register, which is calibrated to units of flow.
- Electromagnetic (EM) – This meter uses electromagnetic principles to measure water flow. This type of meter requires a battery to provide the magnetic field where the water's flow will create a voltage transferred to the register for recording the units of flow. There are no moving parts to wear out, as is the case for PD meters.
- Ultrasonic (US) – This meter uses ultrasonic soundwaves to determine the velocity of water moving through a pipe. This type of meter requires a battery to produce an ultrasonic soundwave. The frequencies of an ultrasonic soundwave are transmitted in the measuring tube, and its

reflections from the flowing fluid create a shift in the frequency. The frequency is transferred to the register. There are no moving parts to wear out, as is the case for PD meters.

- Turbo – Turbo meters are mechanical, with a propeller-type measuring chamber that rotates with water flow. These meters are typically used for commercial and industrial customers having consistent rates of water use.
- Compound – This meter type consists of two meters in one (a turbine meter and a PD meter). The turbine component measures high flow rates through the meter. An in-series PD meter measures the low flow rates. There are two registers on the meter; one for each of the two components. The reads from each one must be added together in order to obtain total water use for a given billing cycle.
- Omni – This is a particular model of meter manufactured by Sensus. The measurement technology is achieved with utilization of a Floating Ball Technology (FBT). FBT uses an impeller ball design. The impeller is essentially weightless in the water line and, thus, is very sensitive to various flow rates and has limited wear on its moving parts. This meter model usually replaces compound meters.
- Fire – This is a large, heavy meter that measures both domestic and fire flow, generally with a large turbine meter on the fire flow side of the meter and a smaller PD meter for the domestic flow.

The primary meter type used for meters sized 5/8 through 2 inches for all agencies is PD. At present, many participating agencies report trusting the durability and reliability of long-used mechanical meters over other types of static technologies such as US or EM. One exception to this trend is SJWD, which has shifted to Sensus iPERL® EM meters for approximately 10% of its inventory. CHWD deploys a US meter, the Neptune Mach-10, in 1 to 2-inch size. A few other agencies use turbo meters in the 2-inch size. It is difficult to compare the long-term reliability of static meters compared to the more commonly used mechanical meters because they have not been in service as long.

For meters larger than 2 inches, agencies use turbine meters and compounds, depending on the customer type and predicted pattern of water use. SJWD uses the Sensus Omni meter for 3-inch and larger. It has a floating ball technology which can measure a wide range of flows broader than the turbine with no need to have two registers as required with compound meters. Because Sensus has discontinued certain large meter models, SCWA switched to using the Omni meter technology in 2012 for meters 1.5-inch and larger. However, these are not yet the primary meter installed.

Table 3.4. Primary Meter Type for Each Meter Size (Inches) by Agency

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
0.625"	PD	PD	PD	PD		PD	PD
0.75"	PD	PD	PD	PD		PD	PD
1"	PD, US	PD	PD	PD	PD	PD	PD, EM
1.5"	PD, US, Turbo	PD, Turbo	PD	PD	PD	PD	PD
2"	PD, US, Turbo	Compound, Turbo	PD, Turbo	PD, Compound, Turbo	PD	PD	PD
3"	Compound, Turbo	Compound, Turbo	Compound, Turbo	Compound, Turbo	Turbo	Compound	Omni
4"	Compound, Turbo	Compound, Turbo	Compound, Turbo	Compound, Turbo	Turbo, Compound	Compound	Omni
6"	Compound	Compound, Turbo	Compound, Turbo	Compound, Turbo, Prop	Compound, Turbo	Compound, US	Omni
8"	Compound, Turbo	Compound, Turbo	Fire, Compound, Turbo	Turbo, Mag, Prop	Compound, Turbo	Compound	
10"	Compound	Turbo, Compound	Turbo, Fire	Prop		Compound	
12"		Mag Meter		Prop, Mag			
16"				Mag			
18"				Mag			

3.5 Meter Reading Platform

Consortium agencies employ three basic types of meter reading technologies through several providers. CHWD, SJWD, and SCWA have the largest inventory of manual or touch read meters. Several participating agencies employ AMR (drive-by) reading platforms, including CHWD, PCWA, SCWA, SJWD and SSWD. Table 3.5.1 indicates the primary and secondary meter reading platforms deployed by each agency.

Table 3.5.1. Trend in Meter Reading Platforms by Agency

	CHWD	SJWD	SCWA	PCWA	SSWD	FOLSOM	CITY OF SAC
Manual or Touch Read	X	X	X				
AMR	x	x	x	X	x		
AMI (Fixed Network)			x		X	X	X
AMI (Cellular)				x	x		x

X - Primary platform, x - secondary platform

The majority of participating agencies have already or are currently transitioning to an AMI platform as described in Table 3.5.2. The Cities of Folsom and Sacramento are currently the only agencies with a complete rollout of AMI. SCWA and SSWD are in the process of transitioning to AMI coverage. Most AMI systems among consortium agencies are radio-frequency, fixed-network. This means, that meter reads are transmitted wirelessly through agency-owned data collectors (gateways) that are positioned throughout the service area. City of Sacramento and PCWA both have a limited cellular-based network. These are also fixed networks. However, in this case, the data is transmitted through privately-owned gateways (via a cellular service provider such as Verizon or AT&T. SSWD also plans to deploy a cellular-based AMI network alongside a fixed-network AMI system.

Table 3.5.2. Type of Meter Reading Platform by Agency

CHWD	Touch Read (95%) and Neptune AMR (5%)
CITY OF SAC	AMI, Badger Orion SC-2 way fixed network system (99.5%) and Orion Cellular AMI (0.5%)
FOLSOM	Zenner AMI (100%)
PCWA	Itron AMR (96%) and Badger Orion Cellular AMI (4%)
SCWA	Touch Read (65%), the rest are a combination of Sensus AMR and Sensus Flexnet (fixed network) AMI. Plan to add additional towers.
SJWD	Manual (8%), Touch (86%), Sensus AMR (6%)
SSWD	Badger Orion AMR (17%), Badger Orion Cellular AMI (33%), and Meganet AMI (50%).

3.6 Meter Manufacturer

Table 3.6 indicates that the primary meter manufacturers among the consortium are Badger, Neptune, and Sensus. These are all long-time US manufacturers of potable water meters and enjoy the largest share of the US water meter market. A primary concern with multiple meter manufacturers is meter and register compatibility to meter reading technology solutions, such as AMI radio and cell phone endpoint transmitter alternatives.

- Badger is the primary meter manufacturer for the City of Sacramento, PCWA, and SSWD. The most commonly deployed small meter (less than 2 inch) model is the Recordall Disc Series with a positive displacement design.
- Sensus is the primary meter manufacturer for the City of Folsom, SCWA, and SJWD. The most commonly deployed small meter model is the SRII series with a positive displacement design.
- Neptune is the primary meter manufacturer for CHWD. The most commonly deployed small meter model is the T-10 series with a positive displacement design.

Table 3.6. Primary Meter Manufacturers for Each Meter Size (Inches) by Agency

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
0.625"	Sensus, Neptune	Sensus, Hersey	Badger	Badger		Badger	Sensus, Neptune
0.75"	Neptune, Sensus	Sensus, Hersey	Badger	Badger		Badger	Sensus, Neptune
1"	Neptune, Sensus	Sensus, Badger	Badger	Badger	Sensus	Badger	Sensus
1.5"	Neptune, Sensus	Sensus, Badger	Badger, Hersey	Badger	Sensus	Badger	Sensus
2"	Neptune, Sensus	Sensus, Badger	Badger, Neptune, Sensus	Badger	Sensus	Badger	Sensus
3"	Neptune, Sensus	Sensus, Hersey	Badger, Neptune	Badger	Sensus	Badger	Sensus
4"	Neptune, Sensus	Sensus, Hersey	Badger, Neptune	Badger, McCrometer, Siemens	Sensus	Badger	Sensus
6"	Neptune	Sensus, Hersey	Badger, Sensus, Neptune	Badger, McCrometer, Siemens	Sensus	Badger, Master	Sensus
8"	Neptune, Sensus	Sensus, Hersey	Sensus, Neptune, Badger	Badger, Foxboro, ABB, McCrometer, Sparling	Sensus	Badger	
10"	Neptune	Sensus, McCrometer	Sensus, Badger	McCrometer		Badger	
12"		McCrometer		McCrometer, Endress + Hauser			
16"				Endress + Hauser, ABB, Yokogawa			
18"				ABB			

3.7 Meter Register

Table 3.7 indicates the agency reported number of digits readable on registers typically found on meters of a specific size. This data represents digits used for monthly water billing rather than digits potentially readable by an AMI system. The intent of this data request was to determine potential register compatibility with future AMI meter reading technology. Most agencies informed the Team that their meters had encoder registers that are programmable to up to 8-digit precision. This kind of precision is desirable for AMI solutions and hourly interval data. However, 6 or 7-digit registers may suffice for AMI systems that are configured for daily reads. Since this type of information is not generally stored in a utility billing file, the existing agency meter inventory databases do not provide the exact count of individual meter registers. As a result, more investigation is required to determine the compatibility of currently deployed meters with potential AMI solutions. For example, some agencies are replacing the registers of their existing meters without replacing the meter, whereby the new meter register provides the capability for manual, touch, drive-by, and AMI reading capabilities.

Table 3.7. Number of Meter Register Digits for Each Meter Size (Inches) by Agency

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
0.625"	4	6	6-9	4		6	4 to 8
0.75"	4	6	6-9	4		6	4 to 8
1"	4	6	6-9	4	4 or 6	6	4 to 8
1.5"	4 to 5	7	6-9	5	5 or 7	6	4 to 8
2"	4 to 5	7	6-9	5	5 or 7	6	4 to 8
3"	4 to 5	7	6-9	6	4, 6, 7, 8	6	4 to 8
4"	5	7	6-9	5	6, 7, 8	6	4 to 8
6"	6	7	6-9	6	4,6, 8	6	
8"	6	7	6-9	6	6	6	
10"	6	7	6-9			6	
12"		7					

3.8 Meter Lids

Consortium agencies employ a variety of lid types that are either reinforced concrete, composite or metal. Converting from the existing meter reading method to another may require changes to meter box lid configurations. This is because platforms that transmit meter data via touch or wireless reading must allow for the touch pad or signal to transmit outside of the meter box. Transmitters also can vary in size and configuration. Several agencies have reported needing to make significant investments in replacement lids in order to switch meter and/or meter reading technologies. Some agencies are currently in the process of upgrading installed lids that are not compatible with their current platform.

Table 3.8. Meter Box/Lid Information for Small Meter Installations for Each Agency

CHWD	Carson or Christy models are specified
CITY OF SAC	Christy B30 Concrete are specified. Fibrelyte (Oldcastle), tier 22 (concrete polymer mix), and heavy traffic H20 (steel) are also in use.
FOLSOM	Concrete with steel flip lid and probe hole for endpoint installation are specified
PCWA	Concrete with steel lids are specified (about 85% of current inventory). Steel traffic lids, concrete, concrete polymer (1%) are also in use.
SCWA	Christy B30 & B36 (or equivalent) are specified
SJWD	B16 Christy Concrete or FL12 Fibrelyte Composite are specified
SSWD	Armorcast, B30, B36 and 48" box and lids w/endpoint holes are in use

3.9 Meter Accuracy

The Team used the Utah State Water Research Laboratory meter age versus accuracy equations developed in its 2011 extensive Water Research Foundation and EPA-funded meter accuracy project (see list of references in Appendix D) to a Water Research Foundation project from 2011) to estimate meter accuracy for meters sized 5/8-inch through 2-inch. The results are provided in Appendix C for each participating agency. Applications of these equations to the average meter age calculated for each agency resulted in high accuracies for all meters sized ¾-inch and larger. These equations do not take into account unmeasured flow. SCWA is the only agency that did not report having 5/8-inch meters in its inventory. Calculations of weighted accuracy for these meters produced the lowest accuracies. Based on the very old age of some installed meters, the application of Utah State age equations to meters aged 25 years and older results in total weighted meter accuracy of less than 90 percent. Using the database provided by each agency, it is possible to estimate existing accuracy of all meters and recommend replacement based on estimated accuracy. There are many other factors that should be considered for meter replacement, including volumetric throughput, economics of water loss, historical performance, meter warranty, manufacturer and distributor service, to name a few.

A summary of accuracy estimations for 5/8-inch meters is presented below for the average 5/8-inch meter at the average age shown. This size is shown as an example only. Accuracy estimations for other meter sizes through 2-inch are shown in Appendix B. Weighting was based on 20% low flow, 40% normal flow, and 40% high flow (20-40-40), estimated by the Team to be more reasonable than estimates in the current AWWA manual M6 based on the 2016 Residential End Uses Study funded by the Water Research Foundation (see references in Appendix D). The pattern of usage by an agency is highly variable by season and is agency specific. Time of day recorders can also be placed on new meters for a period of at least two weeks in multiple seasons to characterize usage distribution by meter size. The AWWA Manual M6 residential water use weighted testing distribution recommends using 15-70-15 percent for low, medium, and high flow. However, The Team believes this distribution is outdated based on the Residential End Uses Study of 2016.

Table 3.9.1. Calculated Estimated Accuracy of 5/8-inch Meter by Agency

	Average Age of 5/8-inch Meter	**Calculated Accuracy**
CHWD	10.8	94.0
FOLSOM	13	93.2
CITY OF SAC	21	90.3
PCWA	11.8	93.6
SCWA	N/A	N/A
SSWD	6.1	95.7
SJWD	23.3	89.5

As previously mentioned, meter age has been shown to affect accuracy of mechanical meters at low flow. The Water Research Laboratory at Utah State performed the most extensive water meter accuracy study in 2011 and developed relationships between meter age at low, normal, and high AWWA test flow rates for meters sized 2-inch and smaller. They also developed accuracy relationships for meter throughput volume. Calculated results are very similar for both age and volumetric throughput. The age equations have been used in this study to predict meter accuracy at the three AWWA test flow rates and a weighted accuracy for mechanical meters sized 5/8 through 2-inch. Therefore, meter age is often a major criterion for testing and replacement. Smaller meters typically have longer replacement cycles.

Utilities with high quality water sources and low total dissolved solids (TDS) tend to enjoy longer meter life than utilities serving water higher in TDS. High TDS water tends to deposit certain salts on meter measurement components which make the meter less accurate, because the deposits cause a greater amount of friction for the mechanical meters to overcome before initiating flow measurements. Therefore, water quality can affect the useful life of a meter.

The following Table 3.9.2 represents data provided by consortium members from meter accuracy testing done internally and externally for both small and large meters. The City of Sacramento has experienced data extraction issues with their test bench software but hopefully can extract and provide later. Average weighted meter accuracy test data are tabulated by meter size based on weighting by the testing agency. For large meters, this typically is an average of all accuracies at all test flow rates consistent with guidance in AWWA manual M6. For small meters, some outside testing agencies, such as UMS for SSWD, have used 2012 M6 guidance of 15-70-15 weighting for low-intermediate-high flow, respectively. The updated version of M6 is anticipated to change this, consistent with the 2016 Residential End Uses Study. There is also national AWWA debate on what flow ranges by a residential customer represent low flow, intermediate flow, and high flow. This issue should also be discussed in the forthcoming update of M6.

Meter testing benches and procedures vary considerably per recent research in testing variability performed by the Utah State Water Research Laboratory. Centralization and standardization of testing for consortium members, both on the testing bench for smaller meters and in the field for larger meters, would remove some of the variables involved with different test benches and different test procedures.

Table 3.9.2. Agency-Reported Meter Accuracy by Size

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
0.625”		100.31		95.36			101.30
0.75”				97.43		100.6, 87.1,100.1	98.12
1”		90.73		97.4	99.5		99.39
1.5”				96.6	98		98.44
2”				94.9	91.7		
3”	91.72	77.66		97.41	95.5		94.56, 99.2
4”	97.73	82.80		99.57			98.37,98.22
6”	91.9	98.14		95.07			
8”	96.03			96.75			
10”	100.62						

4. METER COST INVENTORY

As mentioned earlier, development of meter cost ratios using the preliminary data inventory indicated a significant range of values. Further refinement of the data is in development and the total cost ratios will be re-calculated later. At this phase of The Study, cost data that could influence the selection of meter technology on a consortium wide basis is being reported, specifically:

1. Current meter reading technology and resources
2. Current meter testing resources
3. Total internal meter resources
4. Indirect costs
5. 2019 meter purchases

4.1 Meter Reading Technology and Resources

As meter technologies move across the spectrum from Manual or Touch Read to AMI (Cellular), a shift is expected in meter reading personnel resources and costs. The table below summarizes the different Meter Reading Technologies by agency shown earlier in this section.

Table 4.1.1. Trend in Meter Reading Platforms by Agency

	CHWD	SJWD	SCWA	PCWA	SSWD	FOLSOM	CITY OF SAC
Manual or Touch Read	X	X	X				
AMR	x	x	x	X	x		
AMI (Fixed Network)			x		X	X	X
AMI (Cellular)				x	x		x

X - Primary platform, x - secondary platform

Agencies use both in-house staff and contracted staff to read meters. In order to get to a consistent basis of comparison, such as FTE staff, all reported meter reading contract costs were converted to FTEs by dividing by average meter related FTE salary and benefit costs for that agency to arrive at an estimated FTE level for meter reading. The table below shows the total Meter Reading Resources Organization as reported by agency, either through internal FTE count or contracted staff.

Table 4.1.2. Meter Reading Equivalent FTES (includes internal staff and contracted amounts converted to FTEs)

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
Number of Meters	19,955	21,647	131,507	37,202	53,454	42,675	10,586
Meter Reading FTE	1.4 (1)	3 (2)	4(3)	1 (4)	3.8 (5)	1.3(6)	1(7)

Notes:
(1) Calculated based on annual meter reading contract costs divided by average salary + benefits of internal meter staff or $113,600/$78,700 = 1.4 FTE. Under review by CHWD.
(2) Per estimate provided by agency in Folsom worksheet, 3 FTEs maintain fixed network system.
(3) Meter readers not including supervisor or 3 customer service representatives.
(4) Estimate is a combination of staff from Placer Salaries worksheet.
(5) Calculated based on annual meter reading contract costs divided by average salary + benefits of internal meter staff or $405,860/$107,000 = 3.8 FTE.
(6) Based on estimated 3 days meter reading per month done by 9 FTEs. (3 days/22 working days per month ~.14. 9 FTE x .14 = 1.3 FTE).
(7) Per San Juan Revised worksheet.

4.2 Meter Testing Resources

Agencies use both in-house staff and contracted staff to test meters. In order to get to a consistent basis of comparison, such as FTE staff, all reported meter testing contract costs were converted to FTEs by dividing by average meter related FTE salary and benefits costs for that agency to arrive at an estimated FTE level for meter testing. The Team did not ask for number of meters tested on an annual basis. The table below shows the total Meter Testing Resources Organization reported by agency.

Table 4.2. Meter Testing

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
Number of Meters	19,955	21,647	131,507	37,202	53,454	42,675	10,586
Meter Testing FTE	0.2 (1)	0.4 (2)	1 (3)	0.6 (4)	N/A(5)	0.1(6)	0.1 (7)

Notes:
(1) Calculated based on annual meter testing contract costs divided by average salary + benefits of internal meter staff of $15,000/$78,700 = 0.2 FTE.
(2) Calculated based on annual meter testing contract costs divided by average salary + benefits of $50,000/$139,200 = 0.4 FTE.
(3) Has 1 staff member dedicated to meter testing.
(4) Calculated based on annual meter testing contract costs divided by average salary + benefits of $80,000/$140,600 = 0.6 FTE
(5) No routine meter testing performed from 2016-2019.
(6) Calculation based on $13,150 annual meter testing contract costs for small meter testing divided by average salary + benefits of $123,000 = 0.1 FTE. Large meter testing is done internally and included in the O&M cost.

(7) Calculation based on combination of internal staff time of approximately .05 FTE (113 hrs/2080 hrs) and outside contract costs for large meter testing converted to 0.04 FTE by dividing contract costs by average salary and benefit costs of meter testing FTE ($4k/$111k), rounded to 0.1 FTE.

4.3 Total Internal Meter Resources

Total meter resources by agency include only internal staff. Agencies estimated the percent of time that was spent on meter related work for staff in areas that worked on meters, defined as meter installation, repair, replacement, maintenance, meter reading and meter testing. The table below shows the total Meter Resources Organization reported by agency. This does not include contract staff for meter reading or meter testing.

Table 4.3. Internal Meter Resources

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
Number of Meters	19,955	21,647	131,507	37,202	53,454	42,675	10,586
Meter FTEs(1)	1.5(4)	5	19	6	6.5	9	1.5
Average Salary/Benefits per FTE	$78,700(4)	$139,200	$81,500(2)	$103,503	$107,000	$123,000	$117,100(3)

Notes:
(1) Meter portion of staff time includes installation, repair, replacement, maintenance, reading and testing; this number can represent portions of many staff members' time.
(2) Excludes "Other meter capital costs – City staff benefits"
(3) Based on average hourly loaded rates of meter related staff
(4) Under review by CHWD.

4.4 Indirect costs

Cost allocations from overhead functions such as finance, legal, HR and computer services will not be included, unless there is a specific cost impact from the change to different meter technologies. For example, this might be expected in the case of computer services where additional computer support may be needed if an agency moves to AMI. Most agencies did not identify or report indirect costs. The table below shows the indirect costs that were reported by three agencies. Other agencies are planning to provide these costs in the future. These examples will serve as good models moving forward and if it decided to focus on certain aspects of these indirect costs that may be impacted as agencies transition from one meter reading technology to another.

Table 4.4. Indirect Costs

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
Number of Meters	19,955	21,647	131,507	37,202	53,454	42,675	10,586
Indirect Costs Reported[1]	N/A	$352,037(1)	N/A	N/A	$166,500 (2)	$785,300(3)	N/A

Notes:
(1) Indirect/administrative costs include the meter portion of computers, legal, etc. provided by other City Departments of $139,300 plus other costs of $212, 737.
(2) Indirect costs include central administrative services costs including Sensus software costs and County Utility Billing Services costs
(3) Indirect costs are defined as training, overtime, meals, operating supplies, inventory issues, equipment maintenance services, hazardous waste disposal, and construction services

4.5 Meter Purchases in 2019

This initial inventory phase focused on current year costs assuming that all agencies purchased meters each year. This is not always the case as one agency didn't report meter purchases in 2019. Also, these meter purchases include a variety of other costs besides meters, including registers, other parts, some installation costs and some contractor costs. None of the agencies indicated how many meters were associated with the purchase costs reported. Some installation costs could also be included as part of these costs. It will be important to get a clearer picture of the purchasing requirements and specifications for meter purchases. The table below shows the meter purchases reported by agency.

Table 4.5 Meter Purchases

	CHWD	FOLSOM	CITY OF SAC	PCWA	SCWA	SSWD	SJWD
Number of Meters	19,955	21,647	131,507	37,202	53,454	42,675	10,586
2019 Meter Purchase Costs	$200,000[1]	$600,000	$1,674,200	$180,906	$671,000	$2,052,800	$101,900

Notes:

(1) Under review by CHWD.

As the data analyses is refined, it may need to address additional areas that might be impacted by consortium decisions. These cost areas could include:

- Customer service costs
- Computer related costs
- Billing costs
- Materials procurement and storage costs

5. NEXT STEPS

Technical Memo #1 provides an overview and synthesis of the information collected in Phase 1, Individual Agency Assessments. The information collected will serve as the basis for subsequent phases. The primary conclusions derived from this quantitative and qualitative information include:

- Participating agencies are grouped in three categories in terms of their meter reading platforms:
  - CHWD and SJWD primarily have manual or touch read meters. These agencies have not yet decided to invest in an AMI platform.
  - PCWA and SCWA have selected AMI solutions but still have a significant percentage of their meters on manual/touch or AMR platforms.
  - SSWD has selected and partially converted its deployed meter inventory to AMI platforms.
  - The Cities of Folsom and Sacramento have both selected and fully converted to AMI platforms.
- Average meter age varies across participating agencies. Folsom has the youngest inventory with an average age of 7.5 years. CHWD and SJWD have the oldest inventories, with an average age of 14.8 years and 14.6 years respectively.
- Participating agencies generally prefer PD (mechanical) meters for their small size applications (less than 2-inches). Meters are generally purchased from three vendors: Neptune, Badger, and Sensus.
- To date, participating agencies have largely selected fixed-network AMI systems. One exception is SSWD, which has 33% of its deployed meter inventory on a cellular platform. The City of Sacramento and PCWA also have a small subset of meters on cellular platforms. The most common platforms are Badger Orion (City of Sacramento, PCWA, and SSWD) and Sensus Flexnet (SCWA and SSWD).
- Participating agencies do not employ an expansive small-meter testing program, but do test these small meters when they are replaced due to failure of some sort or when a customer challenges their meter's accuracy. Most agencies, but not all, have a schedule for testing or replacing large meters (greater than 1.5-inches). As a result, most agencies employ age-based replacement criteria for small meters.

The next step in The Study will be to conduct Phase 2, Next Generation Analysis, which involves an investigation of different options in meter technology, vendors, and accompanying meter specifications. It will include a detailed evaluation of the top 3-5 meter vendors according to criteria set forth by participating agencies.

The information on each participating agency's meter program serves as an integral component of Phase 2. Finding opportunities to better align technology investments and transitions are based on the existing decisions each agency has made and perhaps more importantly, how each agency makes decisions. The meter hardware and cost inventories will be used to inform technology evaluations moving forward. It will also be used to inform opportunities for collaboration, including ways for agencies to support one another and develop joint initiatives moving forward.

6. APPENDICES

Appendix A, Data Collection Templates

A.1. Deployed Meter Data Template

Meter ID	Serial Number	Manufacturer	Model	Type	Size	Install Year	Rebuild Year	Units of Use	Number of Reg Digits	AMR/ AMI	Register Type	Customer Class	2016 Use	2017 Use	2018 Use	2019 Use	Total Use Since Install or Rebuild

A.2. Small Meter Accuracy Test Data Template

SACRAMENTO REGIONAL WATER METER REPLACEMENT PROGRAM
SMALL METER ACCURACY TEST DATA TEMPLATE
METERS SIZED 5/8- THROUGH 2- INCH

Meter Serial No.	Manufacturer	Model	Type	Size	Install Year	Rebuild Year	Test Date	Total Use	Low Flow ACC.	Int. Flow ACC.	High Flow ACC.	Flow Distribution	Weighted ACC.	Notes

A.3. Large Meter Accuracy Test Data Template

SACRAMENTO REGIONAL WATER METER REPLACEMENT PROGRAM
LARGE METER ACCURACY TEST DATA TEMPLATE
METERS SIZED 3 INCHES and LARGER

Meter Serial No.	Manufacturer	Model	Type	Size	Compound L/H	Install Year	Rebuild Year	Test Date	Total Use	Low Flow ACC.	Int. Flow ACC.	High Flow ACC.	Flow Distribution	Weighted ACC.	Notes

A.4. Cost Inventory Template

		Data Requested	2016 Historical	2017 Historical	2018 Historical	2019 Budget	2020 Projected	2021 Projected	2022 Projected	2023 Projected	Notes
	UTILITY DATA										
1	Name of Utility										
2	Name of Primary Division or Group Responsible for Installing, Maintaining and Replacing Meters										This is likely Field Operations or similarly named group.
3	Name of Secondary Division or Group Responsible for Installing, Maintaining and Replacing Meters, if more than one group has responsibility										This may be Customer Service if meter readers are in this group or they may be in Finance; alternatively this could another Field group if there is a split between small and large meter staff.
4	Current FTE Count of Primary Division or Group										
5	Current FTE Count of Secondary Division or Group										
6	Current FTE Count of Meter Readers										
7	Current Organization Chart showing FTEs if possible										
8	Number of Meters Replaced/Planned for Replacement										
9	Number of New Meters Installed/Planned for Installation										
10	Current Utility Plant Assets, showing meter assets separately										This is a list of plant assets showing the meter asset class.
11	Copy of Most Recent Water Rate Study										Please provide this report or a link to the report; this will be important to understand overhead allocations and meter costs of service previously developed.
12	**OPERATING COSTS**										
13	Salary Costs of Staff Installing, Maintaining and Replacing Meters										This data would be contained in a document that compares annual budget vs. actual performance by each group in the utility. We need the historical dollars for salaries tied to meter staff - field, meter readers, others.
14	Benefit Costs of Staff Installing, Maintaining and Replacing Meters										This data would be contained in a document that compares annual budget vs. actual performance by each group in the utility. We need the historical dollars for benefits tied to meter staff - field, meter readers, others.
15	Meter Purchase Costs (if from Operating Budget)										This data would be contained in a document that compares annual budget vs. actual performance; we are looking for meter purchases if shown in the O&M budget.
16	Meter Testing Costs for Small and Large Meters										This data would be contained in a document that compares annual budget vs. actual performance; we are looking for meter testing costs if shown in the O&M budget.
17	Other Meter Operating Costs ____________										If there are other meter related costs please indicate, e.g. specifc software/IT costs.
18	Other Meter Operating Costs ____________										
19											
20	**CAPITAL COSTS**										
21	Meter Purchase Costs (if from Capital Budget)										This data would be contained in a historical reporting of capital expenditures; including identification of sources of funding; budget and projected data would come from a financial plan. This may not be one item; it could be multiple lines of meter, meter components and parts.
22	Other Meter Capital Costs______________										
23	Other Meter Capital Costs______________										
24	Other Meter Capital Costs______________										
25	Sources of Funds for Meter Purchase										This data would be contained in a historical reporting of capital expenditures; including identification of sources of funding; budget and projected data would come from a financial plan.
26											

Appendix B, Individual Agency Inventory Data Summaries

B.1. Citrus Heights Water District

B.1.A. Meter Count by Size

METER SIZE	NUMBER OF METERS
0.625"	66
0.75"	1,828
1"	16,789
1.5"	573
2"	613
3"	42
4"	21
6"	12
8"	10
10"	1
12"	
16"	
TOTAL	19,955

B.1.B. Meter Average Age and Age Count by Size

	AVERAGE AGE OF METER	AGE COUNT		
Age		>8	>13	>18
Install Year		2010	2005	2000
0.625"	10.8	31	21	19
0.75"	15.6	1,784	1,197	305
1"	16.8	16,356	14,635	3,778
1.5"	20.7	542	483	443
2"	20.3	532	502	481
3"	9	14	11	9
4"	14	14	11	10
6"	13.4	8	8	8
8"	17.4	9	8	7
10"	10	1	0	0
12"				
16"				
AVERAGE AGE	14.8			
TOTAL AGE COUNT		19,291	16,876	5,060
% TOTAL		97%	85%	25%

B.1.C. 2018 Usage by Size

METER SIZE	2018 USAGE		
	2018 CCF	2018 KGAL	% TOTAL
0.625”	13,266	9,923	0.3%
0.75”	140,822	105,335	3.4%
1”	3,265,869	2,442,870	79.8%
1.5”	356,200	266,438	8.7%
2”	69,670	52,113	1.7%
3”	87,837	65,702	2.1%
4”	120,197	89,907	2.9%
6”	14,328	10,717	0.3%
8”	23,585	17,642	0.6%
10”	3,240	2,424	0.1%
12”			
16”			
TOTAL	4,095,014	3,063,070	100%
Use/Conn		153,498.90	

B.1.D. Meter Manufacturer and Meter Type by Size

METER SIZE	MANUFACTURER NAME	METER TYPE
0.625”	Sensus, Neptune	PD
0.75”	Neptune, Sensus	PD
1”	Neptune, Sensus	PD, US
1.5”	Neptune, Sensus	PD, Turbo, US
2”	Neptune, Sensus	PD, Turbo, US
3”	Neptune, Sensus	Turbo, Compound
4”	Neptune, Sensus	Turbo, Compound
6”	Neptune	PRO
8”	Neptune, Sensus	Turbo, Compound
10”	Neptune	Compound
12”		
16”		

B.1.E. Register Digits by Size

METER SIZE	REGISTER DIGITS
0.625”	4
0.75”	4
1”	4
1.5”	4 to 5
2”	4 to 5
3”	4 to 5
4”	5
6”	6
8”	6
10”	6
12”	
16”	

B.1.F. Average Accuracy Predictions Based on Age

METER SIZE	AGE	LOW ACC	MID ACC	HIGH ACC	WEIGHTED ACC
0.625”	10.8	81.62	96.68	97.52	94.00
0.75”	15.6	98.60	100.83	99.51	99.86
1”	16.8	97.15	99.95	98.69	98.88
1.5”	20.7	95.85	100.17	100.40	99.40
2”	20.3	95.93	100.18	100.38	99.41
3”	9				
4”	14				
6”	13.4				
8”	17.4				
10”	10				
12”					
16”					
AVERAGE	14.8				

B.2. City of Folsom

B.2.A. Meter Count by Size

METER SIZE	NUMBER OF METERS
0.625”	4,598
0.75”	236
1”	15,620
1.5”	228
2”	704
3”	101
4”	53
6”	7
8”	4
10”	6
12”	1
16”	
TOTAL	21,562

B.2.B. Meter Average Age and Age Count by Size

METER SIZE	AVERAGE AGE OF METER	AGE COUNT		
Age		>8	>13	>18
Install Year		2010	2005	2000
0.625”	13	2924	2058	1429
0.75”	7	60	26	24
1”	9	6826	1528	518
1.5”	4	7	6	5
2”	1.5	5	5	1
3”	1	0	0	0
4”	9	22	17	14
6”	9	3	1	1
8”	16	4	3	3
10”	3	0	0	0
12”	3	0	0	0
16”				
AVERAGE AGE	7.5			
TOTAL AGE COUNT		9,851	3,644	1,995
% TOTAL		46%	17%	9%

B.2.C. 2018 Usage by Size

METER SIZE	2018 USAGE		
	2018 CCF	2018 KGAL	% TOTAL
0.625"	1,966,615	1,471,028	28.8%
0.75"	96,123	71,900	1.4%
1"	4,431,218	3,314,551	65.0%
1.5"	66,095	49,439	1.0%
2"	140,579	105,153	2.1%
3"	2,097	1,569	0.0%
4"	15,692	11,738	0.2%
6"	35,856	26,820	0.5%
8"	58,574	43,813	0.9%
10"	3,855	2,884	0.1%
12"	268	200	0.0%
16"			
TOTAL	6,817,692	5,099,634	100%
Use/Conn		190,818.84	

B.2.D. Meter Manufacturer and Meter Type by Size

METER SIZE	MANUFACTURER NAME	METER TYPE
0.625"	Sensus, Hersey	PD
0.75"	Sensus	PD
1"	Sensus	PD
1.5"	Sensus	PD, Turbo
2"	Sensus	PD, Turbo, Compound
3"	Sensus	Turbo, Compound
4"	Sensus	Turbo, Compound
6"	Sensus	Turbo, Compound
8"	Sensus	Compound, Turbo, Mag-meter
10"	Sensus	Compound, Turbo, Mag-meter
12"	Sensus	Mag-meter
16"		

B.2.E. Register Digits by Size

METER SIZE	REGISTER DIGITS
0.625"	6
0.75"	6
1"	6
1.5"	6
2"	6
3"	6
4"	6
6"	6
8"	4
10"	6
12"	7
16"	

B.2.F. Average Accuracy Predictions Based on Age

METER SIZE	AGE	LOW ACC	MID ACC	HIGH ACC	WEIGHTED ACC
0.625"	13	79.44	96.01	97.28	93.20
0.75"	7	98.87	100.81	99.49	99.89
1"	9	98.77	101.00	99.46	99.94
1.5"	4	99.04	100.46	99.52	99.80
2"	1.5	99.52	100.50	99.39	99.86
3"	1				
4"	9				
6"	9				
8"	16				
10"	3				
12"	3				
16"					
AVERAGE	7.5				

B.3. City of Sacramento

B.3.A. Meter Count by Size

METER SIZE	NUMBER OF METERS
0.625”	185
0.75”	213
1”	121,494
1.5”	3,415
2”	3,779
3”	1,123
4”	886
6”	266
8”	131
10”	15
12”	
16”	
TOTAL	131,507

B.3.B. Meter Average Age and Age Count by Size

METER SIZE	AVERAGE AGE OF METERS		AGE COUNT	
Age		>8	>13	>18
Install Year		2010	2005	2000
0.625”	21	178	177	91
0.75”	18.5	180	177	90
1”	6.6	42,273	18,585	3,809
1.5”	5.7	919	180	123
2”	6.7	852	365	288
3”	8	345	158	87
4”	7.1	193	69	42
6”	8.3	63	30	21
8”	5.9	6	2	2
10”	8.1	1	1	1
12”				
16”				
AVERAGE AGE	9.6			
TOTAL AGE COUNT		45,010	19,744	4,554
% TOTAL		34%	15%	3%

B.3.C. 2018 Usage by Size

METER SIZE	2018 USAGE		
	2018 CCF	2018 KGAL	% TOTAL
0.625”	25,819	19,313	0.1%
0.75”	33,043	24,716	0.1%
1”	15,381,740	11,505,542	34.6%
1.5”	1,881,062	1,407,034	4.2%
2”	8,756,707	6,550,017	19.7%
3”	8,677,899	6,491,068	19.5%
4”	4,393,121	3,286,055	9.9%
6”	3,128,575	2,340,174	7.0%
8”	1,376,902	1,029,923	3.1%
10”	751,335	561,999	1.7%
12”			
16”			
TOTAL	44,406,203	33,215,840	100%
Use/Conn		252,578.49	

B.3.D. Meter Manufacturer and Meter Type by Size

METER SIZE	MANUFACTURER NAME	METER TYPE
0.625”	Badger	PD
0.75”	Badger	PD
1”	Badger	PD
1.5”	Badger, Hersey	PD
2”	Badger, Neptune, Sensus	PD, Turbo
3”	Badger, Neptune	Compound, Turbo
4”	Badger, Neptune	Compound, Turbo
6”	Badger, Sensus, Neptune	Compound, Turbo
8”	Sensus, Neptune, Badger	Fire, Comp, Turbo
10”	Sensus, Badger	Turbo, Fire
12”		
16”		

B.3.E. Register Digits by Size

METER SIZE	REGISTER DIGITS
0.625”	6-9
0.75”	6-9
1”	6-9
1.5”	6-9
2”	6-9
3”	6-9
4”	6-9
6”	6-9
8”	6-9
10”	6-9
12”	
16”	

B.3.F. Average Accuracy Predictions Based on Age

METER SIZE	AGE	LOW ACC	MID ACC	HIGH ACC	WEIGHTED ACC
0.625”	21	71.50	93.58	96.40	90.29
0.75”	18.5	98.52	100.84	99.52	99.84
1”	6.6	99.27	101.32	99.70	100.26
1.5”	5.7	98.71	100.43	99.61	99.76
2”	6.7	98.52	100.41	99.66	99.74
3”	8				
4”	7.1				
6”	8.3				
8”	5.9				
10”	8.1				
12”					
16”					
AVERAGE	9.6				

B. 4. Placer County Water Agency

B.4.A. Meter Count by Size

METER SIZE	NUMBER OF METERS
0.625"	29,154
0.75"	2,129
1"	4,819
1.5"	606
2"	370
3"	83
4"	19
6"	12
8"	1
10"	
12"	
TOTAL	37,202

B.4.B. Meter Average Age and Age Count by Size

METER SIZE	AVERAGE AGE OF METER		AGE COUNT	
Age		>8	>13	>18
Install Year		2010	2005	2000
0.625"	11.8	25,439	9,218	9
0.75"	11.2	1,674	678	1
1"	5.6	1,254	525	34
1.5"	12.8	524	257	74
2"	11	301	97	12
3"	10.4	67	10	0
4"	9.2	12	1	0
6"	12.3	11	4	1
8"	11	1	0	0
10"				
12"				
AVERAGE AGE	11.0			
TOTAL AGE COUNT		29,283	10,790	131
% Total		79%	29%	0%

B.4.C. 2018 Usage by Size

METER SIZE	2018 USAGE		
	2018 CCF	**2018 KGAL**	**% TOTAL**
0.625"	8,297,896	6,206,826	52.7%
0.75"	831,347	621,848	5.3%
1"	6,254,397	4,678,289	39.7%
1.5"	211,989	158,568	1.3%
2"	113,668	85,024	0.7%
3"	15,763	11,791	0.1%
4"	6,643	4,969	0.0%
6"	1,669	1,248	0.0%
8"	92	69	0.0%
10"			
12"			
16"			
TOTAL	15,735,304	11,770,007	100%
Use/Conn		316,381.04	

B.4.D. Meter Manufacturer and Meter Type by Size

METER SIZE	MANUFACTURER NAME	METER TYPE
0.625"	Badger	PD
0.75"	Badger	PD
1"	Badger	PD
1.5"	Badger	PD
2"	Badger	PD, Comp, Turbo
3"	Badger	Comp, Turbo
4"	Badger	Comp, Turbo
6"	Badger	Comp, Turbo
8"	Badger	Turbo
10"		
12"		
16"		

B.4.E. Register Digits by Size

METER SIZE	REGISTER DIGITS
0.625"	4
0.75"	4
1"	4
1.5"	5
2"	5
3"	6
4"	5
6"	6
8"	6
10"	
12"	
16"	

B.4.F. Average Accuracy Predictions Based on Age

METER SIZE	AGE	LOW ACC	MID ACC	HIGH ACC	WEIGHTED ACC
0.625"	11.8	80.63	96.37	97.41	93.64
0.75"	11.2	98.74	100.82	99.50	99.87
1"	5.6	99.48	101.46	99.80	100.40
1.5"	12.8	97.36	100.31	99.98	99.59
2"	11	97.70	100.34	99.89	99.63
3"	10.4				
4"	9.2				
6"	12.3				
8"	11				
10"					
12"					
16"					
AVERAGE	10.6				

B.5. Sacramento County Water Agency

B.5.A. Meter Count by Size

METER SIZE	NUMBER OF METERS
0.625”	
0.75”	
1”	50,073
1.5”	1,687
2”	1,360
3”	249
4”	64
6”	18
8”	3
10”	
12”	
16”	
TOTAL	53,454

B.5.B. Meter Average Age and Age Count by Size

METER SIZE	AVERAGE AGE OF METER		AGE COUNT	
Age		>8	>13	>18
Install Year		2010	2005	2000
0.625”				
0.75”				
1”	13.3	35,191	29,468	18,646
1.5”	10.1	661	469	430
2”	14.3	1,068	849	770
3”	13.8	203	149	120
4”	13.6	52	36	29
6”	15.9	17	13	12
8”	18	3	3	2
10”				
12”				
16”				
AVERAGE AGE	14.1			
TOTAL AGE COUNT		37,195	30,987	20,009
% TOTAL		70%	58%	37%

B.5.C. 2018 Usage by Size

METER SIZE	2018 USAGE		
	2018 CCF	2018 KGAL	% TOTAL
0.625"			
0.75"			
1"	8,084,461	6,047,176	69.6%
1.5"	680,277	508,847	5.9%
2"	1,418,390	1,060,956	12.2%
3"	809,663	605,628	7.0%
4"	452,489	338,462	3.9%
6"	152,882	114,356	1.3%
8"	21,565	16,131	0.2%
10"			
12"			
16"			
TOTAL	11,619,726	8,691,555	100%
Use/Conn		203,668.54	

B.5.D. Meter Manufacturer and Meter Type by Size

METER SIZE	MANUFACTURER NAME	METER TYPE
0.625"		
0.75"		
1"	Sensus	PD
1.5"	Sensus	PD, FBT
2"	Sensus	PD, FBT
3"	Sensus	Turbo, FBT
4"	Sensus	Turbo, Compound, FBT
6"	Sensus	Compound, Turbo, FBT
8"	Sensus	Compound, Turbo, FBT
10"		
12"		
16"		

B.5.E. Register Digits by Size

METER SIZE	REGISTER DIGITS
0.625”	
0.75”	
1”	4 or 6
1.5”	5 or 7
2”	5 or 7
3”	4, 6, 7, 8
4”	6, 7, 8
6”	4, 6, 8
8”	6
10”	
12”	
16”	

B.5.F. Average Accuracy Predictions Based on Age

METER SIZE	AGE	LOW ACC	MID ACC	HIGH ACC	WEIGHTED ACC
0.625”					
0.75”					
1”	13.3	97.88	100.42	99.03	99.36
1.5”	10.1	97.87	100.36	99.84	99.65
2”	14.3	97.07	100.28	100.06	99.55
3”	13.8				
4”	13.6				
6”	15.9				
8”	18				
10”					
12”					
16”					
AVERAGE	14.1				

B.6. Sacramento Suburban Water District

B.6.A. Meter Count by Size

METER SIZE	NUMBER OF METERS
0.625"	2,442
0.75"	33,697
1"	3,649
1.5"	1,026
2"	1,411
3"	310
4"	104
6"	27
8"	5
10"	1
12"	
16"	
TOTAL	42,675

B.6.B. Meter Average Age and Age Count by Size

METER SIZE	AVERAGE AGE OF METERS			AGE
Age		>8	>13	>18
Install Year		2010	2005	2000
0.625"	6.1	79	1	1
0.75"	8.8	16,579	7,670	2,245
1"	10.3	2,076	1,112	420
1.5"	12.8	623	417	250
2"	15	910	721	542
3"	9.9	206	41	7
4"	9.7	72	6	1
6"	5.1	9	0	0
8"	11.2	4	2	0
10"	12	1	0	0
12"				
16"				
AVERAGE AGE	9.2			
TOTAL AGE COUNT		20,559	9,970	3,466
% TOTAL		48%	23%	8%

B.6.C. 2018 Usage by Size

METER SIZE	2018 USAGE		
	2018 CCF	2018 KGAL	% TOTAL
0.625"	153,086	114,508	1.3%
0.75"	5,680,504	4,249,017	48.5%
1"	1,100,868	823,449	9.4%
1.5"	781,807	584,792	6.7%
2"	2,158,888	1,614,848	18.4%
3"	1,003,306	750,473	8.6%
4"	549,706	411,180	4.7%
6"	255,037	190,768	2.2%
8"	28,305	21,172	0.2%
10"	23	17	0.0%
12"			
16"			
TOTAL	11,711,529	8,760,224	100%
Use/Conn		205,277.66	

B.6.D. Meter Manufacturer and Meter Type by Size

METER SIZE	MANUFACTURER NAME	METER TYPE
0.625"	Badger	PD
0.75"	Badger	PD
1"	Badger	PD
1.5"	Badger	PD
2"	Badger	PD
3"	Badger	Compound
4"	Badger	Compound
6"	Badger, Master M	Compound, US
8"	Badger	Compound
10"	Badger	Compound
12"		
16"		

B.6.E. Register Digits by Size

METER SIZE	REGISTER DIGITS
0.625”	6
0.75”	6
1”	6
1.5”	6
2”	6
3”	6
4”	6
6”	6
8”	6
10”	6
12”	
16”	

B.6.F. Average Accuracy Predictions Based on Age

METER SIZE	AGE	LOW ACC	MID ACC	HIGH ACC	WEIGHTED ACC
0.625”	6.1	86.28	98.10	98.03	95.71
0.75”	8.8	98.81	100.81	99.49	99.88
1”	10.3	98.50	100.82	99.33	99.76
1.5”	12.8	97.36	100.31	99.98	99.59
2”	15	96.94	100.27	100.10	99.54
3”	9.9				
4”	9.7				
6”	5.1				
8”	11.2				
10”	12				
12”					
16”					
AVERAGE	10.1				

B.7. San Juan Water District

B.7.A. Meter Count by Size

METER SIZE	NUMBER OF METERS
0.625"	40
0.75"	2,396
1"	7,657
1.5"	301
2"	164
3"	24
4"	4
6"	
8"	
10"	
12"	
16"	
TOTAL	10,586

B.7.B. Meter Average Age and Age Count by Size

METER SIZE	AVERAGE AGE OF METERS		AGE COUNT	
Age		>8	>13	>18
Install Year		2010	2005	2000
0.625"	23.3	41	39	38
0.75"	20.7	2,382	2,319	1,802
1"	14.4	6,131	5,178	2,264
1.5"	17.9	277	238	188
2"	17	137	107	62
3"	11.1	12	12	6
4"	11.3	2	2	1
6"	1			
8"				
10"				
12"				
16"				
AVERAGE AGE	14.6			
TOTAL AGE COUNT		8,982	7,895	4,361
% TOTAL		85%	75%	41%

B.7.C. 2018 Usage by Size

METER SIZE	2018 USAGE		
	2018 CCF	2018 KGAL	% TOTAL
0.625"	13,697	10,245	0.3%
0.75"	863,334	645,774	19.6%
1"	3,192,067	2,387,666	72.3%
1.5"	150,573	112,629	3.4%
2"	151,989	113,688	3.4%
3"	34,506	25,810	0.8%
4"	9,498	7,105	0.2%
6"			
8"			
10"			
12"			
16"			
TOTAL	4,415,664	3,302,917	100%
Use/Conn		312,008.00	

B.7.D. Meter Manufacturer and Meter Type by Size

METER SIZE	**MANUFACTURER NAME**	**METER TYPE**
0.625"	Sensus, Neptune	PD
0.75"	Sensus, Neptune	PD
1"	Sensus	PD, EM
1.5"	Sensus	PD
2"	Sensus	PD
3"	Sensus	Omni
4"	Sensus	Omni
6"	Sensus	Omni
8"		
10"		
12"		
16"		

B.7.E. Register Digits by Size

METER SIZE	REGISTER DIGITS
0.625”	4 to 8
0.75”	4 to 8
1”	4 to 8
1.5”	4 to 8
2”	4 to 8
3”	4 to 8
4”	4 to 8
6”	
8”	
10”	
12”	
16”	

B.7.F. Average Accuracy Predictions Based on Age

METER SIZE	AGE	LOW ACC	MID ACC	HIGH ACC	WEIGHTED ACC
0.625”	23.3	69.22	92.88	96.15	89.45
0.75”	20.7	98.45	100.84	99.52	99.84
1”	14.4	97.65	100.27	98.92	99.21
1.5”	17.9	96.38	100.22	100.25	99.47
2”	17	96.56	100.24	100.20	99.49
3”	11.1				
4”	11.3				
6”	1				
8”					
10”					
12”					
16”					
AVERAGE	14.6				

Appendix C, Meter Program Summary Tables

1. **Meter Specifications (focus on small meters)**

CHWD	There are no standard requirements for meter type. Neptune mechanical or US meters are currently purchased exclusively.
CITY OF SAC	Compatibility with Badger Orion SE endpoints and communications protocols is required. Currently, only Badger meters meet this requirement.
FOLSOM	The details are located in their most recent RFP. Small meters must be PD and made of copper alloy. Meters must communicate with the Zenner Stealth Reader MIU through Sensus protocol.
PCWA	Badger meters are currently sole-sourced.
SCWA	The residential 1" meter spec calls for Sensus SR II-EB TR/PL with a touch read module and housing.
SJWD	Since 2015, Sensus Omni is predominantly installed. The SR II was dominant before that. Neptune and Badger meters were used in the 80s and 90s.
SSWD	For small meters (1" and smaller), meters must be PD. The meters must be compatible with SSWD AMI system(s); both registers & endpoints.

2. **AMR/AMI Provider**

CHWD	Neptune AMR – ARB Nsight (5%)
CITY OF SAC	Orion SC 2-way fixed network AMI system (99.5%). Limited use of cellular AMI network (also Orion).
FOLSOM	Zenner mesh network AMI (100%)
PCWA	Itron AMR (96%) and Badger Orion AMI (4%)
SCWA	Sensus AMR and AMI
SJWD	Sensus AMR
SSWD	Badger Orion AMR (17%), Sensus Orion Cellular AMI (33%), and Meganet AMI (50%). Badger Orion Cellular and Sensus Flexnet will be used moving forward.

3. **Meter Box/Lid Information**

CHWD	Carson or Christy models are specified.
CITY OF SAC	Christy B30 Concrete are specified. Fibrelyte (Oldcastle), tier 22 (concrete polymer mix), and heavy traffic H20 (steel) are also in use.
FOLSOM	Concrete with steel flip lid and probe hole for endpoint installation are specified.
PCWA	Concrete with steel lids are specified (about 85% of current inventory). Steel traffic lids, concrete, concrete polymer (1%) are also in use.
SCWA	Christy B30 & B36 (or equivalent) are specified.
SJWD	B16 Christy Concrete or FL12 Fibrelyte Composite are specified.
SSWD	Armorcast, B30, B36 and 48" box and lids w/endpoint holes are in use.

4. **System Pressure Information**

CHWD	The service area terrain is fairly flat. The system is gravity fed. System pressure ranges from 70-100 psi. There are future plans to implement pressure reduction measures in high-pressure locations.
CITY OF SAC	The service area terrain is fairly flat. The system pressure range is fairly narrow: 40-55 psi.
FOLSOM	The service area terrain varies substantially. System pressure can vary from 30-140 psi.
PCWA	The service area terrain varies substantially. The system is gravity fed and system pressures can range from 40 to 100 psi. Average operating pressure is 82 psi.
SCWA	Pressure is maintained between 35-90 psi, but is normally 50-65 psi.
SJWD	The service area is fairly flat. System pressure ranges from 24- 100 psi.
SSWD	The service area is fairly flat. System pressure ranges from 40-70 psi.

5. Meter Testing Procedures

CHWD	Employs AWWA standards for all tests.
CITY OF SAC	Employs AWWA standards. Has 3 test benches which can each do 3-4 at a time for meter sizes less than 1”. The benches can do endurance or regular testing.
FOLSOM	Employs AWWA standards for all tests. A meter bench capable of testing up to 2” meters was recently approved. Folsom can test 1.5” and 4” meters in-place with a mobile tester.
PCWA	There is a large meter testing program with a written procedure. Small meters are tested as needed, which is when there is an indication of failure.
SCWA	There is no current routine meter testing program. Small pilot studies in the past.
SJWD	Test bench is Mars 2005.
SSWD	Employs AWWA standards for all tests.

6. Meter Sampling Strategy

CHWD	All large meters (3” and above) are were tested in 2018 & 2019, however there is no formal sampling strategy in place. Reported failures and customer validation requests have been the only meters that have been tested prior to 2019. In 2019, CHWD field tested +50 of their installed 1” meters, across all years of installation.
CITY OF SAC	The City tests 100% of meters that are replaced. City of Sac tests 10% of new deliveries. If test failures occur on a specific model, a higher sample size may be adopted.
FOLSOM	The City tests all commercial meters as well as a 40 meter sample group annually which depends upon age and consumption.
PCWA	1.5” to 2” meters are tested every 7 years unless they are rebuilt. 3” to 4” meters are tested every 3 years. 6” and 8” meters are tested every year. 2” compound and turbo meters are tested every 4 years. Smaller meters are not tested.
SCWA	There is no formal test strategy currently in place other than testing reported issues.
SJWD	Manual testing is performed on meters that are replaced.

SSWD	1.5" to 2" are rebuilt every 10 years (~250 per year). 3"and 4" are tested every 5 years. 6" and bigger are tested annually. If meters fail the test, they are rebuilt.

7. **Meter Failure Information**

CHWD	Approximately 25 mechanical failures per year.
CITY OF SAC	Trends are not currently tracked.
FOLSOM	Trends are not currently tracked.
PCWA	For large meters there is information on the spreadsheet. Small meter inventory is young, so few failures have been reported to date.
SCWA	Average of 950 per year (during 4 year period)
SJWD	No data provided.
SSWD	No data provided.

8. **Existing Meter Replacement Criteria**

CHWD	There is no criteria currently in place other than replacing failures.
CITY OF SAC	The 1.5" to 2" meter sizes are replaced every 10-13 years. Meter sizes 1" and smaller are intended to be replaced every 20 years.
FOLSOM	There is no criteria currently in place other than replacing failures.
PCWA	There is no active program to replace meters. Previously, 10% were replaced a year until about 7 years ago.
SCWA	There is no criteria currently in place other than replacing failures. A budget allocation of $325,000/year is available for replacements (based on actual past annul expenditure history).
SJWD	1% per year are replaced, 27 large meters (3" and greater) are tested every year.
SSWD	About 1,000 meters are replaced per year based on age and budget. About 1,500 to 2,000 unmetered connections are added each year as well. 4-5k are still unmetered.

9. **Delivered Water Quality Information/Source/Salts**

CHWD	SJWD provides ~90% of water, with ~10% from CHWD's groundwater wells. TDS is 110 to 150 PPM
CITY OF SAC	Mostly surface water (roughly 80%)
FOLSOM	Mostly surface water, TDS is 35 to 49 PPM
PCWA	Average TDS ranges from 18 to 44 PPM
SCWA	TDS ranges from 77 to 605 PPM
SJWD	TDS ranges from 110 to 150 PPM
SSWD	TDS ranges from 150 to 600 PPM

10. **Time of Day Customer Use**

CHWD	Not currently available through standard meter data. From the 2015 average diurnal chart (on file), there are two peaks at 7am and 9pm at about 1.25 M gallons per hour and two lows at 4am and 4pm at 0.8 and 0.75 respectively
CITY OF SAC	Not currently available
FOLSOM	Hourly use reported to AMI system

PCWA	A packet of hourly data is collected every 24 hours for the Colfax neighborhood and Applegate (I-80 corridor). The rest are read bi-monthly.
SCWA	Hourly data is collected from AMI system.
SJWD	Not currently available.
SSWD	Not available, 4am to 10am and 4pm to 10pm are peak demand periods.

11. Billing Information (CIS, frequency, etc.)

CHWD	The Cogsdale software is used. Customers are billed bi-monthly.
CITY OF SAC	Oracle CCB (newly installed). City of Sac did not purchase a meter inventory database module. It is difficult for staff to run meter-oriented reports.
FOLSOM	Water is billed monthly.
PCWA	Noveline HTML5 through Central Square. Bills are sent bi-monthly with the exception of AMI and large meters (monthly). The large HOAs, the university, and other agencies are billed monthly. Shifting the remaining customers to monthly would impact customer service.
SCWA	Sacramento County Consolidated Utility Billing & Service. Reads are collected monthly but the majority of customers are billed bi-monthly unless requested to be monthly.
SJWD	Not provided
SSWD	TruePoint, billed monthly on four cycles.

12. Relevant Water Loss Audit Information (FWAS Workbook)

CHWD	From the 2019 Audit (on file), real losses are about 1.5% and apparent losses are about 3.4%. No meter losses have been included in audit calculations.
CITY OF SAC	From the 2018 audit (on file), real losses are about 8.3% and apparent losses are about 2%. Meter losses estimated to be about 1.6%.
FOLSOM	From the 2018 Audit (on file), real losses are about 12% and apparent losses are about 3%. Meter losses are estimated to be about 2.7%.
PCWA	From the 2018 Audit (on file), real losses are about 11.8% and apparent losses are about 3.5%. Meter inaccuracies are identified as 3.2%.
SCWA	From the 2018 Audit (on file), real losses are about 6.9% and apparent losses are about 1.4%. Meter losses are estimated to be about 0.9%.
SJWD	From the 2018 Audit (on file), real losses are about 4.6% and apparent losses are about 1.9%. Meter losses are estimated to be about 1.4%.
SSWD	Not provided

13. Meter Sizing Criteria

CHWD	Detached SFRs and condos must have 1” connections (state law for fire-flow). Res parcels can be 1” to 2” depending on size (on file).
CITY OF SAC	Not Provided
FOLSOM	New residential meters must be 1” minimum.
PCWA	5/8” to 1” are used for SFRs. Size selection depends on required capacity for non-residential between 5/8” to 4” meters are used.

SCWA	1” meter is standard for Residential (also determined by lot size and service size). 1-1/2" min. for Commercial (and design water demands).
SJWD	There are few new meter installations at present, so no current criteria.
SSWD	Sizing is established by developer/Owner Request and/or SSWD Demand/Calculations.

14. Water Rate Tables

CHWD	Fixed fee plus unit use (on file). Fixed fee dependent on meter size. Unit use fee fixed for all types of users ($1.0674 / CCF).
CITY OF SAC	Metered customers pay a fixed fee plus unit use (on file). Fixed fee dependent on meter size. Unit use fee fixed at $1.4587 (9/1/19).
FOLSOM	Fixed fee plus unit use (on file). Fixed fee based on type of home. Unit use fee is tiered. 0-20 CCF is $1.08; 20-40 CCF is $1.30; over 40 CCF is $1.60.
PCWA	Fixed fee plus unit use (on file). Fixed fee dependent on category and size of meter. Block rates for residential per unit use starting at $1.52 for the first 9 CCF.
SCWA	Fixed fee plus unit use (on file). Fixed fee dependent on category. Quantity rate per category. Residential is $1.63 per CCF. Non-residential is $1.24 per CCF. There is a conservation discount.
SJWD	Rate study provided in file. Rate organized by daily base charge, plus unit use charge by meter size.
SSWD	Flat Accounts, Meter Accounts and Other Charges/Residential and Non-Residential (Commercial/Institutional).

15. Previous assessments and evaluations of meter reading technology

CHWD	No major previous studies have been conducted. The meter technology has been consistent from the beginning (late 1990s).
CITY OF SAC	Several studies have been conducted leading up to the current AMI system selection.
FOLSOM	There were no studies provided. Previous studies related to current AMI system and upgrades.
PCWA	In 2015-16 a feasibility study with MC Engineering was conducted. PCWA evaluated four manufacturers for AMI, including a quick cost-benefit analysis. The recommendation was to replace 2M meters. There were propagation studies done for four systems. The ballpark cost was about 10M. None were implemented. Developed RFP but didn’t follow up. Bought endpoints, got billing system up and running. Adding Cycle10 to that system. Their current and future preference is cellular.
SCWA	Not considered in recent past (longstanding preference is to use Sensus AMR/AMI products)
SJWD	No previous studies on AMR or AMI
SSWD	There is the original evaluation for the current KP/Mueller Meganet (MTU) system. Propagation studies have also been done for Orion Cellular, Sensus, and Meganet.

16. Are meters encoded or pulsed?

CHWD	The newer registers associated with AMR are encoded but these account for only about 5% of total meters.
CITY OF SAC	Most are encoded, including any that are connected to the AMI systems. Some compound meters have one side that is still pulsed.
FOLSOM	All registers are encoded.
PCWA	Encoder registers and endpoints for the AMI system. The vast majority of meter data on the AMR system are pulsed but PCWA does not manufacture the pulsed registers anymore. As a result, PCWA is now shifting towards encoders. These are the new HRELCD (digital display) Badger. The old ones (Badger iTRON RTRs) were pulsed endpoints.
SCWA	All new meters are encoded (digital). Older ones with digital register likely to be the touch read ones.
SJWD	The Omni meters are pulsed, The SL IIs and iPERLs® are encoded.
SSWD	Nearly all meters are encoded. There may be a small quantity of older pulsed registers in use.

17. Do existing meter registers have 2 or 3-wire connections and what are the representative proportions of each configuration in a system?

CHWD	There are very few 2-wire connections left. Most meters now have 3-wire connections.
CITY OF SAC	All are 3-wire
FOLSOM	All are 3-wire
PCWA	All 3-wire. No touch reads
SCWA	Mostly 3-wire. Unsure of oldest meters (Sensus or otherwise)
SJWD	Most are 3-wire
SSWD	Most are 3-wire

18. Are all meters located in pits/meter boxes within a system?

CHWD	Most meters are in pits or boxes. There are a handful of the larger ones in the open.
CITY OF SAC	Most meter are in pits or boxes. There may be a handful still in the open.
FOLSOM	All meters are in boxes or vaults with few exceptions
PCWA	The majority are in boxes or pits. There are a handful of firelines and canals in the open.
SCWA	Most meters are in pits or boxes, except for a few, which are above-ground.
SJWD	The residential meters are in boxes.
SSWD	All meters are in either boxes or vaults.

19. Are there any large meter installs in confined space areas?

CHWD	There are a few large meters in confined spaces but this is an exception.
CITY OF SAC	Large meter installs are mostly above ground. Below ground installations are generally in standard boxes (B-48 or 52 lid). A couple large meters are in vaults.
FOLSOM	There are some. The City is in the process of retrofitting them.
PCWA	There are a few
SCWA	There are a few

SJWD	There are a few
SSWD	There are a few

20. Meter/AMI Provider/Distributor/Contractor experience, preferences, and exclusions

CHWD	Neptune is preferred. This is based on the performance, consistency, durability and warranty on the meter and registers. CHWD goes through a distributor, but only tend to buy several dozen units at a time (small order quantities).
CITY OF SAC	Staff have a good relationship with Badger and are able to provide performance feedback.
FOLSOM	Every vendor has met expectations and Folsom has not excluded any manufacturer from bidding on new meter purchases.
PCWA	Badger is the preferred vendor but there are constant issues with system. The 50Ws and 60Ws failed a lot. The 100Ws doing better. Several thousand endpoints have been replaced because big batches failed. PCWA has received free replacements and have had fewer problems moving forward, but lots of mistrust. ITron has been difficult to manage. The software always seems out of date. PCWA has evergreen contracts and keep wanting to establish a new contract but hesitant to sign. Not updating mapping. PCWA has talked to Sensus, but the system is expensive andraw data wasn't correct. PCWA did a propagation study a year after the study. Things are going well with cellular pilot. There are some issues with AMI endpoints, but issues are more associated with coverage. Topography is the challenge in this service area.
SCWA	Sensus is preferred. Distributor is Golden State Flow Measurement.
SJWD	8% are manual, 86% are touch, and 6% are AMR. Sensus iPERL® is solely purchased now with AMR radio registers. There are no specific preferences or exclusions noted.
SSWD	SSWD is shifting to a dual AMI system comprised of Orion Cellular and Sensus Flex Net. Their meter preferences are not fixed to a brand but are described in their meter specification (Qu. 1) as long as they are compatible with their AMI systems (registers and end-points).

21. Relevant Procurement Methods/Restrictions

CHWD	Purchases are done in small batches. CHWD has established a per-unit price in late 90s. Since then, meters are purchased on an as needed basis (through Ferguson).
CITY OF SAC	Currently, only Badger meters meet their specs. The City has a multi-year purchase agreement for Badger meters.
FOLSOM	City Council approval and low bidder is required. The most recent RFP is on file.
PCWA	There is no contract for the AMI network (nor service unit cost). PCWA sole sources Badger and iTRON endpoints. Purchase about 5k req. 3 bids. 30k board approval, 50k req. formal bids.
SCWA	Sensus products are exclusively procured.
SJWD	None provided

SSWD	Back Yard Services and Budget

22. Are collectors currently installed on agency-owned assets and/or does the agency own assets on which collectors can be installed (e.g. reservoirs, streetlights, etc.)?

CHWD	There is no AMI infrastructure. CHWD only uses mobile readers (AMR) or collects data from individual meters.
CITY OF SAC	There are over 200 towers in the City's service area.
FOLSOM	All collectors are mounted on agency-owned assets.
PCWA	PCWA has one Itron CCU on a Midus tank. PCWA is not a municipality so there are no streetlights to use. They have tank sites and private stations (little water testing stations) that could potentially be used. They have done two prop. Studies: REVA and RW. Currently they would need tons of repeaters.
SCWA	Collectors are installed on agency-owned property (TGBs).
SJWD	No collectors currently in use. There are tanks where collectors could be positioned, but they are limited to the upper boundary of their system.
SSWD	Collectors are on owned facilities, including well sites and reservoirs.

23. What are the average heights of assets/infrastructure which are currently used for collector installations and/or could be used for collector installations?

CHWD	N/A
CITY OF SAC	Information not collected
FOLSOM	20-40 feet
PCWA	PCWA has about 20 tanks at about 30 ft., Auburn tower at 130 ft. and Sunset tower at 120 ft.
SCWA	There are three tower (collectors), approximate height varies from 50 to 190 ft. for each tower.
SJWD	The District ranges from elevation +/-200 to 600 ft. The tank and reservoir sites are: Kokila Reservoir: 520 ft, Mooney Tank: 606 ft, and Los Lagos Tank: 570 ft
SSWD	30 ft and 150 ft at groundwater well sites and elevated tanks.

24. Are there any known restrictions worth noting regarding potential meter reading infrastructure installations, e.g. tower height variances, which would need to be considered?

CHWD	N/A
CITY OF SAC	N/A
FOLSOM	None known
PCWA	Topography is the primary restriction. Also, there is lack of agency-owned land and therefore places to put repeaters and endpoints.
SCWA	There is a pre-existing tower restriction height for Arden Service Area.
SJWD	Terrain in the northern service area may be an issue.
SSWD	Lack of District-owned structures on areas where propagation studies recommend infrastructure.

25. Are there any known issues with commercial cellular coverage in your service area?

CHWD	There are probably a few minor dead zones, but the coverage area is almost completely built-up and centrally located.

CITY OF SAC	Further details can be found in the City's Badger Cellular propagation study.
FOLSOM	Coverage is good, with a few carrier specific locations.
PCWA	There are lots of hotspots, particularly in zones 3 and 6.
SCWA	None known
SJWD	None known
SSWD	As per Badger cellular propagation study, there are no known issues.

Appendix D, Additional Information on Water Meter Sizing and Accuracy

Water meters serve to provide a record of water usage for financial, system evaluation, and resource planning purposes. Consortium members continually install new water meters based on demand for new service connections and replacement of aged or malfunctioning meters. Over recent years, metering technology has undergone a period of rapid advances, improving meter performance, accuracy, data storage, and data collection. Although meter selection and sizing for individual users are based on technical requirements for accurate and reliable data collection, meter sizing also serves as the basis for establishing service connection fees and monthly billing service fees.

Based on the water usage data presented in Table 1.X, water meter sizing policy is important for establishing monthly water billing rates as well as service connection fees. Many factors beyond water usage affect potable water utility metering decisions today, including:

- Changing government regulations
- Water conservation (required by code/ordinance and customer response)
- Enhanced efficiencies (low-flow plumbing fixtures)
- Drought conditions
- Increasing costs of water production and treatment
- Increased utility accountability
- Water restriction levels defined for many agencies
- Updates to sizing guidance (AWWA Manual M22 revised in 2014 and to be updated in 2022) now use SMOC
- Antiquated flow estimation approaches (Hunter Curves) using plumbing fixture types, count, and flow values to calculate peak demand leading to over-sized meters and reduced low-flow sensitivity
- Changing technology (meters, meter reading (AMI/AMR), analytics, radio-cellular communications, communication gadgets such as temperature, pressure, water quality, etc.)
- Increased costs for manual reading
- Carbon footprint reduction ethic/benefits
- Utility/customer demand for more information (this advocates for AMI)
- AMI on inaccurate meters gives inaccurate interval data (this advocates for better meter accuracy)

Five of the seven agencies participating in Phase 1 of the Meter Replacement Program have the predominant water meter size of 1-inch. Having this minimum meter size has significant impacts on the apparent water loss calculation from an AWWA Manual M36 water audit. One-inch PD water meters are designed to start measuring flow accurately at 3/4 gpm, the low flow accuracy test rate indicated in Table 5-3 of AWWA Manual M6, *Water Meters-Selection, Installation, Testing, and Maintenance,* Fifth Edition (2012). Below this flow rate, mechanical water meters are woefully inaccurate.

Each agency participant provided a spreadsheet of the entire meter inventory containing meter number, meter manufacturer, size, installation date, years in service, cumulative use (if available), and other relevant meter inventory information. Each utility database was used to estimate meter accuracy for each small meter using results of a Utah State Water Research Laboratory research project entitled “Accuracy of In-Service Water Meters at Low and High Flow Rates” (Water Research Foundation, 2011). This project was funded by the Water Research Foundation and the United States Environmental Protection Agency (US EPA). Results for low, intermediate, and high flow rates were plotted for meter accuracy versus years in service and meter accuracy versus cumulative flow through the meter. Due to the large variability in results for meters obtained from multiple North American utilities, the best-fit linear correlation factors were less than desired. However, the linear equations have been applied to other large utility meter inventories with believable and defensible results for predicted meter accuracy at the three test flow rates.

Table D1 below indicates the UWRL equations used for meter accuracy calculation by meter size for low, intermediate, and high flow test rates, as recommended by AWWA Manual M6, *Water Meters-Selection, Installation, Testing, and Maintenance, Fifth Edition* (AWWA, 2012).

Table D1. UWRL Meter Accuracy Formulas for Meter Age (X=Years)

Meter Size (in)	Low Flow	Intermediate Flow	High Flow
5/8x3/4	-0.9924X + 92.338	-0.3036X + 99.954	-0.1097X + 98.702
3/4	-0.0304X + 99.078	0.0025X + 100.79	0.0026X + 99.469
1	-0.2077X + 100.64	-0.1347X + 102.21	-0.0990X + 100.35
1-1/2	-1.3998X + 110.36	-0.0667X +102.21	-0.4354X + 103.99
2	-0.1910X + 99.803	-0.0173X + 100.53	0.0526X + 99.31

Table D2 indicates the results of the Utah State meter accuracy best linear fit analysis for cumulative meter throughput by meter size. In the table, "Y" represents cumulative volume in million gallons.

Table D2 UWRL Meter Accuracy Formulas for Meter Volume Throughput

Meter Size (inches)	Low Flow	Intermediate Flow	High Flow
5/8x3/4	$-1*10^{-5}Y+98.954$	$-4*10^{-6}Y+101.17$	$-2*10^{-6}Y+99.44$
3/4	$-2*10^{-6}Y+99.347$	$-2*10^{-7}Y+100.87$	$-4*10^{-7}Y+99.874$
1	$-1*10^{-6}Y+100.33$	$-3*10^{-7}Y+100.97$	$-3*10^{-7}Y+99.948$
1-1/2	$-1*10^{-5}Y+99.847$	$-8*10^{-9}Y+101.62$	$-4*10^{-8}Y+100.59$
2	$-1*10^{-7}Y+97.51$	$-8*10^{-8}Y+100.15$	$-3*10^{-8}Y+99.743$

Fire Sprinkler Requirements

The State of California requires that all new single-family residential construction include fire sprinklers. Fire sprinklers require a specific flow capacity at a specific delivery pressure at each sprinkler head. The number of sprinkler heads required depends on the room type. The combined fire sprinkler flow rate and domestic flow rate exceeds the 20 gpm capability of a standard 5/8 by 3/4-inch water meter. Although it's possible to deliver fire demand separately from domestic demand (in-house plus outside irrigation), single family residences typically deliver all water demand requirements through a single water meter. Since fire sprinkler demand and domestic peak demand is often estimated at 40 or more gpm, utilities often establish their minimum residential water meter size at 1-inch. The SMOC of a 1-inch meter is indicated as 50 gpm in product data sheets available through manufacturer websites.

Meter Aging

The primary factor involved in meter longevity is accuracy. There are multiple factors known in the industry to affect meter accuracy, including the following:

- Mechanical wear over time, excess cumulative volume, poor water quality, damage, and vandalism
- Incorrect installation or lack of maintenance
- Incorrect sizing
- Incorrect meter type for the application
- Spinning or jetting
- Environmental problems (freezing, overheating)
- Low flow rates due to evaporative coolers and basement/rooftop storage tanks
- Changing flow patterns due to water conservation, changes in building codes, and plumbing fixture design

Proper sizing practices, selection, and installation; routine testing; and optimal meter replacement will mitigate most of the accuracy degradation issues listed above. The ability to determine the optimal meter replacement program is dependent on the collection and assessment of customer meter information found in a meter asset database.

Potential Criteria for Utility Water Meter Replacement

Utilities develop their own criteria for meter replacement based on their history with meter manufacturers, types and failure rates. Consortium members have done similarly. Depending on the degree of success a utility has had with its current meter manufacturer and type and its future goals for incorporating advanced metering infrastructure, the following list contains many of the variables considered by utilities today in making meter selection decisions. If decisions involve a potential meter technology change from PD types to new static meter types, a pilot comparison of in series installation of both meter types is often warranted, if practical. Otherwise, the billing history of the customer can be used to note performance accuracy differences in registration.

- Performance
- Warranty
- Age
- Throughput
- Maintenance Issues
- Technology
- Functionality
- Life Cycle Cost
- Confidence in Meter Manufacturer and Type

Meter manufacturers offer different warranty terms for varying meter types, sizes, and components. The warranty applies to the purchasing utility and not to individual customers. Typical water meter warranties have different subheadings. These include Products, Materials and Workmanship, Meter Accuracy, Extended Low-Flow Meter Accuracy (if offered), Product Returns, and Limits of Liability. Manufacturers are generally required to submit nationally publicized warranties for meter bids.

Warranty provisions can be used to differentiate meters for a specific size and compute life cycle costs based on meter accuracy provisions. Differentiating warranty provisions are generally based on new and repaired meter accuracy. PD meters have warranties for new meter accuracy based on years and throughput volume in total gallons. New electronic (static) meters of residential size typically have 20-year new meter accuracy warranties and no repaired meter provisions. Since static meters need to be replaced if broken and internal electronic batteries cannot be individually replaced due to water proofing, repaired meter provisions are not applicable.

The 20-year accuracy warranties for static meters can be a life-time warranty or a 10-year warranty with an additional 10-year limited warranty based on a prorated depreciation schedule.

Water meter life is variable. One criterion used to determine meter life is the end of a warranted repaired meter accuracy period. This is typically 15 years for residential-sized meters. Based on local utility economics, water quality, and water rates, some agencies define a meter life as when the meter is losing more revenue due to inaccuracy than it costs to replace. Life cycle analyses should have the same time period for economic comparisons.

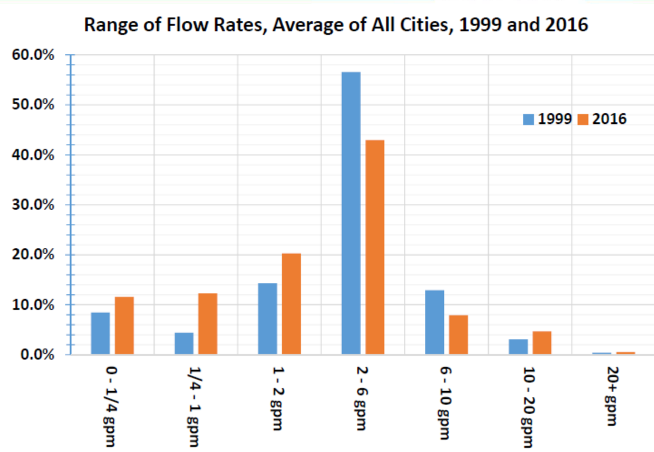
Low Flow Water Demand

Recent utility and customer interest in water loss control have prompted multiple studies to further understand typical single-family residential water demand patterns in different U.S. geographies. In states experiencing long-term drought conditions, low flow rates may take on increased significance for some utilities (depending upon rate structure). This is because a greater proportion of water use may be through low flow rates under water conservation conditions.

New ultrasonic and electromagnetic metering designs such as the Sensus iPERL®, Neptune Mach 10®, Badger E-Series, Mueller Solid State Meter (SSM) series, and Kamstrup meters allow measurement of lower flows heretofore unavailable in PD designs. The Water Research Foundation originally conducted its first Residential End Uses Study in 1999. The Foundation's 2016 study evaluated residential end uses by using meters having the improved low flow metering technology to evaluate the entire flow range for single family residences in eight U.S cities. Data from this study was presented at the AWWA Annual Conference and Exposition in Philadelphia in June 2017. The data indicated significant low flow usage below the typical minimum reading capability of a PD meter. The design and application of lower flow residential plumbing fixtures, such as shower heads and toilets, have increased the amount and percentage of ultra-low flow in the total use profile of a single-family residential customer. A chart comparing the 1999 results and the 2016 results is presented below as Figure D3.

Figure D3 Average range of flow rate for all Cities, 1999 and 2016

Range of Flow Rates	Average for All Cities	
	1999	2016
0 - 1/4 gpm	8.4%	11.54%
1/4 - 1 gpm	4.4%	12.24%
1 - 2 gpm	14.3%	20.23%
2 - 6 gpm	56.6%	42.96%
6 - 10 gpm	12.9%	7.87%
10 - 20 gpm	3.0%	4.63%
20+ gpm	0.4%	0.53%



Results for 2016 indicate that about 11.5 % of all residential flow occurs below 1/4 gpm, the AWWA low flow test rate for 5/8-inch water meters. Extrapolating research results above indicate that about another 9% of residential flow occurs between 1/4 and 3/4 gpm, the AWWA low flow test rate for a 1-inch water meter. This indicates that about 21% of all residential flow is not being accurately measured by a 1-inch mechanical water meter, the predominant meter size and type used by most consortium members in this Study.

The following three primary recent references address the quantitative value of unmeasured flow by mechanical water meters:

1. East Bay Municipal Utility District (EBMUD) Unmeasured Flow Study- D. Wallenstein (WSI, 2016): Unmeasured Small Mechanical PD Meter Flow is between 4-7%
2. 2016 Residential End Uses Study- Water Research Foundation Study: 11.5 % of Total Flow below ¼ GPM (M6 low test flow rate)
3. Calculation Proposal for the Economic Level of Apparent Losses (ELAL) in a Water Supply System- F. Arregui et. al. (2018 Spanish research): Initial Weighted Error of Small Mechanical Meters = 5%

The amount of unmeasured flow by mechanical water meters affects meter accuracy assumptions and apparent water loss determinations in the AWWA Free Water Audit Software (FWAS). Additionally, the amount and value of unmeasured flow affects meter life cycle costs, sometimes used in meter evaluation studies comparing meter types and meter manufacturers.

The EBMUD in California presented a paper in late 2016 on its Unmeasured Flow Study. This study used Sensus iPERL® meters and one-minute read interval endpoints to evaluate single family residential use within its study area. A major study finding was that unmeasured flow below the reading range of a typical PD meter varied from 4 to 7 percent of the total single-family residential use. For agencies using PD meters, this could result in a significant revenue loss from single family customers, based upon the agency's specific rate structure. An unmeasured water use component of 5 percent for single family residential PD meters is a good starting assumption until agency-specific information is determined. Measurement of ultra-low flow for single family customers is important to reduce apparent losses calculated in the AWWA manual M36 (Water Audits and Loss Control Programs, 4th Ed., 2016).

Factors Affecting Unmeasured Flow in Mechanical Water Meters

The amount of unmeasured flow experienced in a utility's water system is highly variable and dependent upon a number of factors specific to an individual water utility. Some of these factors include the following:

- Customer demand characteristics
- Residential plumbing conditions
- Plumbing/fixture leaks
- Delivered water quality
- Type of mechanical meter
- Age/condition of mechanical meter
- Water system pressure
- System operating conditions

More research is needed to better quantify the impacts of the above variables. Additionally, newer, static meters are designed to have a better flow range than mechanical meters of the same size, and many utilities are piloting newer designs and comparing results to determine specific historical unmeasured flow quantities.

Additional Relevant Meter Selection and Sizing References

The following list of references contains specific sources often referred to in this Technical Memorandum. Some references are provided as guidance for future meter sizing decisions based on recent research into existing peak customer demands and plumbing fixture counts used for larger meter sizing.

AWWA. 2016. *Water Audits and Loss Control Programs – AWWA Manual of Water Supply Practices M36 (4th Edition)*. N.p.: American Water Works Association / Colorado, 2016. Print.

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Appendix B. Technical Memorandum No. 2 - Next Generation Program Options Analysis

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SUBMISSION DRAFT

Meter Replacement Program Planning Study

Technical Memorandum No. 2
Next Generation Program Options Analysis

May 2020

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AMI	**Advanced metering infrastructure** includes the installation of a meter data collection network and the backhaul of metering data to a meter data management system.
AMR	**Automatic meter reading** is the automated collection of meter reads that still requires a meter reader to visit a property or be near a property.
API	**Application programming interface** is a software intermediary that allows two software applications to communicate.
AWS	**Amazon Web Services** is a comprehensive and broadly adopted cloud platform offering over 175 fully featured services from data centers globally.
AWWA	**American Water Works Association**
Backhaul	**Backhaul** is a method of transferring information from data collectors to the AMI headend system; options include Ethernet, fiber optics, landline telephone, broadband over power line, General Packet Radio Service, Cellular Digital Packet Data, Institute of Electrical and Electronics Engineers 802.11 (Wi-Fi), 802.16 (WiMAX), 802.15.4 (ZigBee), 802.15.3 (ultra-wideband), and most recently low-power wide-area networks.
CCA	**Cellular coverage analysis** includes the evaluation of cellular coverage radius and the coverage probability of an actual network and a network quality assessment.
CHWD	**Citrus Heights Water District**
Consortium	**Water Meter Replacement Program Consortium** includes Carmichael Water District, Citrus Heights Water District, City of Folsom, City of Sacramento, Fair Oaks Water District, Golden State Water Company, Orange Vale Water Company, Placer County Water Agency, the Regional Water Authority, Sacramento County Water Agency, Sacramento Suburban Water District, and San Juan Water District.
CSS	**Chirp spread spectrum**, in digital communications, CSS is a spread spectrum technique that uses wideband linear frequency modulated chirp pulses to encode information.
DCU	**Data collection unit**, also known as “collector,” “gateway,” and “base station,” is a data collection device installed throughout a network on infrastructure such as poles, buildings, water tanks, or towers to capture meter readings and transmit data to the AMI headend system; depending on signal propagation and internal data capacity capabilities, one DCU can be used for thousands of meter endpoints.

DMA	**District meter area** is a method in which a geographical area is divided into sections, and the flow of water that enters each section is checked against a theoretical flow of water.
Encoder	**Encoder** is a meter register specially equipped for automated meter reading (automated register).
Endpoint	**Endpoint** is a device that is connected by wires to an encoder and transmits digitized water use data to a meter reading system
FCC	**Federal Communications Commission** is an independent agency of the U.S. Government that regulates communications by radio, television, wire, satellite, and cable across the U.S.
FHSS	**Frequency-hopping spread spectrum** is a method of transmitting radio signals by rapidly changing the carrier frequency among many distinct frequencies occupying a large spectral band.
gpm	**gallons per minute**
GPRS	**General Packet Radio Service** is a packet-oriented mobile data standard on the 2G and 3G cellular communication network's global system for mobile communications and is a common backhaul option.
HES	**Headend system**, also referred to as the "meter control system," is hardware and software that receives meter data sent to the utility through meter reading technology.
IDT	**Informational Data Technologies**
IEEE 802	**Institute of Electrical and Electronics Engineers (IEEE)** standards for local area networks and metropolitan area networks (LAN/MAN); Examples of IEEE 802 networks are 802.11 (Wi-Fi), 802.16 (WiMax), 802.15.4 (Zigbee), and 802.15.3 (ultra-wideband).
IoT	**Internet of Things** is a growing system of interrelated computing devices and mechanical and digital machines provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
ISM	**Industrial, scientific, and medical** radio bands are portions of the radio spectrum reserved internationally for industrial, scientific, and medical purposes other than telecommunications.
ISO	**International Organization for Standardization**
IT	**Information technology**

LAN	**Local area network** is a computer network that interconnects computers within a limited area, such as a residence, school, laboratory, university campus, or office building.
LoRa	**Long range** is a low-power technology based on a communication technique, or modulation, that allows data to travel farther distances than traditional methods; it is derived from CSS technology.
LoRaWAN	**Long-range wide-area network**
LPWA	**Low-power wide-area**
LPWAN	**LPWA network** is a type of wireless telecommunication wide-area network designed to allow LoRa communications for relatively small amounts of data to be sent between connected objects; types of technologies include long-term evolution for machines (LTE-M), Sigfox, LoRa, and Narrowband IoT.
LTE	**Long-term evolution** is a standard for 4G wireless broadband technology for cellular device users.
LTE-M	**LTE-M** (also known as eMTC and Cat-M1) is a Low-Power Wide-Area Network (LPWAN) technology suitable for low-bandwidth IoT applications. LTE-M uses licensed spectrum just like NB-IoT.
M2M	**Machine to machine** is direct communication between devices using any communications channel, including wired and wireless.
MDM	**Meter data management** refers to software that performs long-term data storage and management for the quantities of data delivered by smart metering systems.
MHz	**Megahertz**
MRP	**Meter replacement program** is a proactive program for replacing water meters as they near the end of their life.
NA	**Not applicable**
NaaS	**Network as a service** is a business model for delivering enterprise-wide area network services virtually on a subscription basis.
NB-IoT	**Narrowband IoT** is a LPWAN radio technology standard developed by the 3rd Generation Partnership Project to enable a wide range of cellular devices and services; it focuses on indoor coverage, low cost, long battery life, and high connection density. Also see "Internet of Things."
O&M	**Operations and maintenance** is the care and minor maintenance of equipment required for metering system functionality.

OTA	**Over-the-air** updates is a term for wireless delivery of new software or code to cellular devices.
PCWA	**Placer County Water Agency**
PD	**Positive displacement** pertains to a mechanical meter type that consists of either a nutating disc, oscillating piston, turbine, or vertical turbine to measure flow.
psi	**pounds per square inch**
RF	**Radio frequency** refers to a wireless electromagnetic signal used as a form of communication in the range 10^4 to 10^{12} Hertz, which is suitable for use in telecommunication.
RFP	**Request for proposals**
RFU	**Remote firmware upgrade**, also known as "OTA updates."
SaaS	**Software as a service** is a software distribution model in which a third-party provider hosts software applications and makes them available to customers over the internet.
SCWA	**Sacramento County Water Agency**
SJWD	**San Juan Water District**
Solid-State Meter	**Solid-state meters** pass electromagnetic or ultrasonic signals through the flow of water to determine the flow rate and feature no moving parts.
SSWD	**Sacramento Suburban Water District**
Study	**MRP Planning Study**
TAC	**Technical advisory committee** includes technical staff members representing each Consortium agency.
WAN	**Wide-area network** is a telecommunications network that extends over a large geographical area for the primary purpose of computer networking.

Executive Summary

Meter and meter reading technologies have become increasingly digital and more complex in recent decades. These advancements have improved performance, accuracy, and efficiency. For example, newer meter designs specify increased accuracy at low and ultra-low flows. Automatic meter reading platforms offer improved access to data with fewer inconsistencies and greater granularity. Although at different rates of change, the Water Meter Replacement Program (MRP) Consortium (Consortium) agencies have evolved their meter programs to incorporate new technologies. However, the complexity of more digital hardware and systems makes this transformation challenging. Meter reading technologies are offered across a variety of communication networks and configurations. Although emerging technologies might be specified to offer superior performance and capabilities, Consortium agencies must have confidence that these technologies will function dependably and cost effectively in the field before they unseat the proven technologies the Consortium agencies depend on to provide reliable and affordable water service.

The purpose of Technical Memorandum No. 2 is to compare and contrast the proven and emerging meter and meter reading technologies that are currently available to Consortium agencies. It includes a detailed breakdown of key technology characteristics to provide a strong evidence base for future near- and long-term meter technology deployment decisions. This information will be combined with additional information collected during Phase 3, Meter Testing Program Strategy, and a propagation study (Recommendation 4) to inform strategic meter program decisions for Consortium agencies.

Meter Technologies

A detailed comparison of meter characteristics focuses on the differences between mechanical and solid-state meters. Consortium agencies predominantly deploy proven mechanical meter technologies, which have been commercially available for decades. In recent years, solid-state models, which feature onboard electronics instead of moving parts, have become commercially available. Emerging solid-state models are specified to register a wider range of ultra-low flows compared to mechanical meters. However, it is not currently known how much additional flow (and associated revenue) could be captured by deploying solid-state meters in place of existing mechanical ones. In addition, incremental changes in registered water use corresponds with a proportionally smaller change in revenue. For example, for small meters (one-inch or smaller), a one percent change in captured flow corresponds with a 0.3 to 0.8 percent change in revenue. This is because fixed charges represent a significant percentage of total billing for Consortium agencies.

Recommendation 1: Develop and Employ a Joint Request for Proposals for Consortium-Level Small Meter Purchasing. Significant cost savings could be achieved through joint meter purchasing at the Consortium level. Putting in place a large purchasing contract with common specifications could achieve more competitive unit pricing through economies of scale.

Recommendation 2: Establish a Consistent Meter Database Across Consortium Agencies. A consistent Consortium-level data collection and management system would enable individual agencies to make improved meter and meter reading investment decisions. Meter testing data will be beneficial at the Consortium level, but it should be coupled with deployment data to yield maximum value so that agencies can associate test results with context, age, and flow characteristics.

Recommendation 3: Establish a Consortium-Wide Meter Pilot Program. Emerging meter technology specifications provided by vendors must be validated in real-world operating conditions. An evaluation program that leverages the tools, capabilities, context, and interests of all Consortium agencies could be established to foster a more efficient cross-agency adoption of emerging meter technologies. This could be done by establishing a consistent process that combines bench testing, pilot deployments, data collection and data dissemination across the Consortium (also see Recommendation 2).

Meter Reading Technologies

Currently, the proven and commonly deployed advanced metering infrastructure (AMI) systems are offered through radio frequency (RF)-based fixed networks or cellular networks. Emerging technologies, such as next generation cellular technologies (e.g., Narrowband Internet of Things [NB-IoT] and 5G) and low-power wide-area network (LPWAN) technologies, will drive future anticipated improvements in AMI systems, such as lower data transmission costs, better battery performance, and the ability to connect more IoT devices across an AMI network. Automated meter reading using satellite communication is another emerging option. However, this technology has connectivity limitations in urban service areas and has yet to be cost-effectively deployed.

A detailed comparison was conducted of fixed network RF systems by Neptune, Mueller, Sensus, Aclara, Itron, and Zenner and the cellular network system by Badger. Utility-owned fixed network RF systems require the agency to manage the data transmission infrastructure. In contrast, cellular networks are managed by the service provider through existing cellular networks, such as AT&T. Cellular networks may be advantageous in places where there are limited opportunities to place data transmission infrastructure or to avoid large capital expenditures. With the exception of the Aclara fixed network RF system, meter reads can be collected through drive-by as a backup to the other fixed network RF systems.

The analytics offered by each of the evaluated options at no additional cost and regardless of the meter manufacturer include detection of suspected customer leaks, reverse flows, other tamper alerts, errors or invalid reads, and other types of network diagnostics. Enhanced features, such as register replacement or low battery alarms and empty pipe notifications, are more likely to only be available to the meter models specific to the AMI provider. Vendors may be willing to extend these features to other meter vendors if a strong business case is provided to them by a customer (or a group of customers). For example, Badger is in the process of extending its Advanced Protocol functionalities to Neptune Mach-10 meters by late 2020.

There are potential advantages to explore through meter reading collaborations across Consortium agencies. One such option is the opportunity to secure cost savings through joint purchasing and/or sharing of hardware, software, operations, and maintenance resources. Many Consortium agencies have already deployed meter reading systems. Existing infrastructure across the Consortium service area may be capable of supporting other Consortium agency meter reading systems.

Recommendation 4: Conduct a Consortium-Level Propagation Study. As a next step in the MRP Planning Study, a Consortium-scale propagation study should be conducted. A propagation study determines the required hardware components to achieve the service requirements for reading the meters of a larger, multi-agency area. The propagation study will assess opportunities for the Consortium to leverage existing hardware or share new hardware. Agencies that deploy the same AMI system(s) could secure cost savings through Consortium-pricing for hardware, software, and service agreements. The consulting team will use the results of the propagation study to collect detailed cost information and to assess the benefits of different collaboration opportunities. The cost data will be organized in capital, operations, and maintenance categories.

Recommendation 5: Conduct a Consortium Approach to Piloting Emerging Technologies. Newer meter reading technologies, such as LPWANs, are available but not yet widely deployed. Similar to solid-state meter technologies, some Consortium agencies are positioned to pilot new meter reading technologies without great additional cost. Joint pilot initiatives could help align future AMI deployments across the Consortium.

Recommendation 6: Develop a Consortium-Wide Analytics Program. Deploying AMI meter reading platforms provides a number of benefits beyond the basic ones that relate to the shift from manual to automated meter reading. In addition to near real-time consumption data, which is significantly more actionable than data collected on a monthly or less frequent basis, AMI systems allow for the monitoring of the network's data collection and transmission components in near real-time. Additional analytics tools can be implemented across AMI communication networks, including distribution system sensors for leaks, pressure, and water quality. Taking advantage of these capabilities can require significant effort, but Consortium agencies have the opportunity to leverage collective experiences and develop common processes. This may allow Consortium agencies to assimilate a larger number of benefits more quickly and cost effectively. For example, standardized reporting could lead to a consistent meter-related apparent water loss reporting process.

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Section 1 Study Overview

1.1 Introduction

The Meter Replacement Program (MRP) Planning Study (Study) presents a unique opportunity for neighboring water agencies in the greater Sacramento area to explore the potential benefits of working together. Water MRP Consortium (Consortium) agencies understand that the utilities of the future will operate in a different paradigm—one that is largely built on public and stakeholder trust, along with cooperation and collaboration with adjoining entities with common interests (Figure 1). The purpose of the Study is as follows:

- Develop a strategy for the replacement of the first generation of water meters for some participating water agencies or next generation for others.
- Determine the feasibility and a strategy, as appropriate, for long-term, full, or partial integration of MRPs for participating water agencies.

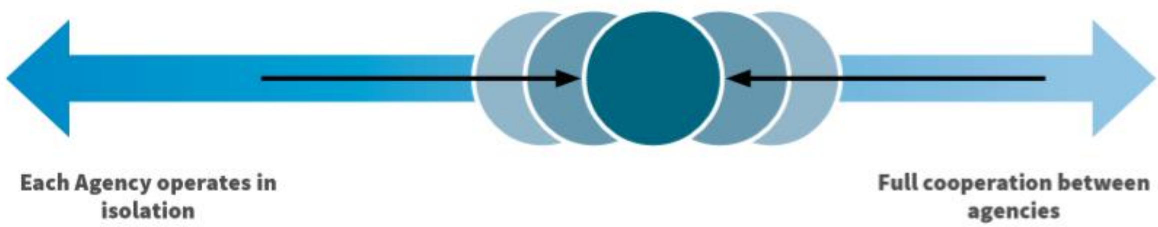

Figure 1. The purpose of the Study is to determine how participating agencies can sensibly integrate their meter programs over time.

Agencies participating in the Study include the following:

- Citrus Heights Water District (CHWD)
- City of Folsom
- City of Sacramento
- Golden State Water Company
- Placer County Water Agency (PCWA)
- Sacramento County Water Agency (SCWA)
- Sacramento Suburban Water District (SSWD)
- San Juan Water District (SJWD)

Agencies that are members of the Consortium but are not directly participating in the Study include the following:

- Carmichael Water District
- Fair Oaks Water District

- Orange Vale Water Company
- Regional Water Authority

Meter programs are composed of a collection of hardware, software, and skilled professionals that are organized into an integrated set of systems (i.e., data collection, meter reading, billing, operations, and maintenance). Fundamentally, water meters are used to obtain information on the flow of water at particular locations in a water distribution system. The purpose of this information has historically been to support customer billing. Thus, the water meter is often considered to be the "cash register" of the water utility. In recent years, this data has come to serve additional important purposes, including leak reduction, water auditing, regulatory compliance, demand management, and operational efficiency. Water meter programs have evolved over time to serve these various functions. Methods for collecting and using meter data have become more advanced and automated. These changes require skill sets to evolve with them.

The meter program for any agency will be unique because of the specific context, priorities, and needs of the community it serves. First, the Study will provide guidance on opportunities to match technologies and business models with the specific context of each agency. Secondly, the Study will look across agencies to identify where contexts and interests align. These will be the areas in which the Study will explore specific opportunities for collaboration between agencies. Some possible areas of meter program collaboration that will be investigated over the course of the Study include operations and maintenance (O&M) of different hardware and software, installation, testing, customer service, leak detection, and compliance monitoring systems (Figure 2).

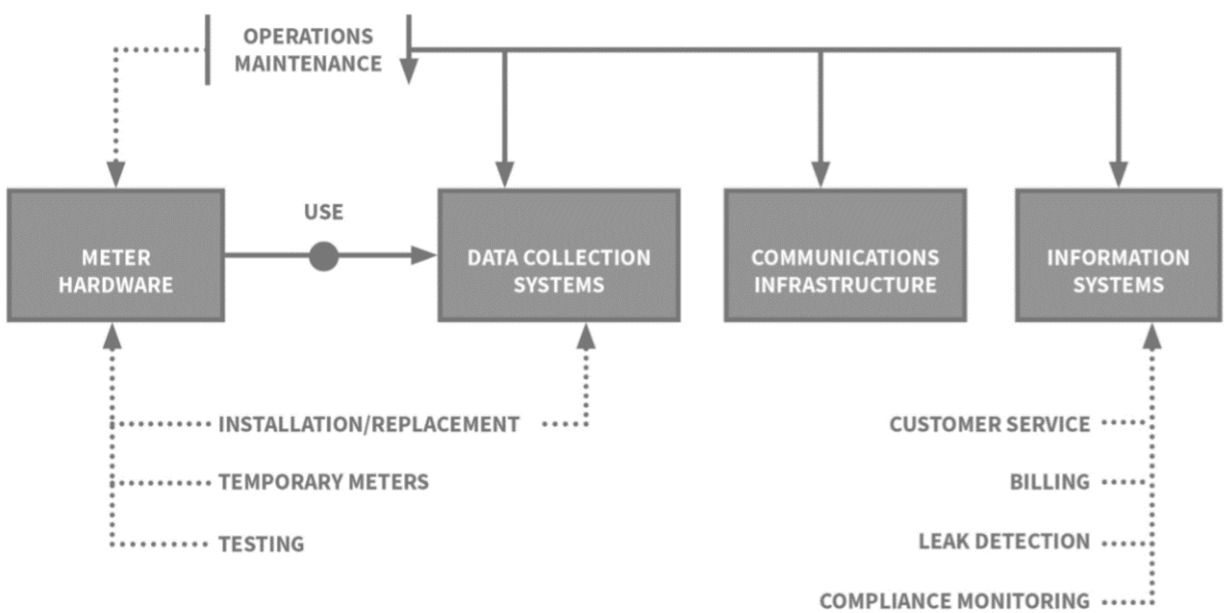

Figure 2. Elements of a meter program, including the efforts required to operate, maintain, and optimize the systems, and ancillary efforts, such as customer service, billing, and compliance monitoring.

The Study will explore several specific opportunities for sensible meter program integration, including the following:

- **Capital –** Sharing large capital investments, such as communications towers
- **Common software platforms –** Greater potential for collaboration
- **Equipment –** Sharing testing or other high-value items
- **Lessons learned –** Higher performance at the regional scale
- **Redundancy –** Increased collaboration, making it easier to react and respond to risk
- **Shared inventory –** Cost savings and quicker access to inventory
- **Staffing –** A deeper and more consistent pool of relevantly skilled staff in the greater Sacramento area

The consulting team is composed of the following firms:

- **Harris and Associates –** Serves as the consulting team lead with project management and financial analysis responsibilities
- **Isle Utilities –** Provides meter technology expertise
- **Laura Mason-Smith –** Provides public outreach expertise for CHWD and SJWD customer engagement
- **M.E. Simpson and Company –** Provides water meter hardware, software, and testing expertise

1.2 Overview of Study Phases

The Study is organized as follows, with a technical memorandum accompanying each of the first six phases (Figure 3):

- **Phase 0, Consortium-Level Opportunities Assessment –** A pre-contract process for understanding the needs and priorities related to each participating agency's meter program to understand how the Study can best serve each agency.
- **Phase 1, Individual Agency Assessment –** An investigation of each participating agency's current inventory and a financial assessment for each of their deployed meter fleets. Data collection and presentation will be assembled in a standardized format for participating agencies.
- **Phase 2, Next Generation Program Options Analysis –** An investigation of different options for meter technology, vendors, and accompanying meter specifications. This phase will include a detailed evaluation of the top meter vendors that are relevant to the Sacramento area according to criteria set by the participating agencies.
- **Phase 3, Meter Testing Program Strategy –** A review of each participating agency's current water meter testing program and available water testing facilities (in-house and regional). Opportunities for Consortium-level collaboration will be researched in this phase to identify the feasibility of joint meter testing options.

- **Phase 4, Implementation Strategy –** A blueprint for action that participating agencies will employ to guide policies, programs, projects, and tasks associated with a shift toward meter program collaboration. The implementation strategy will be developed as a "to-do list" for policy leaders and program managers to follow and implement the recommendations of the Study.
- **Phase 5, Long-Term Planning –** Development of tools and a strategy for planning for future generations of meter replacements, both at the individual agency level and at the Consortium level. This will include replacement timing and phasing, financial implications, and best practices.
- **Phase 6, Final Report –** A compilation of the entire set of technical memorandums (No. 1–6) and an executive summary.
- **Phase 7, Public Outreach –** Ongoing support for public engagement over the course of the Study.

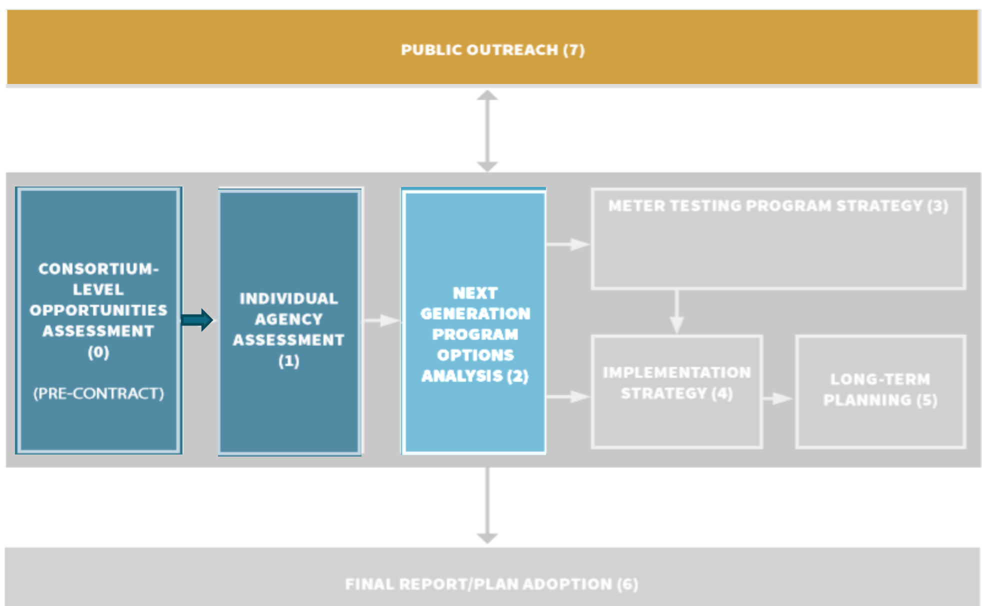

Figure 3. The Study is composed of seven phases. As shown, this technical memorandum (No. 2) pertains to work completed under Phase 2, Next Generation Program Options Analysis.

Section 2 Phase 2 Introduction

2.1 Purpose

The purpose of Phase 2 was to support the Consortium agencies in their evaluation of different meter and meter reading technologies. In addition to offering insights into technology trends and differences between advanced metering infrastructure (AMI) solution offerings, this phase gave Consortium agencies the opportunity to share feedback regarding their experience with meters, meter reading, and meter data management (MDM) products and solution providers. The outcomes of Phase 2 summarized in this technical memorandum will provide Consortium agencies the ability to assess specific meter and meter reading options. The next step for meter technologies will be to conduct a joint meter purchasing request for proposals (RFP) and a Consortium-level propagation study. These steps will enable Consortium agencies to fully assess the costs and benefits of selected solutions, including the ability to leverage economies of scale from the Consortium perspective.

2.2 Overview

This technical memorandum provides salient information from the Phase 2 activities and outcomes as a basis for subsequent phases of the Study. Because Consortium agencies are at different stages of meter technology deployment, Phase 2 began with an overview of the advanced metering technology landscape, including trends in meter reading technologies, supporting software, and major solution providers. A comparative evaluation of well-positioned vendors was conducted to help participating agencies consider opportunities to maximize investments in equipment, capital, software, and staffing through a more collaborative approach to meter program decision-making. The Phase 2 scope of work included the following activities:

- Review trends in meter technology, including meter reading systems and software solutions
- Identify the predominant solution providers of meter technology in the U.S. market
- Compare a subset of vendors against performance criteria of interest to the Consortium

2.3 Methodology

2.3.1 Meter Technologies

This section provides an overview of meter technologies with a focus on the key differences and tradeoffs between the more predominantly deployed mechanical meter options compared to the emerging solid-state models. Meter technologies were compared in terms of specified form, function, warrantied performance, and retail price.

2.3.2 Meter Reading Technologies

This section presents an overview of meter reading technologies with a focus on the key differences between the most predominantly deployed types of automatic meter reading (AMR) and AMI systems and the current trends in these technologies. The overview covered the standard components of meter reading systems and the key tradeoffs between systems, including infrastructure requirements, system redundancy, and communication signal strength. Meter reading technologies are organized into two groups: proven and emerging. The proven technologies included radio frequency (RF) fixed network and cellular systems. Emerging technologies include the next generation (5G) cellular, low-power wide-area (LPWA) technologies, and satellite systems.

2.3.3 Comparative Vendor Evaluation

This section provides a detailed comparison of the most commonly deployed meter reading platforms selected by the Consortium. During the Technical Advisory Committee (TAC) 2.1 workshop, Consortium agencies shared information about their respective meter programs and prioritized performance characteristics for meter technologies. Each agency was given 21 points to allocate across the following six categories of metering solution characteristics:

- **Accuracy –** The degree to which the water meter can correctly convey the quantity of water that flows through it.
- **Simplicity –** The ability of a system to operate with minimal required infrastructure and O&M while still delivering reliable service.
- **Reliability –** The ability to ensure proper functioning and decrease single point of failure. This includes long life of components, secure data storage protocols, and data loss prevention.
- **Responsiveness –** The ability to include analytics or instrumentation as turnkey features that support the monitoring of the AMI system. This may include leak detection, high-flow detection, remote shutoff or turn-on, pressure monitoring, reverse flow alarms, and tampering detection and alerts.
- **Flexibility –** The ability to integrate with other components and information systems. This includes both physical components like meters and information and data management systems (e.g., customer portals and billing software).
- **Redundancy –** The ability to deliver water use data from the meter to the agency by providing multiple communication pathways and providing alternatives and/or back up options so that information is preserved and transmitted in any event or case of failure.

Additionally, the Consortium agencies discussed drivers of meter purchasing decisions, meter reading technology decisions, concerns about existing and future meter program components, system capabilities they are most excited about, and agency-specific objectives for the Study. A summary of the information captured during this session can be found in Appendix A.

The feedback collected during this session provided a basis for selecting the subset of seven vendors and the eight evaluation criteria used to compare them. The vendors and evaluation criteria are detailed in Section 5, Meter Reading System Evaluation, of this technical memorandum.

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Section 3 Meter Technologies

Water utilities use water meters to measure and record the amount of water delivered to customers. Water meters are available in several sizes in order to connect to service lines that vary in size. Meters for single-family residences typically range from 5/8 inch to one inch (Figure 4). Meters for multi-family residences and small commercial uses typically range from 1.5 inches to two inches. Commercial and industrial uses typically range from three inches to 12 inches or larger. Meters are paired with a register, which displays the meter reading and converts the reading to a digital form that can be transmitted to a meter reading system. The deployed meter inventories by meter size are provided in Technical Memorandum No. 1. There is potential for Consortium agencies to achieve cost savings through joint purchasing of residential meter hardware and joint meter reading. This section describes the primary residential water meter models in the U.S. market and contrasts their differences. The focus of this section is to compare and contrast proven mechanical meter technologies with emerging solid-state options.

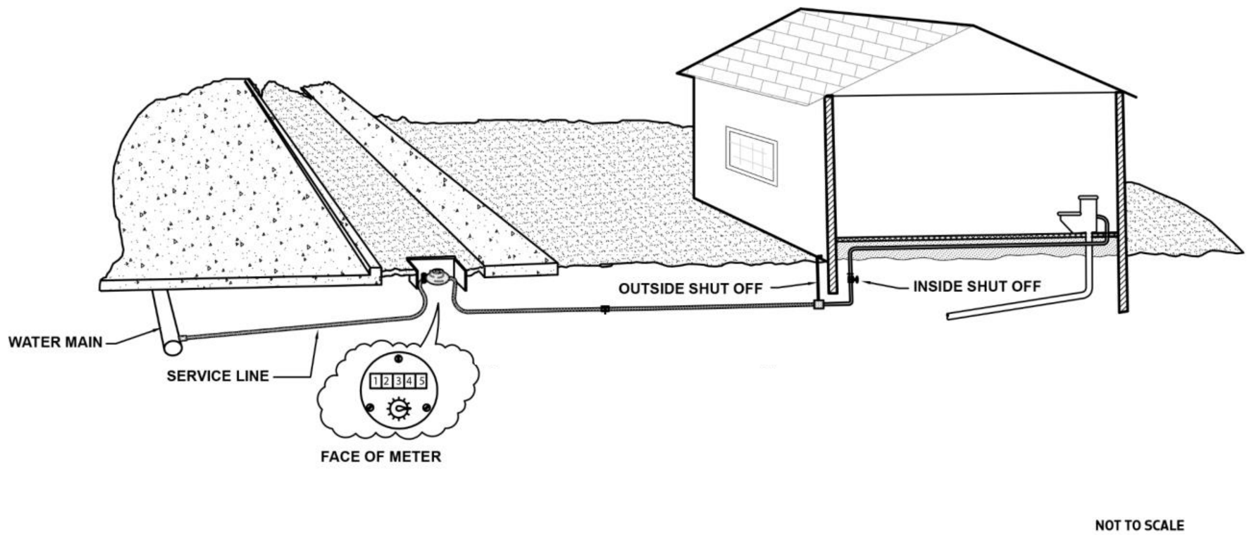

Figure 4. A common residential water meter measures the amount of water that flows from the water utility to the customer.

Mechanical meters have been widely deployed by several Consortium agencies for decades. These technologies have undergone several generations of iterations. As a result, a more complete dataset on performance and service life exists. By comparison, there are few solid-state meters, particularly in the smaller sizes (two inches and smaller) that have been deployed over their complete warrantied service life.

Mechanical meters function by moving water through a chamber in fixed quantities. These meters count the rate at which these known quantities pass through them. Mechanical meters have been in service for over 100 years and represent the predominant meter type for Consortium agencies.

The most commonly deployed models among the Consortium are the Sensus SRII, the Badger Recordall Disc, the Neptune T-10, and the Zenner PPD Magnetic Drive.

To measure the flow of water, mechanical meters require moving parts that can wear over time. As a result, it is possible for mechanical meters to degrade in performance over time, though performance changes (including accuracy) can depend on other factors, including water quality, environmental conditions, type of technology, and component materials. Mechanical meters have replaceable mechanical and battery-powered registers. If these registers fail, they can be removed without replacing the entire meter.

In recent years, meter vendors have developed solid-state technologies that do not rely on any moving parts, which are not as susceptible to mechanical wear and tear compared to mechanical meters. Solid-state meters pass electromagnetic (EM) or ultrasonic (US) signals through the flow of water to determine the flow rate. These types of meters require onboard electronics in order to function. Solid-state meters are constructed with integrated and non-removable registers. This is because the electronics required to measure flow are calibrated to each individual meter and cannot be substituted without recalibration. Solid-state meters for residential use have been commercially available for approximately 10 years. Solid-state meters require power to function. When the battery fails, the meter is no longer usable and must be replaced.

The following types of meters are included in the inventories of participating agencies:

- **Positive Displacement (PD) –** A mechanical meter type consisting of either a nutating disc or an oscillating piston to measure flow. A nutating disc meter has a disc mounted to a central ball. When fluid enters the chamber, it causes the disc to wobble (nutate). An oscillating piston meter uses a precision-machined chamber containing a cylindrical piston that oscillates as liquid flows through it. The nutations and oscillations are directly transferred to the register, which is calibrated to units of flow.
- **Solid-State** – Solid-state or static meters use EM or US signals to measure the flow of water through a meter. These types of meters have no moving parts and require onboard electronics powered by a built-in battery.

The following sections present key characteristics of meters and the primary differences between mechanical and solid-state models commercially available to Consortium agencies.

Composition – In general, meter models are available in bronze, stainless steel, or composite configurations that include metal and plastic components (Table 1). Composite or polymer models can be less expensive than metal ones. The solid-state meter options currently available (in 2020) in copper alloy are the Neptune Mach 10, Mueller Solid State, and Zenner Stealth models.

Table 1. Casing Information for One-Inch Meters Commonly Available to Consortium Agencies

Meter	Casing Material
Badger E-Series (US)	Stainless steel
Badger E-Series (US)	Composite polymer
Badger E-Series (US)	Composite polymer or stainless steel
Badger Recordall Disk 55 PD)	Copper alloy
Kamstrup flowIQ 2250 (US)	Composite polymer
Kamstrup flowIQ 3101 (US)	Composite polymer with fiberglass reinforcement
Master Meter (PD)	Copper alloy
Master Meter Sonata (US)	Composite polymer
Mueller 452 Series Magnetic Drive (PD)	Copper Alloy
Mueller Solid State (US)	Copper alloy body & polymer measuring tube
Neptune Mach 10 (US)	Copper alloy
Neptune T-10 Residential (PD)	Copper alloy
Sensus accuSTREAM (PD)	Composite polymer
Sensus iPERL (EM)	Composite polymer
Sensus SR II Water (PD)	Copper alloy
Zenner PPD Magnetic Drive (PD)	Copper alloy
Zenner Stealth (US)	Copper alloy or stainless steel body, polymer measuring tube

Maximum Operating Pressure – This is the highest pressure that a meter can withstand and continue to function to specifications. Water meters must be selected to perform under the range of operating pressures occurring in a water agency’s distribution system. Many, but not all, solid-state meters provide higher pressure ratings than mechanical meters. Where mechanical meters have a maximum operating pressure of 150 pounds per square inch (psi), some solid-state models can operate up to 200 and even 250 psi (see Table 2). In typical distribution networks, it is rare for meters to be subject to pressures greater than 150 psi.

Maximum Continuous Flow – This is the largest flow rate that a meter can withstand and continue to function to specification. In California, minimum fire flow requirements have become an important factor in the selection of residential water meters because of revisions to the California Fire Code (2019). As a result, combined fire sprinkler and peak domestic water demand warrant a one-inch water meter due to its Safe Maximum Operating Capacity of 50 gallons per minute (gpm). Prior to that, the common meter size for residential connections was 5/8- or 3/4-inch, with a Safe Maximum Operating Capacity of 20 gpm. This smaller flow capacity is sufficient to provide typical single-family residential peak domestic use and variable land irrigation use.

Pressure Loss – This is the reduction in pressure across the meter. Larger pressure losses reduce efficiency and increase expenses. Pressure loss by meter and meter type varies and is generally lower for solid-state meters compared to PD models, particularly at higher flow rates. One exception, is the Badger Disc Series 55 PD meter, which has comparable pressure loss specifications to many of the solid-state models.

Table 2. Flow and Pressure Characteristics of One-Inch Meters Available in the U.S.

Meter	Pressure Loss (at 25 gpm)	Pressure Loss (at maximum flow)	Maximum Continuous Flow (gpm)	Maximum Operating Pressure (psi)
Badger Disc Series 55 (PD)	1.5	6.5	55	150
Badger E-Series (US)	1.8	6.8	55	175
Kamstrup flowIQ (US)	1.0	4.0	55	250
Master Meter (PD)	2.0	7.9	50	150
Master Meter Sonata (US)	Not listed	Not listed	55	175
Mueller 452 Series Magnetic Drive (PD)	2.0	8.0	50	150
Mueller Solid-State (US)	1.5	Not listed	55	200
Neptune Mach 10 (US)	2.5	10.6	55	175
Neptune T-10 Residential (PD)	2.5	8.0	50	150
Sensus accuSTREAM (PD)	3.7	13.0	50	150
Sensus iPERL (EM)	2.0	7.8	55	150
Sensus SR II Water (PD)	2.0	7.3	50	150
Zenner PPD Magnetic Drive (PD)	2.2	8.5	50	150
Zenner Stealth Meter (US)	Not listed	5.5	55	225

Accuracy – This is a measure of how well a meter is able to read and record the actual flow of water through it. The mechanical and solid-state meters in Table 3 are specified to meet American Water Works Association (AWWA)/American National Standards Institute C700/710 performance standards, which are intended to apply to mechanical meters (Figure 5). New standards (AWWA/American National Standards Institute C715) have been developed for solid-state meters. Low- and normal-flow accuracy requirements are different for mechanical and solid-state meters. Solid-state meters have a larger "normal" accuracy range than mechanical meters. While providing similar accuracy compared to mechanical meters at nominal and high-flows, solid-state meters are specified to provide increased accuracy at lower flow rates and register lower (ultra-low) flows. For example, one-inch solid-state meters are required to provide accuracy of 100 percent +/− 1.5 percent) for flow down to 0.4 gpm or lower in some cases. Mechanical models compare similarly to one another with the exception of the Badger Recordall Disc 55 meter, which is specified to provide better accuracy at lower flow rates. This model's normal accuracy range extends to 0.5 gpm compared to other PD meters, which extend to 0.75 gpm.

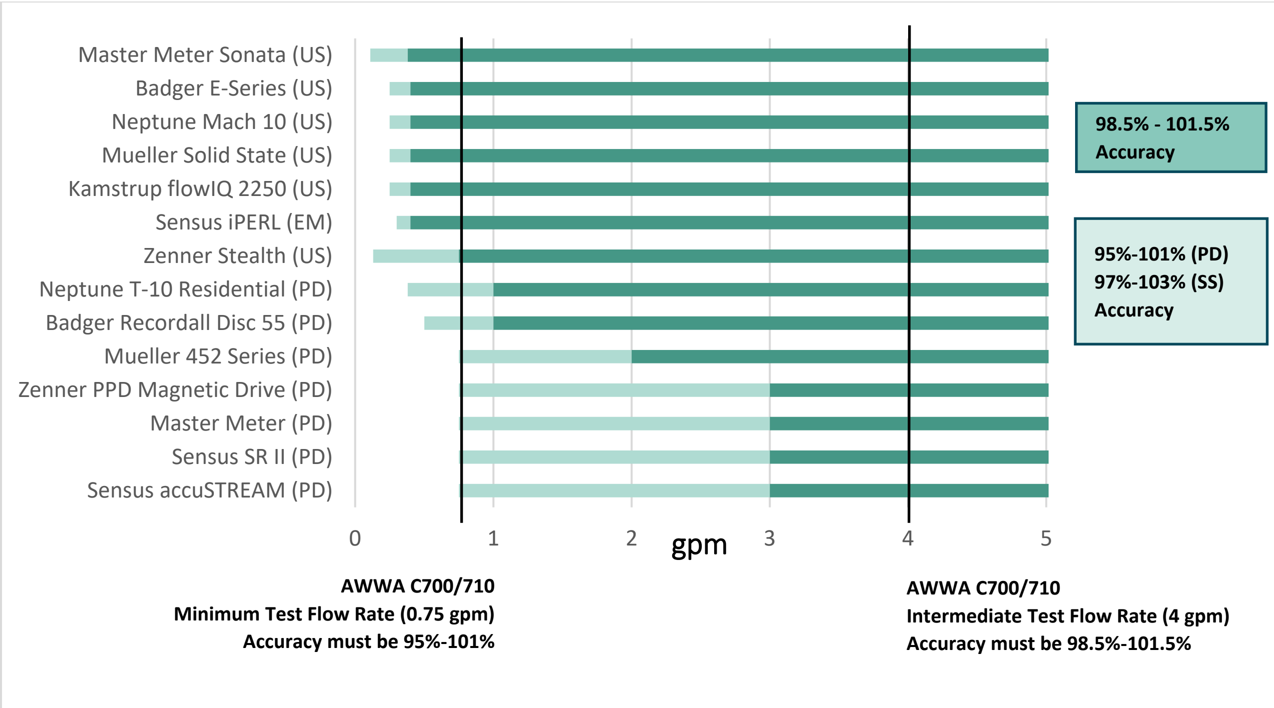

Figure 5. One-inch solid-state (SS) meters are specified to provide increased accuracy at lower flow rates compared to mechanical (PD) meters. Models shown are specified to meet AWWA test requirements for one-inch meters.

Warranties – Mechanical meters have two types of warranties. A new meter warranty typically covers the first five years (or a certain total flow through the meter) from the date of purchase. The Zenner PPD meter is an exception and covers the first 15 years. New meter warranties apply the AWWA normal test flow limits, which are 100 percent +/− 1.5 percent. Repaired meter warranties apply the lower AWWA repaired test flow limits, which are a minimum of 90 percent at the minimum flow rate. A repaired meter warranty typically covers 15 years (or a certain total flow through the meter). Solid-state new meter accuracy warranty periods are longer than those of mechanical meters and range between 15 and 20 years (Figure 6).

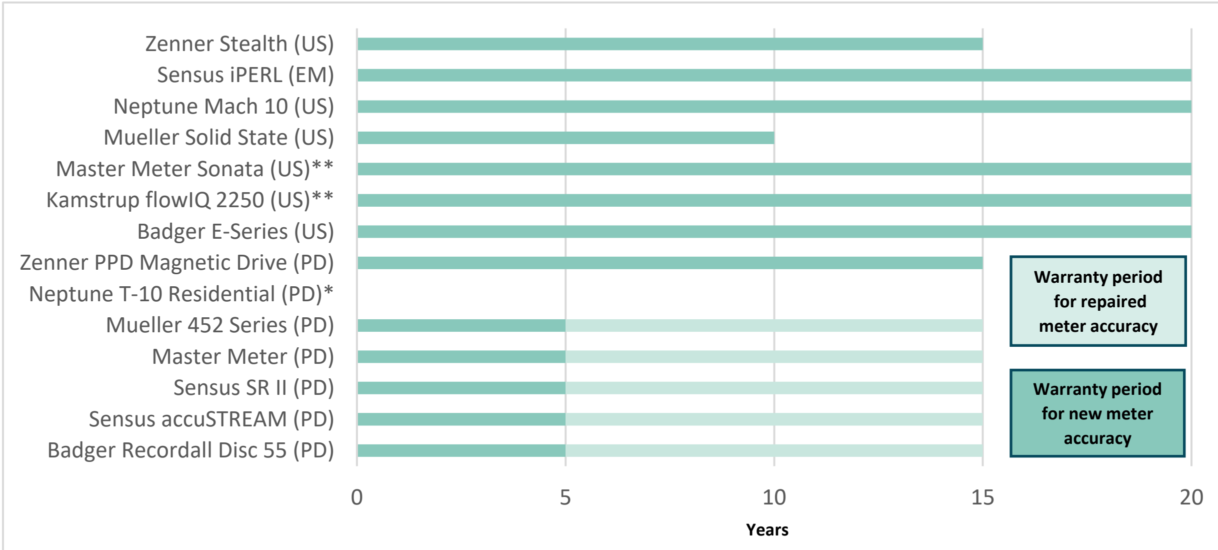

Figure 6. Mechanical meters have two types of warranties: new and repaired. Repaired warranties are associated with reduced accuracy requirements compared to new warranties. Solid-state meters only come with new warranties.

**The new warranty is for one million gallons of total flow, and the repaired warranty is for three million gallons.*

*** The warranty is prorated. Full replacement value for the first 10 years with a decreasing percentage for years 11–20.*

Meters also come with warranties for their casings and electronics. The casing warranty covers the integrity of the body of the meter. Most mechanical (PD) meters come with a 25-year casing warranty, although Mueller is an exception with a 15-year casing warranty. Solid-state meter casing warranties range between 15 and 20 years.

Electronics and register warranties range between 10 and 25 years but are predominantly 20 years (10-year full replacement value then a decreasing percentage for years 11–20). In addition to any onboard electronics (for solid-state meters), the electronics warranty also covers the battery and the register/encoder. The Badger Recordall Disc 55 and Zenner PPD mechanical meters notably come with 25-year register and electronics warranties. The Master Meter Sonata solid-state meter notably comes with a full 20-year register and electronics warranty.

Table 3. Accuracy and Warranty Information for One-Inch Meters

	Accuracy Information					Warranty Information			
	Low Range			Normal Range					
Model	Rate (gpm)	Repaired	New	Rate (gpm)	New and Repaired	Accuracy, New	Accuracy, Repaired	Casing	Register, Battery, Electronics
Badger E-Series (US)	0.25–0.4	NA	97%–103%	0.4–55	98.5%–101.5%	20 years	NA	20 years	10 years – 100% 11–20 prorated
Badger Recordall Disc Series 55 (PD)	0.5–1	Min. 90%	Min. 95%	1–55	98.5%–101.5%	5 years or 1.1 million gallons	15 years or 3.25 million gallons	25.5 years	25.5 years
Kamstrup flowIQ 2250 (US)	0.25–0.4	NA	97%–103%	0.4–55	98.5%–101.5%	10 years – 100% 11–20 prorated	NA	Not Listed	10 years – 100% 11–20 prorated
Master Meter (PD)	0.75–3	Min. 90%	Min. 95%	3–50	98.5%–101.5%	5 years or 1.1 million gallons	15 years or 3.25 million gallons	25 years	15 years
Master Meter Sonata (US)	0.11–0.38	NA	97%–103%	0.38–55	98.5%–101.5%	10 years – 100% 11–20 prorated	NA	20 years	10 years – 100% 11–20 prorated
Mueller 452 Series (PD)	0.75–2	Min. 90%	Min. 95%	2–50	98.5%–101.5%	5 years or 1 million gallons	15 years or 3 million gallons	15 years	10 years – 100% 11–20 prorated
Mueller Solid State (US)	0.25–0.4	NA	−5% +/−1.5%	0.4–55	98.5%–101.5%	10 years	NA	15 years	10 years – 100% 11–20 prorated
Neptune Mach 10 (US)	0.25–0.4	NA	97%–103%	0.4–55	98.5%–101.5%	20 years	NA	20 years	10 years – 100% 11–20 prorated
Neptune T-10 (PD)	0.38–1	Min. 90%	Min. 95%	1–50	98.5%–101.5%	1 million gallons	3 million gallons	Lifetime	10 years
Sensus accuSTREAM (PD)	0.75–3	Min. 90%	95%-101%	3–50	98.5%–101.5%	5 years or 1 million gallons	15 years or 3 million gallons	25 years	Standard – 25 years Encoder, 10 years
Sensus iPERL (EM)	0.3–0.4	NA	97%–103%	0.4–55	98.5%–101.5%	20 years	NA	10 years – 100% 11–20 prorated	

Table 3. Accuracy and Warranty Information for One-Inch Meters

Model	Accuracy Information					Warranty Information			
	Low Range			Normal Range					
	Rate (gpm)	Repaired	New	Rate (gpm)	New and Repaired	Accuracy, New	Accuracy, Repaired	Casing	Register, Battery, Electronics
Sensus SR II (PD)	0.75–3	Min. 90%	95%–101%	3–50	98.5%–101.5%	5 years or 1 million gallons	15 years or 3 million gallons	25 years	Standard – 25 years Encoder, 10 years
Zenner PPD Magnetic Drive (PD)	0.75–3	NA	95%–101%	3–50	98.5%–101.5%	15 years or 3 million gallons	NA	25 years	25 years
Zenner Stealth (US)	0.13–0.75	NA	95%–105%	0.75–55	98.5%–101.5%	15 years	NA	15 years	10 years

Additional Considerations – Without a controlled study, it is not currently known how much additional flow could be captured by solid-state meters as a result of their increased accuracy at ultra-low flows. Moreover, each agency has a different customer base, with specific water use patterns. For Consortium agencies, incremental changes in registered water use as a result of increased water meter accuracy corresponds with a proportionally smaller increase in revenue. For residential meters, a one percent change in captured flow corresponds with a 0.3 to 0.8 percent change in revenue (see Table 4). This is because fixed charges represent a significant percentage of total billing for Consortium agencies.

Table 4. Changes in Revenue Associated with Changes in Registered Use for Small Meters (One-Inch or Smaller)

Agency	Total Annual Use in CCF (2018)	Average Annual Use per Connection in CCF (2018)	Additional Annual Revenue (+1% Use)	Additional Annual Revenue per Connection (+1% Use)	Percent Increase in Revenue (+1% Use)
CHWD	3,419,278	184	$40,437	$2.17	0.3%
City of Folsom	4,292,280	211	$52,137	$2.56	0.6%
City of Sacramento	15,340,528	126	$223,972	$1.84	0.3%
PCWA	10,133,124	297	$180,861	$5.29	0.5%
SCWA	8,084,461	161	$180,888	$3.61	0.8%
SJWD	4,060,756	403	$35,979	$3.50	0.3%
SSWD	8,379,064	209	$80,310	$2.00	0.3%

Notes: CCF = hundred cubic feet; CHWD = Citrus Heights Water District; PCWA = Placer County Water Agency; SCWA = Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Water agencies that are considering deploying solid-state meters can compare their potential benefits in the form of additional revenue against potential increases in meter cost. This comparison can definitively be made using the final negotiated meter pricing through an RFP process. For the purpose of general comparison, 2020 retail prices for select one-inch meters available in the U.S. that meet fire flow requirements is shown to vary between $148.84 and $343.75. The Zenner and Badger meter models are the most competitively priced at the retail level. Many models come with 10-year encoder warranties. Retail pricing with warranty information is shown in Table 5. This data is provided for illustrative purposes and was not collected using a public bidding process for specific quantities. There is no real trend between mechanical and solid-state meters.

A key difference to consider is that registers and encoders can be replaced for mechanical models, while solid-state meters have non-replaceable registers and encoders. Consequently, if there is a register-related failure, the usable life of mechanical meters can be extended by replacing the meter. This is not the case with solid-state meters. However, mechanical models are available, including the Badger Recordall Disc 55 and PPD Magnetic Drive, with 25-year electronics/register warranties that extend well beyond their accuracy warranties. Thus, it should be possible to deploy meter registers that are warrantied to function over the useful life of a mechanical meter.

Table 5. Retail Pricing for Select One-Inch Residential Meters with Warranty Information

Model	Retail Price	Warranty Information			
		Accuracy, New	Accuracy, Repaired	Casing	Register, Battery, Electronics[1]
Zenner PPD Magnetic Drive (PD)	$148.84	15 years or 3 million gallons	NA	25 years	25 years
Zenner Stealth (US)	$173.00	15 years	NA	15 years	10 years
Badger Recordall Disc 55 (PD)	$183.40	5 years or 1.1 million gallons	15 years or 3.25 million gallons	25.5 years	25.5 years
Badger E-Series (US)	$190.75	20 years	NA	20 years	10 years – 100% 11–20 prorated
Mueller 452 Series (PD)	$222.00	5 years or 1 million gallons	15 years or 3 million gallons	15 years	10 years – 100% 11–20 prorated
Master Meter (PD)	$222.52	5 years or 1.1 million gallons	15 years or 3.25 million gallons	25 years	15 years
Master Meter Sonata (US)	$224.09	10 years – 100% 11–20 prorated	NA	20 years	10 years – 100% 11–20 prorated
Sensus iPERL (EM)	$254.00	20 years	NA	10 years – 100% 11–20 prorated	
Mueller Solid State (US)	$307.00	10 years	NA	15 years	10 years – 100% 11–20 prorated
Sensus accuSTREAM (PD)	$307.50	5 years or 1 million gallons	15 years or 3 million gallons	25 years	Standard – 25 years Encoder, 10 years
Sensus SR II (PD)	$307.50	5 years or 1 million gallons	15 years or 3 million gallons	25 years	Standard – 25 years Encoder, 10 years
Kamstrup flowIQ 2250 (US)	$330.00	10 years – 100% 11–20 prorated	NA	Not listed	10 years – 100% 11–20 prorated
Neptune Mach 10 (US)	$337.50	20 years	NA	20 years	10 years – 100% 11–20 prorated
Neptune T-10 (PD)	$343.75	1 million gallons	3 million gallons	Lifetime	10 years

Notes: This pricing information was not collected using a public bidding process for specific quantities. It is provided for illustrative purposes only.

[1] Solid-state meters come with warranties that cover their electrical components for registering flow, including the internal battery. Mechanical meters come with warranties that cover the replaceable register. In this case, the warranty can depend upon the type of register that is purchased.

Section 4 Meter Reading Technologies

There are three types of meter reading technologies currently (in 2020) deployed by Consortium agencies. Each type of system requires a meter equipped with technology that converts water use into a digital format:

- Touch-read systems employ a reading pad that is secured to the meter lid and wired to the meter. The meter read is obtained by touching the pad with reading devices or wands.
- Automatic Meter Reading (AMR) is the automated collection of meter reads that still requires a meter reader to visit a property or be near a property. Mobile, or "drive-by," meter reading requires a reading device to be installed in a vehicle.
- Advanced Metering Infrastructure (AMI) is an integrated system of meters, communications networks, and data management systems (Figure 7), which theoretically eliminates (or significantly reduces) the need for deployed meter reading personnel. Emerging AMI technologies include satellite-based systems and LPWA communication networks. However, the two most commonly deployed communication platforms are:
  - **Fixed Network Systems –** Meter reading data is sent from the endpoint using radio signals to dedicated data collection units (DCUs) deployed across the service area. Data is transmitted from the DCUs to a headend database for ongoing analysis, and reporting, and billing.
  - **Cellular Network Systems –** Meter reading data is sent from the endpoint using existing cellular technology networks rather than DCUs. Data is then forwarded directly to the headend, which is a database for ongoing analysis, reporting, and billing.

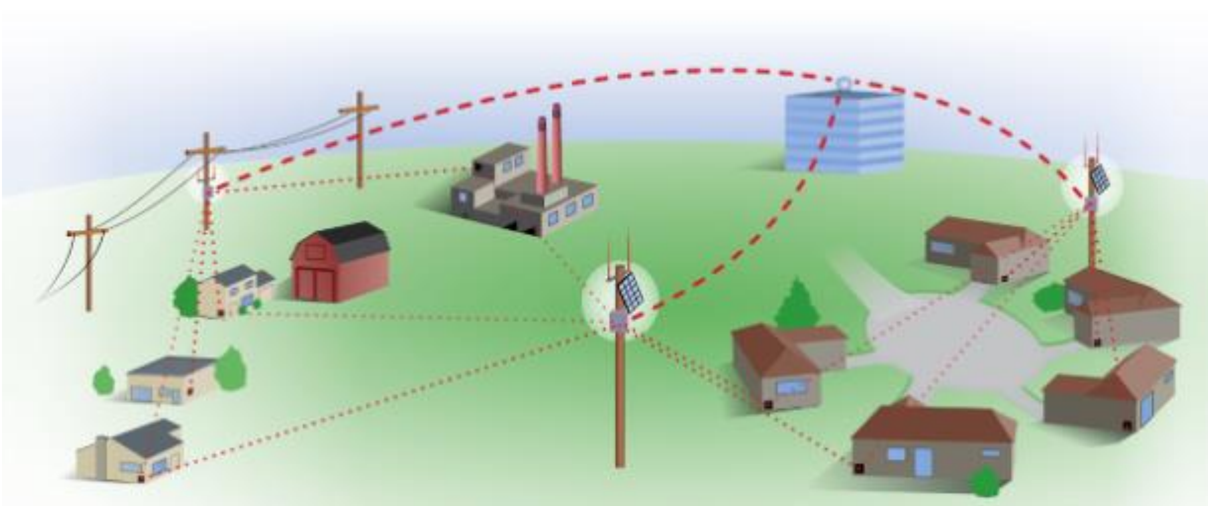

Figure 7. Simplified AMI Configuration using DCUs to transmit meter reading data to the utility database.

4.1 Overview of Meter Reading System Components

Register/Encoder – Conveys water use, displays it, and converts it into a digital format for meter reading. As discussed in the previous section, the register and encoder are either removable in a mechanical meter or integrated and non-replaceable in a solid-state meter.

Badger Two-Inch Water Meter Register Model 170 Absolute Digital Encoder ADE 64501-007

Endpoint – Transmits water use data digitized by the encoder. In touch-read systems, the endpoint is read using a handheld reading device, also known as a wand. In AMR systems, the endpoint is read using a vehicle-mounted receiver. In AMI systems, the endpoint transmits data remotely without the need for utility staff to collect data in the field.

Badger Orion Cellular Long-Term Evolution for Machines (LTE-M) Endpoint

DCU – Receives and transmits water use data from endpoints to data collection software. DCUs are installed throughout a service area, and each DCU can receive data from thousands of meters depending on how well the radio signal can travel through any given area. When data is sent from the endpoints to DCUs, it travels across a local area network (LAN) using radio or cellular communication depending on the AMI system. Data transmitted from the DCUs to the headend data collection software travels over a wide-area network (WAN) using backhaul communication such as cellular, Ethernet, or fiber optics.

Sensus Smart Gateway DCU

Repeater – Some AMI systems use repeaters to serve as a network bridge where the repeaters collect data from the meter endpoints within their range and then transmit the data to the closest DCU or another repeater. Repeaters are used to extend the communication range between DCUs and endpoints.

Zenner Stealth Repeater

Backhaul Network – In RF AMI systems, the DCUs aggregate the meter data and send it to the data collection software across a WAN, also known as a backhaul network. AMI vendors do not typically provide WANs. Instead, they work with utility customers to identify and use locally available infrastructure, such as cell towers. For water utility AMI systems, cellular, Ethernet, and fiber optics are common backhaul options.

HES – The headend system, also referred to as the "meter control system," is hardware and software that receives meter data sent to the utility through meter reading technology.

MDM – Once the data is collected by the HES, MDM software processes the data to be used for billing and analytics. MDM systems provide long-term data storage and management of the vast quantities of water meter data produced on an ongoing basis. MDM systems are intended to integrate with utility information systems such as billing, customer information systems, maintenance management systems, and customer-facing portals. Most AMI solution providers offer MDM systems, but there is variation across different platforms, underscoring the importance of considering which features will be most valuable to the utility. There are also third-party MDM systems and customer portal solutions that may offer advantages over those provided by an AMI vendor. Similarly, some AMI vendors have partnerships with preferred software providers for advanced analytics and customer portals.

4.2 Meter Reading System Considerations

AMR offers benefits over manual reads by automatically collecting consumption, diagnostic, or status data from the meter and transferring the data to a central database for billing and analysis. AMR solutions allow for drive-by (mobile) or walk-by (handheld) data collection, making it unnecessary for a meter reader to access a customer's property, yielding significant safety, time, and other efficiency improvements, which translate into cost savings. AMR provides functionality to automate meter reading with a lower financial commitment compared to AMI systems. Some AMR systems have endpoints that transmit data on a continuous basis, while others require a signal to wake up the endpoint for data transmission. Some AMR systems can store consumption data in the meter register/encoder until the data can be collected by a mobile or handheld meter reading device. If a utility wants the AMR endpoint to store data for a longer period (e.g., more than 120 days), it might have to sacrifice the hourly reads for less frequent read intervals. For some AMR endpoints, which can be migrated to AMI, the physical hard drive data storage capacity of the endpoint does not change. However, each vendor determines the optimal storage setting to maximize battery life while taking the increased frequency of AMI data transmission into account.

In addition to consumption data, AMR endpoints also store standard analytics driven alarms, such as continuous flow, no flow, and reverse flow. Meter diagnostics, such as low battery alarms, can also be read with an AMR system. The primary difference is the time delay. With an AMR system, the lag depends on when the alarm event (e.g., continuous flow) occurs and when data is collected. In an AMI system, data is sent at least once per day so an anomalous event can be investigated much more quickly.

AMR systems are traditionally one-way communication systems where data is only transmitted from the endpoint to the meter reading system. Remote disconnect is a feature in certain meters that requires two-way communication between the meter reading system and the physical meter. However, some remote disconnect meters can be controlled using an AMR system. In this Study, Sensus offers this feature and reports that it is particularly valuable for difficult-to-access meters or meters on properties that are unsafe for utility staff. As discussed in Section 2.3.2, Meter Reading Technologies, the meter reading technology and remote disconnect meter would need to be from the same vendor for the AMR control to be possible.

AMR and AMI systems require meters to be fitted with endpoints. In contrast to AMR technology, AMI systems require the development of a data transmission network, which completely automates the communication between the endpoints in the field and the HES. Automating the data collection process enables increased frequency of data collection and greater control capacity of the system, offering a suite of data analytics-related improvements over AMR, from system optimization to water loss management. Often AMR is characterized as a way for utilities to collect data more efficiently than through manual reads, while AMI makes the data more actionable (see Figure 8).

Many solution providers, including many of those presented in the subsequent section, offer hybrid AMR-AMI endpoints and streamlined migration paths so utilities can begin realizing the added benefits of AMI without converting their entire system. These systems feature endpoints that can be converted from AMR to AMI. Hybrid systems can provide utilities with flexibility to phase in AMI at their own pace while prioritizing areas of the system where AMI can offer the most value. Especially in the immediate term, AMR may be better suited for low-density areas or locations prone to challenges with cellular or radio communication, while AMI may be optimal in denser urban areas where more meters can be connected to the same DCU.

Automated Meter Reading Compared to Manual Reading

Advantages	Disadvantages
• Reduced labor costs compared to touch or manual meter reading	• Investment costs in AMR compatible meters, registers, and endpoints
• More efficient billing process	• Limited read frequency
• Improved read accuracy	• Meter reading still requires staff deployments
	• Additional costs related to meter reading hardware and software
	• One-way communication that limits the ability for remote programming of meters

Advanced Metering Infrastructure compared to Automated Meter Reading

Advantages	Disadvantages
• Cost reductions in meter reading compared to AMR	• Fixed networks can require additional and significant capital investment
• Near real-time leak, tamper, and backflow detection, leading to less water loss	• More complex equipment inventory to maintain for infrastructure
• Ability to provide detailed water use data to customers	• Additional possible costs related to data transmission, hardware, and software
• Improved customer service and responsiveness	• Fewer field inspections that identify maintenance issues in a timely manner
• Increased workforce efficiency and reduced risk exposure through reducing staff field time	
• Two-way communication that allows for control features (e.g., on-demand reads), temporary read interval adjustments for investigations, and remote meter disconnect	
• Remote system health monitoring	

Figure 8. Advantages and disadvantages of AMR and AMI systems.

Consortium agencies currently (in 2020) employ a range of different meter reading systems and are considering their options moving forward (Figure 9). Those that are upgrading their systems from touch read must determine whether to continue toward AMR or AMI. Upgrading to AMI technology can require significant capital expenditures and investment in new skill sets. Depending on the AMI configuration (e.g., fixed network, cellular), additional costs, including data transmission, hardware, and software, exist. Additional IT capabilities are required to manage the more complex data system. The final evaluation of factors, including cost, must be based on the specific AMI configuration being considered.

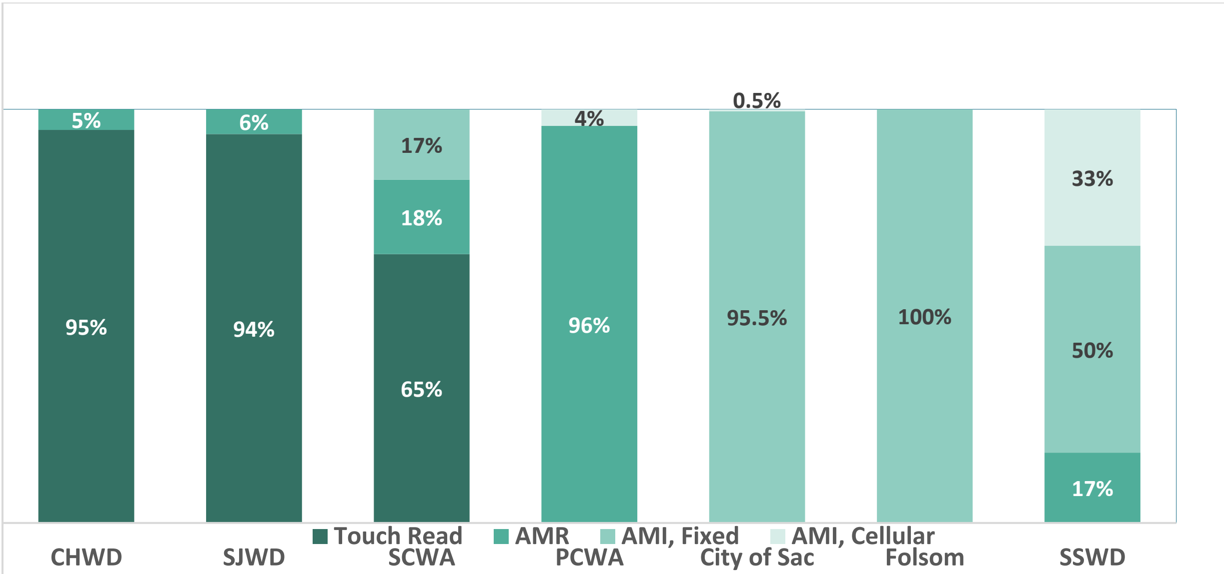

Figure 9. Proportion of deployed Consortium agency meter inventories by type of meter reading technology.

**The City of Sacramento has deployed AMI Cellular endpoint for 0.5 percent of its deployed meter inventory.*

A Consortium approach to meter reading may introduce additional benefits and cost savings. In 2020, Consortium agencies use the systems of several AMR and AMI service providers (Figure 10). These include Sensus FlexNet, Badger Orion Fixed Network, Badger Orion Cellular, Itron, Neptune, and Zenner Stealth. Sensus FlexNet and Badger Orion Cellular are the only systems used by more than one agency.

<table>
<tr><th>SCWA</th><th>SJWD</th><th>SSWD[1]</th><th>City of Sacramento</th><th>PCWA</th><th>CHWD</th><th>City of Folsom</th></tr>
<tr><td colspan="3">Sensus FlexNet (AMR and AMI)</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Badger Orion Cellular (AMI)</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td>Badger Orion Fixed Network (AMI)</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Itron (AMR)</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Neptune (AMR)</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Zenner Stealth (AMI)</td></tr>
</table>

Figure 10. Many different AMR and AMI meter reading system are employed by Consortium agencies. Only Sensus FlexNet and Badger Orion Cellular are used by multiple agencies.

Notes:

[1] SSWD is in the process of converting from Meganet AMR to Sensus FlexNet (AMI).

There are a number of benefits that water agencies can consider by adopting AMI technologies compared to AMR. These benefits must be weighed against the potential disadvantages, which can include capital investments, operational expenses, IT capabilities, and fewer field inspections of meters and meter boxes. While significantly reducing the number of meter reading personnel, AMI systems still require a small team to troubleshoot and collect misreads and non-reads. As noted previously, several key benefits of AMI are related to customer experience, such as access to consumption data, efficient dispute resolution, and faster leak detection. Many of the customer-end benefits also drive operational efficiencies, such as the ability to quickly and remotely resolve disputes without requiring in-person service visits.

It is important to weigh meter program goals and the opportunity costs of not having the enhanced capabilities and benefits of the technology, such as higher-resolution leakage and system monitoring, investigations and faster resolution of billing and service issues, and improved customer engagement and satisfaction.

The following section focuses on AMI communications options, including trends. Specifically, the next section considers communication technology shifts, hybridized systems that deploy multiple communication protocols, and service offerings that aim to address long-term system management concerns.

4.3 AMI Communication Technologies Overview

The leading communication options for AMI in North America are RF and cellular systems. Traditionally, RF has been the most widespread communication technology for AMI systems because of proven reliability. However, cellular technology is increasingly being deployed as data costs decline and cell tower coverage expands. Satellite is the newest option in the market, and it will be a technology to watch as it matures if it can become more robust and affordable. A brief description of AMI communication technologies is provided below.

4.3.1 Widely Deployed Technologies

The following technologies are widely deployed, including in California and by Consortium agencies.

4.3.1.1 Radio Frequency

Both the RF of the system and physical terrain and obstructions will affect the type of equipment needed. AMI/ AMR frequencies are generally 30 MHz or greater. These are referred to as “line-of-sight” systems because the radio signal moves in a straight line. Line-of-sight signals can be blocked by a variety of structural elements such as trees, buildings with lathe and plaster construction materials, telephone poles, and chain link fences. This can sometimes necessitate additional equipment, such as stronger transmitters that can push a signal through obstructions or repeaters to get the signal around the obstruction. Additionally, when signals have to cover long distance, points between the meter and the collector require additional equipment, such as repeaters to ensure the signal gets to the data collector.

RF AMI systems consist of a network of deployed DCUs with a “fixed base” antenna for collecting radio reads from meter endpoints and transmitting them over the backhaul network to the HES. Radio signals move in a straight line and can be impeded by structures such as trees, buildings, telephone poles, and fencing. In addition, some elements of the system act as barriers, including cast iron meter tiles and lids, steel vault lids, reinforced concrete meter box lids, and flooded meter boxes, tiles, and vaults. RF systems typically use the 450–470 megahertz (MHz) radio spectrum or spectrums in the 900 MHz frequency range. These frequencies can either be licensed or unlicensed with the Federal Communications Commission (FCC).

In the water sector, the two common types of RF systems are star (also referred to as “point-to-multipoint”) and mesh (also referred to as “peer-to-peer,” “multi-hop,” and “point-to-point”). In a star network, each meter endpoint transmits directly to a DCU where data is collected and sent to the HES. This network design isolates potential failures since endpoints operate independently of each other. Comparatively, the primary disadvantage of the star configuration is that required infrastructure is dependent on maximum transmission range between endpoints and DCUs that can vary greatly based on site conditions. Similarly, more DCUs may be required to increase redundancy so each endpoint is in range of at least two DCUs in case one fails, while mesh redundancy is not as dependent on DCU density.

In a mesh network, data is transmitted from one endpoint to another, hopping between devices until it reaches a DCU, which then transmits it to the HES. Mesh network endpoints can act as signal repeaters that can be activated at any time to create the most efficient data transmission pathways. Dedicated repeaters can also be used in mesh networks to fill gaps between endpoints and to extend the signal range between endpoints and DCUs. Mesh networks are often described as self-configuring and self-healing, which refers to their ability to adjust the data transmission path to find the strongest signal or to work around failure points in the system if they occur. Since each endpoint can communicate with one another, there is more flexibility to configure mesh systems without the same degree of line-of-sight constraints associated with a star system. This means that mesh networks can potentially require fewer DCUs. Although the data will eventually need to find a path to an endpoint in range or within “sight” of a DCU, a mesh network will adjust the data transmission route as necessary (e.g., hop data around an object temporarily blocking the signal between an endpoint and the DCU). Commonly cited disadvantages of mesh systems are increased complexity, vulnerability to single points of failure, and limitations on data throughput since mesh systems typically send smaller packets of data to keep power consumption low (Figure 11).

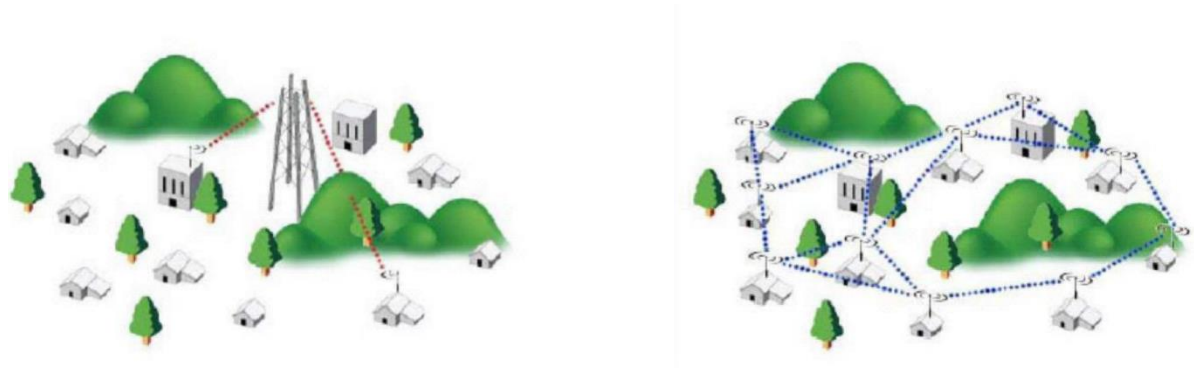

Figure 11. Star (Left) versus mesh (Right). Each meter endpoint in a star network connects only to a DCU, while in a mesh network, each meter endpoint can also connect to other meters, along with intermediate collectors, before the endpoint is transmitted to the HES.

4.3.1.2 Cellular

Cellular AMI technology leverages a commercial cellular network to connect endpoints with the HES. Cellular technology has evolved over several generations of deployment. The third and fourth generation (3G and 4G) technologies are widely used today. Long-term evolution (LTE) is the latest wireless communication standard for the 4G network, characterized by data transmission speeds 10x higher than 3G. In addition to being more cost-effective, 4G LTE is specifically designed to increase the amount of data the network can process, making it ideal for high-speed wireless device communications.

Employing a cellular AMI network can reduce initial capital costs for deployment or provide a viable solution to fill coverage gaps in service areas with a mix of urban, suburban, and rural geographies. Historically, costs for traditional 3G cellular service can add considerable expense to the monthly costs for communicating meter reads, but the next generation cellular networks, such as 4G LTE, continue to reduce the associated data costs. An important consideration is preventing stranded assets as network providers transition to new cellular technologies and older communications platforms become obsolete. Contract protections and service guarantees are particularly useful for mitigating costs related to future technology upgrades.

Cellular endpoints are not compatible with AMR or RF AMI systems. As with other types of endpoints, the battery-powered cellular endpoints are installed in wall or pit applications, and endpoint signal propagation considerations are similar to those associated with traditional RF AMI.

4.3.2 Emerging Technologies

The following technologies are expected to improve the performance of AMI networks in the near future. It is important to note that these technologies are not widely deployed. Rather, they indicate the types of improvements, such as better battery warranties, network connectivity, and remote access, that can be expected in the future.

4.3.2.1 5G Cellular Networks

On the horizon is the fifth generation of cellular technology (5G) that will provide greater speed and responsiveness of wireless networks over a wide coverage area. Although major carriers have started to roll out this technology for specific applications in select cities, it will be several years before 5G networks provide substantially improved service. Envisioned enhancements include the following:

- Increased data rates, both in terms of the theoretical top speed of the network and the speed experienced by users.
- Reduced latency, which is the delay that users experience when they trigger a connection. This should also reduce the overall number of connection failures that occur over time.
- Improved transmission efficiency or ability to send and receive signals using the least amount of power.
- More connections per unit area should reduce the amount of required network hardware.

If cellular service providers are able to provide networks with these characteristics in coming years, it may provide Consortium agencies with opportunities to reduce costs and extract greater performance from their meter data networks. For example, endpoint battery life could improve if transmission efficiency improves. Read rates could improve if the connections are more robust.

4.3.2.2 Low-Power Wide Area

AMI service providers are starting to incorporate LPWA technologies and communication protocols. Low-power wide-area networks (LPWANs) use RFs to provide wireless connectivity for devices with a long operating range and low power consumption. Regional coverage of LPWAN technologies varies significantly. Most LPWAN technologies supplement existing wireless communication technologies rather than replace them. They are not yet widely available in the U.S. and cannot currently (in 2020) compete with traditional communication technologies. LPWANs can support a larger number of connected devices on a single network and aim to deliver longer-range communication capabilities compared to existing RF networks. They are also designed to improve energy efficiency with the goal of enabling LPWA with longer battery lives. A major limitation of LPWAN technologies is that they have lower data transfer capacity than Wi-Fi or the existing cellular technologies. This means they are not well suited for large, complex data sets, but they are well suited for devices sending smaller data sets frequently over long distances. Figure 12 compares the range of major wireless technologies against bandwidth and power consumption.

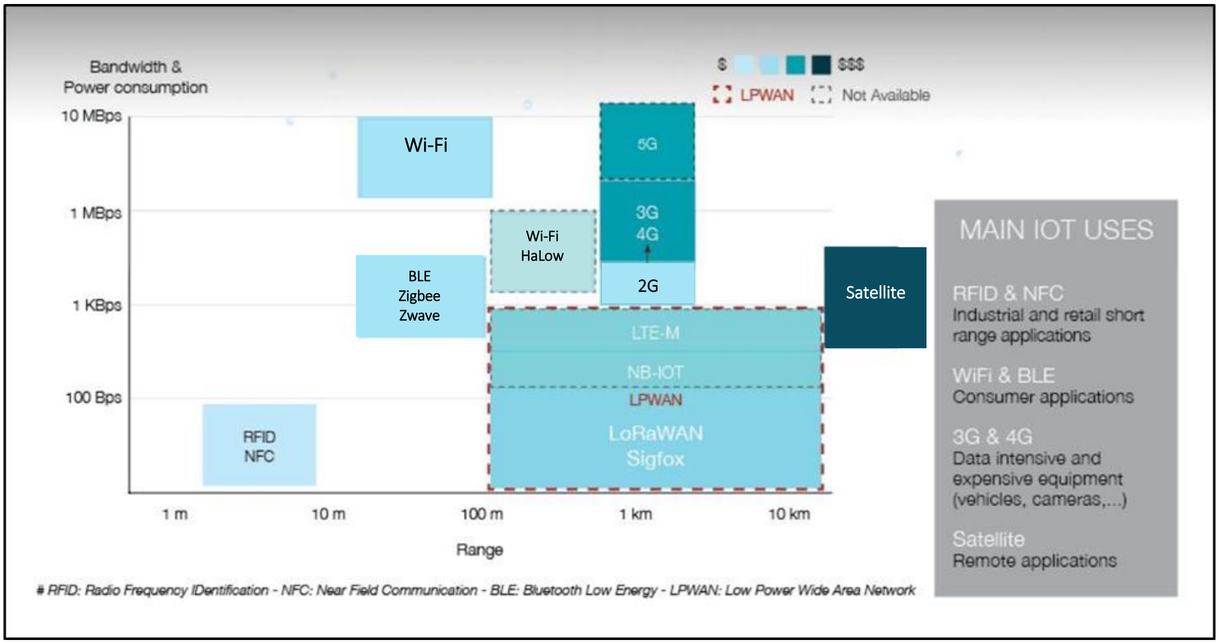

Figure 12. Comparison of wireless communication technologies (Source: IP Carrier 2017).

The two major categories of LPWA technologies are licensed cellular and unlicensed non-cellular IoT technologies. The two leading licensed cellular technologies are Long-Term Evolution Category 1 (LTE-M or LTE Cat-M1) and Narrowband Internet of Things (NB-IoT). These are both cellular carrier-managed networks based on specific telecommunications standards. LTE-M also offers power-saving modes and extended sleep capabilities to extend device battery life (AT&T 2016). In the unlicensed non-cellular category, the leading solutions are SigFox and LoRa, which is short for “long range.” SigFox, a French company started in 2010, has achieved strong traction in the European market as an LPWAN provider offering extremely long-range coverage capability based on its proprietary signal modulation rate. The best applications for SigFox are devices sending small, infrequent bursts of data (Mekki et al. 2019).

The LoRa Alliance is a nonprofit association aimed at promoting certain LPWA technologies with membership across numerous telecommunication companies, equipment manufacturers, and systems integrators. Long-range wide-area network (LoRaWAN) is an open-standard communication protocol established and governed by the LoRa Alliance. LoRa is the physical technology (or chip) that uses the LoRaWAN specification to connect devices across a network. In contrast to narrowband transmission, LoRa distributes data across different frequency channels that can increase data collection capacity. Two of the major AMI solution providers, Neptune and Mueller, are members of the LoRa Alliance and offer systems that use the LoRa communications protocol and offer LoRaWAN specifications as an AMI network option. The biggest benefit to leveraging LPWA technologies is the ease with which you can connect an increasing number of different types of IoT devices (e.g., leak sensor, water quality analyzers, pressure monitors) configured to communicate over these open (e.g., vendor agnostic) communication networks. A growing number of providers are beginning to offer

AMI endpoints enabled for LPWA technologies as they become more commercially viable, but they are not yet widely implemented.

4.3.2.3 Satellite

Satellite-based meter reading technology can now be commercially deployed, although this is currently rare. Like cellular AMI, there are minimal infrastructure requirements for satellite networks because the endpoint connects directly to a network of satellites. This can be an option in rural locations without cellular coverage, particularly where meter locations are widely spaced and it is cost prohibitive for drive-by meter reading. Satellite systems can have two-way communication capabilities, including the ability to receive over-the-air (OTA) commands for system controls (e.g., remote shutoff valves). In 2020, there is one satellite AMI vendor operating in the U.S.: Informational Data Technologies (IDT). IDT's primary customer base is composed of rural water systems in the Midwest, although it has a small installation base in California that is expected to grow in 2020. IDT's satellite gateway devices connect directly to water meters using a cable and the devices are equipped with onboard antenna with no additional equipment required. Battery life is dependent on frequency of reads and data transmissions, but generally, this technology is not ideal for high-frequency reads. While IDT is not included in the following overview of leading AMI solution providers, a completed factsheet from the vendor is available for reference in Appendix B.

4.3.3 Summary Comparison of Meter Reading Technologies

Table 6 presents several high-level comparisons across general performance characteristics, including infrastructure requirements, system redundancy, operating costs, communication signal strength, and advantages and disadvantages for RF, cellular, and satellite AMI technology.

Table 6. Communication Network Comparison

Meter Reading Technology	Description	Advantages	Disadvantages
RF – Star Configuration	This configuration is used by 6 of the 7 evaluated vendors. LoRaWAN can be deployed in a star configuration.	Since endpoints operate independently, individual endpoint failure has no impact on the rest of the system. Endpoints are designed to communicate with at least 2 DCUs so DCU failure is not catastrophic. The direct data transmission from endpoints to DCUs reduces latency or the time between when data is sent and when data is available.	Not as many communication path options for data should DCU failures occur.
RF – Mesh Configuration	This configuration is more common in electric and gas metering systems and combined water/gas/electric networks. Zenner is the only evaluated vendor that uses mesh network.	Multiple communication pathways for data increases redundancy. Easier to scale by adding endpoints or repeaters rather than DCUs. Potential to limit number of DCUs required.	Higher data latency due to multiple hops before reaching DCU. If multiple endpoints fail, functioning endpoints take on more of the data transmission responsibility that can affect battery. Endpoints must be close enough to one another to send and receive AMI data or more repeaters may be required, which can complicate the system architecture in areas with greater distances between meters.
RF – Licensed Spectrum	Private FCC-licensed spectrum network with narrowly defined band within which a licensed user can operate. Requires annual licensing fee.	Low interference and background noise. Increased privacy and security. Higher transmission power that increases range of transmission.	Licensed network must be purchased or leased by AMI vendor.
RF – Unlicensed Spectrum	Public or unlicensed spectrum, often referred to as the frequency is free to use and shared by many devices.	Use of unlicensed band is free, public. Systems using unlicensed spectrums can be designed to be more interference tolerant.	Possible performance issues caused by interference from other users of the unlicensed band. Other devices can increase background noise, which makes it harder to pick up signals. Power output is typically limited to 1-watt so data throughput and range is more limited.
Cellular	Commercial cellular network. Endpoints are supported by the LTE-M cellular network.	Fast deployment. Leverages existing cellular infrastructure without the need for equipment like DCUs or repeaters. Designed to transmit large quantities of data so bandwidth required for AMI data is available.	Limited options if cellular network failures occur. Existing coverage gaps. Cost of data transmission.

Sources: GWID 2018; Marais et al. 2016.

4.4 Advanced Meter Infrastructure Solution Providers

Dominant Advanced Meter Infrastructure Players

Across the major categories of AMI components (meter manufacturers, meter reading technology, and meter data software), there are approximately 10 leading companies that serve water utilities in the U.S. Table 7 presents these AMI vendors with a brief description of their offering. Seven of the 10 companies listed in Table 7 are included in the solution provider evaluation results presented in the following section.

Table 7. Primary Meter Reading Vendors for the Sacramento Area

Company	Summary Description of Configuration
Aclara	RF licensed star network, 450–470 MHz. Only offers AMI. Offers proprietary MDM. Not a meter manufacturer.
Badger	RF unlicensed star network, 902–928 MHz and cellular network using LTE-M and NB-IoT (5G) enabled endpoints. Offers both AMR and AMI. Offers proprietary MDM. Meter manufacturer.
Honeywell (Elster AMCO)	RF unlicensed star and mesh network options, unlicensed 902–928 MHz. Offers both AMR and AMI. Offers proprietary MDM. Meter manufacturer.
Itron	RF unlicensed star network, 900 MHz. Offers both AMR and AMI. AMI options include traditional fixed network or IoT network with routers instead of DCUs. Offers proprietary MDM. Meter manufacturer.
Kamstrup	RF licensed star network, 450–470 MHz. Offers both AMR and AMI. Offers proprietary MDM. Meter manufacturer.
MasterMeter (Arad)	RF licensed star network, 450–470 MHz. Offers both AMR and AMI. Offers proprietary MDM. Meter manufacturer.
Mueller	RF unlicensed star network, 902–928 MHz. Offers both AMR and AMI. Offers proprietary MDM. Meter manufacturer.
Neptune	RF unlicensed star network, 910–920 MHz. Offers both AMR and AMI. AMI options include proprietary RF fixed network or LoRaWAN. Cellular endpoints can be used to augment system if necessary. Offers proprietary MDM. Meter manufacturer.
Sensus	RF licensed star network, 900 MHz. Offers both AMR and AMI. Offers proprietary MDM. Meter manufacturer.
Zenner USA Stealth	RF unlicensed mesh network, 902–928 MHz. Offers both AMR and AMI. Offers proprietary MDM. Meter manufacturer.

Section 5 Meter Reading System Evaluation

This section summarizes the results from an evaluation of selected AMI technology options. The focus of this evaluation is AMI technology because it represents the next generation of advanced metering solutions and AMR is the predecessor of AMI technology. Except for Aclara, all vendors reviewed for this evaluation can read endpoints in AMR mode and can convert RF endpoints from AMR to AMI with minimal or no reprogramming. The following comparison is aimed at presenting the selected vendors' current advanced meter reading technology options. Therefore, only specifications for AMI solutions were requested from each supplier.

Feedback captured during the first Phase 2 workshop (TAC 2.1 workshop) supported the development of performance criteria used to compare seven of the ten leading AMI vendors. The vendors and criteria were selected to provide a comparison of communication options and system characteristics. Eight AMI solutions from seven vendors are compared in the following section because Itron submitted information about two distinct solutions, which were both considered relevant for Consortium agencies. Additionally, the two Itron systems utilize different meter endpoints and data collection equipment with distinct O&M implications. Neptune's R900 endpoint is used for both their proprietary AMR and AMI networks, as well as their LoRaWAN option. There are very few differences across the criteria used in this evaluation, so distinctions were only drawn between Neptune's systems where needed. The eight evaluated AMI vendor options are listed in Table 8.

Table 8. Evaluated AMI Vendor Options

Vendor Option	Communication	Configuration
Aclara – RF	RF	Licensed star network 450–470 MHz
Badger – Orion	RF and Cellular options[2]	RF system employs an unlicensed star network in the 902–928 MHz band, while the cellular system employs LTE-M and NB-IoT (5G) communications
Itron ChoiceConnect	RF	Unlicensed star network 900 MHz
Itron OpenWay Riva	RF	Unlicensed star network 900 MHz, IoT network with Cisco routers
Mueller – Mi.Net	RF	Unlicensed star network 902–928 MHz, LoRa protocol and LoRaWAN options
Neptune – R900	RF with supplemental cellular option[1]	Unlicensed star network 910–920 MHz, proprietary and LoRaWAN options (same endpoint)
Sensus FlexNet	RF	Licensed star network 900 MHz
Zenner – Stealth Reader	RF	Unlicensed mesh network 902–928 MHz, LoRaWAN protocol available in June 2020

Notes:

[1] Neptune markets their AMI solution as a RF fixed network, with a cellular network option to augment it if desired. Neptune prefers to limit the number of cellular endpoints deployed due to a significantly shorter battery life compared to the R900 radio endpoints. All AMI systems currently (in 2020) deployed by Neptune are primarily RF systems.

[2] Badger currently (in 2020) markets its AMI solution as primarily a cellular network and still supports legacy RF fixed network systems. When required by the client, Badger can offer an RF option that uses an unlicensed star network in the 902–928 MHz range, but reports that more recent system deployments are cellular AMI systems.

During the TAC 2.1 workshop, Consortium agencies were asked to discuss their meter programs, including drivers of meter purchasing and meter reading technology, top concerns, benefits they are most excited about, and objectives for this project. At the conclusion of the TAC 2.1 workshop, the following six over-arching categories of priority metering solution characteristics were defined:

- **Accuracy –** Refers to the degree to which the water meter can correctly convey the quantity of water that flows through it. This topic is discussed in detail in Section 3, Meter Technologies.
- **Simplicity –** Covers the ability of a solution to operate with minimal required infrastructure and O&M while still delivering a reliable system. This includes the ability to provide flexible business models, such as network as a service (NaaS) and software as a service (SaaS) agreements, which require less upfront investment. Additionally, the ability to update endpoints and DCUs remotely minimizes required field maintenance.
- **Reliability –** Covers the ability of a solution to ensure proper functioning and decrease single points of failure. This includes long life of components, secure data storage protocols, and data loss prevention.
- **Responsiveness –** Encompasses the ability of a solution to include analytics or instrumentation as turnkey features that support the monitoring of the AMI system. This may include leak detection, high-flow detection, remote shutoff or turn-on, pressure monitoring, reverse flow alarms, and tampering detection and alerts.
- **Flexibility –** Comprises the capabilities and limitations of a solution to integrate with other components and information systems. Given the variety of components in an AMI system, the ability for a vendor to be compatible and able to complement an existing AMI system is advantageous. This includes both physical components like meters and information and data management systems (e.g., customer portals, billing software).
- **Redundancy –** Covers the ability of a solution to ensure the communication and transmission to and from network devices (i.e., endpoint, DCU) with multiple communication pathways, providing alternatives or backup options so that information is preserved and transmitted in any event or case of failure.

Each Consortium agency assigned 21 points across the six high-level categories of meter system characteristics. Results of this ranking exercise are presented in Table 9.

Table 9. Consortium Rankings of Metering and AMI Solution Characteristics

Categories	Aggregated Ranking (across all 7 agencies)
Accuracy	23
Simplicity	36
Reliability	32
Responsiveness	23
Flexibility	18
Redundancy	15

Because accuracy is more relevant for the meter than the meter reading technology, the ranking of the remaining five categories was used to develop eight evaluation criteria for the AMI options listed above. Table 10 lists the evaluation criteria associated with each category of AMI solution characteristics.

Table 10. AMI Solutions Evaluation Criteria

Category	Evaluation Criteria	Description
Simplicity	Required Infrastructure	Minimum infrastructure required and capturing of contracted services that can be arranged with the vendor (i.e., SaaS and NaaS offerings to highlight what might be the minimum investment and other considerations)
	O&M Requirements	Notable maintenance requirements for primary components
Reliability	Equipment Warranty	Warranties for endpoints and DCUs
	Data Storage	Data storage protocols and data loss prevention
Responsiveness	Analytics	Built-in analytics included as turnkey features of system
Flexibility	Compatibility	Intersystem compatibility with other information systems
Redundancy	Read Options	Options for redundancy in case of failure

An AMI Technology Factsheet (Appendix C) was circulated to each vendor to capture information for comparing performance against the evaluation criteria proposed after the TAC 2.1 workshop. The evaluation criteria are listed in Table 10. The form was provided to the seven evaluated vendors as an informal request for information. Copies of each completed factsheet are provided in Appendix B.

The evaluation criteria aim to present each technology in common terms and compare parameters of interest across the evaluated vendors. When necessary, Isle Utilities performed minor edits to maintain consistency in reporting, but all information is based on the submitted factsheets. Additional information from the vendors is provided in Appendix D.

To assess vendor experience with AMI in the water sector, several metrics were compared across the evaluated solution providers. The total number of water sector AMI deployments in the U.S., the number of water AMI customers in California, the longest running water AMI deployment, and the size range of water AMI deployments (measured by total endpoints in a single AMI network) are presented in Table 11.

Table 11. Water Sector AMI Experience by Vendor

Criteria	Aclara	Badger	Itron[1]	Mueller	Neptune	Sensus	Zenner
Total U.S. Deployments	144	1,000	130	250	350	800	250
Customers In California	22	>50	20	4	>20	50	10
Longest Running Deployment (Years)	21	7	10	10	15	13	14
Smallest to Largest Deployment (Endpoints)	300–840,000	150–>150,000	100–450,000	250–380,000	<500–250,000	500–600,000	105–32,000

Notes:
[1] These numbers reflect Itron's combined deployment of their ChoiceConnect and OpenWay Riva systems.

5.1 Simplicity

Under the simplicity category, two criteria were used to compare the various vendors: required infrastructure (service models and components) and O&M requirements for system maintenance. These criteria reflect concerns expressed by Consortium agencies about the implications of increasing the complexity of their metering system. The addition of assets like DCUs and repeaters, along with meter and endpoint upgrades, requires strategic capital investments and hard-to-predict O&M budget increases over the life cycle of these systems. Additionally, these assets will vary from one another in their maintenance and replacement schedules due to staggered installation, battery life, and unplanned equipment changes. There are three primary models for utility AMI systems: utility-owned and managed, utility-owned but vendor managed, and vendor-owned and managed, or NaaS. Regardless, endpoints are always owned and maintained by the utility.

NaaS models are offered by many vendors to mitigate the uncertainty of long-term system maintenance requirements and related costs. With a NaaS contract, the vendor is responsible for DCU and repeater (if applicable) maintenance, equipment replacement, troubleshooting, and network optimization activities. Although water utilities are increasingly interested in the NaaS model, it is not currently (in 2020) widely adopted and only makes up a small percentage of RF AMI system deployments. For example, Sensus only has two NaaS contracts across North America, Aclara only has three NaaS contracts in California, and Neptune currently (in 2020) only has one NaaS system in California. Itron, Zenner, and Mueller will develop NaaS contracts if requested, but they were unable to provide examples of AMI deployments under NaaS agreements. Badger's cellular AMI solution is only offered through a NaaS contract.

Several Consortium agencies noted reluctance to give up ownership of AMI infrastructure, citing concerns about losing functionality of their metering systems during unexpected contract changes. However, NaaS contracts with clear stipulations for continuity of operations or service contracts for select system components may be worth considering to increase confidence in AMI maintenance planning. Buyout options should be included in AMI agreements in addition to well-defined service level agreements that require vendors to enhance the network with additional collectors or infrastructure at no cost to the utility if a system is under-performing. Evaluated RF AMI vendors offer a maintenance or service contract for DCUs, routers, and repeaters. Their contracts represent varying degrees of managed system options for utilities that own their system but, prefer a fixed cost model for required service, especially when equipment warranties end. Vendor-owned or managed network service agreements can be useful for developing reliable O&M budgets.

Evaluated vendors can and prefer to manage the HES through a SaaS agreement. This is the most common approach for water utility AMI deployments. Vendors were also asked to confirm support for on-site hosting. Neptune and Sensus do not support on-site hosting, while the others offer this option if customers prefer to store data on local servers. Although there is lack of consensus across Consortium agencies regarding on-site hosting, this is a consideration that may limit the available AMI options.

While on-site hosting adds another layer of complexity due to staffing and physical infrastructure requirements, the control over data access and security is an important tradeoff. Licensed utility-owned HESs can require a high degree of maintenance from IT staff, such as configuring and managing the software, responding to network alarms, and managing security protocols. Sensus' comparison of software system maintenance requirements in a utility-owned system versus a SaaS scenario is well illustrated in the list of HES maintenance responsibilities included in Appendix B. In short, the limited utility responsibilities under the Sensus SaaS model are user account creation, management, and support.

A summary of vendor options for NaaS, SaaS, and on-site software hosting is provided in Table 12.

Table 12. Required Infrastructure Service Models

Criteria	Aclara	Badger	Itron[1]	Mueller	Neptune	Sensus	Zenner
NaaS	X	X	X	X	X	X	X
SaaS for HES	X	X	X	X	X	X	X
On-Premise Hosting	X	X	X	X	—	—	X

Notes:

[1] These service models are offered for both Itron's ChoiceConnect and OpenWay Riva systems.

There are several distinctions in infrastructure required across the evaluated vendor options. The most apparent difference between cellular and fixed network systems is the data collection equipment. The data collection infrastructure (e.g., DCUs, routers, antennas, and repeaters) is the critical communication backbone for RF AMI systems, while cellular AMI systems do not require utility-owned or managed infrastructure outside of the endpoints. This means that cellular AMI systems do not require upfront infrastructure investment compared to RF.

Certain options, such as Mueller's Mi.Net, Itron's ChoiceConnect, and Zenner's Stealth systems, use repeaters to improve radio signal propagation and maximize the number of endpoints supported by each DCU. Other vendors, namely Aclara and Neptune, are opposed to repeaters because they add potential points of failure and increase system complexity. Regardless of their position, vendors attempt to minimize the number of DCUs installed according to a utility's desired level of redundancy. Shown in Table 13, required components served as one indicator of system complexity. Similarly, DCU antenna height restrictions can add a level of planning complexity. In some municipalities, code exceptions could be required to accommodate antenna height.

Table 13. Required Infrastructure – Components

Criteria	Aclara	Badger	Itron	Mueller	Neptune	Sensus	Zenner
Key components (other than endpoints)	DCUs and antennas	No DCUs, antennas, or repeaters for cellular AMI	DCUs, antennas, and repeaters for ChoiceConnect; routers only for OpenWay Riva	DCUs, antennas, and repeaters	DCUs and antennas	DCUs and antennas, optional repeaters	DCUs, antennas, and repeaters
DCU antenna height	DCU at 12 feet and antenna usually 100 feet above	Not provided by vendor	ChoiceConnect: 25–175 feet and optimal is 75 feet OpenWay Riva: 25–50 feet and 40 feet optimal	30–50 feet is optimal	35 feet to as high as possible to minimize DCUs	30–50 feet is optimal; repeaters can help minimize DCUs	35–60 feet optimal or above the tree line
Max range from endpoints to DCUs	1.5-mile radius (3 miles across) is typical	Not provided by vendor	Up to 2 miles; 0.5 mile is typical	5 miles is typical; 3 miles is expected for Northern California	Average is 5 miles	3–5 miles on average, up to 8 miles	Mesh is different from line-of-sight, so typically 2,500 endpoints to 1 DCU

In Table 13, the estimated antenna heights and ranges from endpoints to DCUs are based on optimal conditions to demonstrate high-level variation across these systems. A propagation study is required to accurately predict the number of DCUs required for a given number of endpoints in a specific coverage area. Vendors were asked to provide the endpoint range as a simple proxy for required infrastructure, because presumably the number of required DCUs would be lower for systems with greater range estimates. This metric proved to be of limited value given the numerous factors that determine signal propagation in each unique service area.

5.2 Operations and Maintenance

O&M considerations relate to the intensity or frequency of maintenance required or recommended by the vendors for their system components. Two key areas of O&M activities related to AMI technology were reviewed: maintenance of the DCUs and the ability to update DCUs and endpoints remotely.

Cellular AMI systems do not require network maintenance since they do not require data collection or transmission devices other than meter endpoints. For RF systems, which use DCUs, the primary routine maintenance includes battery replacements every five to seven years at approximately $1,000 per battery (2020 pricing). DCU battery power is usually reserved as a backup option in case the primary AC power source fails. Some vendors, including Aclara, Zenner, and Neptune, offer solar-powered DCUs as an alternative. Outside of troubleshooting issues that might require a replacement DCU or antenna cable, site visits should be minimal. The HESs are continuously monitoring the health of DCUs to troubleshoot issues as they occur. For RF systems using cellular backhaul communication between DCUs and the HES, cellular modem upgrades to support the latest technology are a long-term O&M consideration. Cellular DCU modems currently (in 2020) installed are configured for LTE connectivity, which is expected to be supported through 2040 (Forsman et al. 2018).

Firmware is a modified form of software used to control data collection and storage. Most vendors can install firmware updates during field visits with handheld devices, but OTA updates allow new firmware for DCUs and endpoints to be remotely downloaded to address new features, enhancements, or defects. This maintains the system’s functionality without interruptions as updates are released. All evaluated vendors can install DCU firmware updates remotely except Badger since its cellular solution does not require DCUs. Similarly, the evaluated vendors can update endpoint firmware OTA, with the exception of Neptune, whose endpoints do not require firmware updates (Table 14).

Table 14. O&M Requirements – System Maintenance

Vendor	Gateway	OTA DCU and Endpoint Firmware Updates
Aclara	Battery replacement every 5 years.	Yes, background while system is operational, AES256 encrypted.
Badger	Not provided by vendor.	Yes, remote endpoint firmware updates, AES256 encrypted.
Itron	Battery replacement every 5–7 years.	Yes, AES256 encrypted while system is operational.
Mueller	Minimal preventative, 5–7 year battery replacements.	Yes, background while system is operational, AES256 encrypted.
Neptune	Battery replacement every 5 years for fixed network. Not applicable for cellular network.	No endpoint firmware updates required; remote updates for the DCUs in background while system is operational, AES256 encrypted.
Sensus	Semiannual site visit, replace batteries every 7 years, backhaul maintenance done upon failure.	Yes, background while system is operational, AES256 encrypted.
Zenner	Battery replacement 5–7 years or sooner if low due to power outages; possible antenna cable or connector maintenance if damaged.	Yes, AES256 encrypted, updates are pushed while system is operational, and there is available bandwidth.

5.2.1.1 Reliability

Under the reliability category, two criteria were used to compare the vendor options: equipment warranties and data storage in the network. For DCUs, routers, and repeaters, a standard one-year manufacturer's warranty is provided by the vendors. The notable variation observed across equipment warranty terms was specific to endpoints. Assuming hourly reads, the standard endpoint warranty is 20 years. As shown in Table 15, the evaluated vendors, except for Sensus, offer terms that cover 100 percent replacement during the first 10 years and prorate coverage after 10 years up to a maximum of 20 years. After 20 years, the end user is responsible for 100 percent of the cost or replacement of the endpoint. The Sensus warranty covers full replacement for the first 15 years and is prorated for an additional five years. With the exception of Zenner, all evaluated vendors confirmed that warranty terms are negotiable, and full replacement can be extended for an additional cost.

Table 15. Reliability – Equipment Warranty

Criteria	Aclara	Badger	Itron	Mueller	Neptune	Sensus	Zenner
Endpoint Hourly reads	20 years 10 full/10 prorated	20 years 10 full/10 prorated	20 years 10 full/10 prorated	20 years 10 full/10 prorated	20 years 10 full/10 prorated	20 years 15 full/5 prorated	20 years 10 full/10 prorated
Endpoint 15-min. reads	Did not provide	20 years 10 full/10 prorated	16 years[1]	Negotiated in contract	NA	1 year full	20 years 10 full/10 prorated
DCUs	1 year	1 year	1 year	1 year	1 year	1 year	1 year
Routers	NA	NA	1 year	NA	NA	NA	NA
Repeaters	NA	NA	1 year[2]	1 year	NA	1 year	1 year

Notes:

[1] Only Itron's OpenWay Riva solution offers 15-minute read intervals.

[2] Only Itron's ChoiceConnect solutions utilizes repeaters.

Endpoint warranties vary with sub-hourly read intervals for Sensus, Mueller, Aclara, and Itron. Neptune does not offer 15-minute interval reads with RF endpoints,[1] and both Badger and Zenner indicated no change to the warranty if the customer opts for 15-minute read intervals. Frequency of data transmission to the DCUs affects endpoint battery life in RF systems, so each vendor has developed optimal transmission protocols to extend battery life and ensure data collection redundancy. Many of the evaluated vendors offer options for temporarily collecting or transmitting data more frequently to support investigations and verifying a meter has been correctly sized.

Aclara endpoints send hourly data four times per day (typically every six hours) to the DCU under the 20-year warranty, but 15-minute read data requires more frequent data transmission and a larger strain on the battery, so the warranty is reduced. Aclara did not provide the exact warranty terms for 15-minute read intervals but confirmed it would be less than 20 years.

Sensus endpoints are warrantied for one year if they are configured for 15-minute read intervals with a data transmission frequency of six times per day, typically spread evenly every four hours. Sensus transmits seven days of hourly read data in every four-hour data transmission.

Itron's OpenWay Riva endpoints are warrantied for 16 years if the read frequency is 15 minutes and read data is transmitted up to four times per day. Itron has a meter rightsizing mode that can be activated for temporary sub-hourly read intervals with its ChoiceConnect solution, but this would be done through a handheld device.

Neptune endpoints, which only support one-way communication from the endpoints to the DCUs, exclusively process hourly reads and are a useful example of data transmission variation. Neptune endpoints send read data to the DCUs every 7.5 minutes, which includes the current read, the previous read, and a read from 12 hours prior. Neptune uses this transmission protocol for data packet redundancy to allow multiple opportunities to complete hourly data sets. Despite more frequent signals from the endpoint to the DCU, the endpoint comes with a 20-year prorated warranty, which is similar to other vendors. This is because the data packets are small. Neptune DCUs typically transmit information to the HES four times per day, but it is a user-definable function of the collector. In Neptune's LoRaWAN configuration, the endpoint time synchronizes with the DCU and transmits data every three hours.

Mueller's endpoints transmit hourly data once per day to DCUs, and similarly, data is sent from the DCUs to the HES once per day. Mueller can ping the endpoint on demand with a 12-second turnaround time, which can provide high-resolution investigative capability without sacrificing

[1] Neither of Neptune's RF solutions (proprietary fixed network or LoRaWAN) offers 15-minute read intervals. However, its cellular endpoints can be programmed for 15-minute intervals if needed for certain meters. Neptune's cellular endpoints are not typically offered as a standalone system and are only used to augment its RF system, which is why its cellular solution is not listed as a distinct option.

endpoint battery life. If 15-minute reads are preferred on an ongoing basis, the Mueller endpoint warranty is reduced to five years.

Zenner is the only evaluated vendor with a mesh fixed network configuration for water systems.[2] A commonly cited concern regarding mesh networks is the potential strain on endpoint battery life due to each endpoint serving as a repeater in the system, especially if a utility has a failure that causes rerouting. However, Zenner's endpoints wake up every 20 minutes to send data through the system regardless of whether the meter is being read hourly or every 15 minutes. The endpoints wake up for six seconds, transmit data for a fraction of a second, and remain in listening mode for the rest of the time as data hops between various endpoints and repeaters in route to a DCU. At midnight, data is time stamped, and the DCUs transmit the collected read data to the HES. In this regard, the frequency of transmission is less important to battery life in a mesh system because the endpoints are sending a smaller packet of data a short distance to the next endpoint or repeater until the packet arrives at the DCU. The shorter, more frequent data "hops" are designed to limit battery consumption. Zenner is also the only vendor offering a field-replaceable endpoint battery. When an endpoint battery reaches the end of its life, the utility can decide if it is more cost-effective to replace it under the warranty or replace it with a new battery.

Badger offers a 20-year warranty for hourly or 15-minute read intervals and transmits data four times per day, typically at six-hour intervals. Badger allows utilities to customize these intervals or space out the data transmissions according to their needs as long as they are only sending data four times within a 24-hour period. Citing a marginal impact on battery life from collecting more frequent reads, Badger does not differentiate between hourly and sub-hourly reads for the warranty.

Beyond understanding battery life implications, variation in data transmission frequencies is relevant for considering how the data will be ultimately used. Hourly data provides accurate billing information and offers valuable insights into daily and peak consumption patterns without strain on batteries and communication networks. Sub-hourly data can be useful for meter rightsizing, high-resolution investigating, and breaking down consumption by specific fixtures or processes at a residential or commercial property.

Data storage is a consideration for system reliability. In the event of power outages or system failures, data storage and backup protocols are critical for maintaining billing functionality and protecting the data collected by the AMI system. For most RF systems, there are multiple data storage points in the system: the endpoints, the DCUs, and the HES software. The MDM and other analytics platforms will often provide even longer-term data storage. For example, Itron's analytics software provides a standard five-year storage capacity.

[2] Itron offers a mesh configuration for combined water and electric utilities. Mueller has the capability to use a mesh configuration but cited battery stress as the primary reason it uses a star configuration. It can also use a mesh protocol when testing endpoints.

As illustrated in Table 16, endpoints often have more storage capacity than DCUs because they are designed to keep recording meter data even if the network is down. Sensus is the exception since its endpoint and DCU storage capacity is similar. Endpoint data storage capacity ranged from <30 to 365 days of hourly reads across the evaluated solutions. Badger does not differentiate between hourly and 15-minute reads for endpoint storage; it stores 42 days of data regardless of read interval. For the other vendors, endpoint data storage is linearly proportional to the frequency of the read data being stored. Zenner's DCU storage is the same regardless of the read interval, but all other vendor DCU storage capacity is also linearly proportional to read frequency. For example, if Itron's OpenWay Riva DCU is collecting hourly reads, it stores 160 days of data. If the same DCU is storing 30-minute reads, 80 days of read data are stored. Similarly, 40 days of 15-minute reads are stored in the same DCU. The number of endpoints transmitting to the DCU is another consideration for data storage capacity. Zenner's DCU data storage assumes the DCU is collecting data from 2,500 to 3,000 endpoints, whereas Itron's DCU storage in its ChoiceConnect system is based on a DCU collecting data from up to 100,000 endpoints.

In addition to well-established data redundancy and database maintenance protocols followed by every software solution provider, HES backups and disaster recovery systems prevent the loss of stored data if a failure occurs. The HES performs regular data backups with frequency variation across vendors as demonstrated in Table 16. SaaS models for HES software will cover backups at these intervals. Disaster recovery systems are used for business continuity in the event of a catastrophic failure at the HES data server. Due to the expense of maintaining additional physical and usually remote locations for backup servers, cloud-based disaster recovery options are common across AMI solution providers. For HESs hosted by Amazon Web Services (AWS) or Microsoft Azure, standard disaster recovery protocols are included as a service. In addition to avoiding capital investments, cloud-based disaster recovery offers scalability and quicker backups. Alternatively, advantages to physical disaster recovery sites include the ability to access data without internet and more control over the data and security measures.

Table 16. Reliability – Data Storage in the Network

Meter	Endpoints	DCU	HES	Disaster Recovery	Prolonged Outage
Aclara	96 days of hourly reads	28 days of hourly reads	Hourly and daily backups to 3 different server locations	Microsoft server security and loss prevention protocols	In event of backhaul failure, 96 days of endpoint storage and all endpoints communicate with at least 2 DCUs
Badger	42 days of hourly or 15-minute reads	NA for cellular	Daily backups to multiple servers	AWS hosted, disaster recovery protocols, ISO 27001 compliant	Cell service often first to return after disaster; data auto backfilled if transmission fails
Itron ChoiceConnect	40 days of hourly reads	5 days of hourly reads, up to 100,000 endpoints	Stores 400 days of hourly reads, managed services covers backups and testing of restore capabilities	Disaster recovery available at additional cost	After outage, HES commands the endpoint to backfill data lost
Itron OpenWay Riva	160 days of hourly reads	No storage, routers immediately send data to HES	Did not provide	Did not provide	If router is down, endpoint will automatically find another one
Mueller	105 days of hourly reads	90 days of hourly reads	Backups 2 times weekly, differential backups every other day, log backups every hour	AWS standards, RAID 10	511 days of data stored in endpoint if connection is lost; data auto backfilled from message logs
Neptune Proprietary	96 days of hourly reads	3 days of hourly reads in proprietary DCU	Weekly backups	AWS protocols	Uploaded to HES with mobile data collection
Sensus	45 days of hourly reads	30 days of hourly reads	Nightly backups, 3-server redundancy, and weekly local server tape backups	Disaster recovery at geographically dispersed site included with SaaS model	Can be pulled locally off the DCU and uploaded directly to the HES
Zenner	365 days of hourly reads	365 days of hourly reads for 2,500–3,000 endpoints	Indefinite data storage; Last 3 years of data available for reporting and 7+ in offline archive if needed	All data stored in Allison, Texas, and 3 additional geographically spaced site locations	Mesh design allows endpoints to transmit to different collector if needed; can collect using walk/drive-by

5.2.1.2 Responsiveness

The responsiveness category was examined through data analytics capabilities offered by the evaluated AMI solutions. These analytics provide alerts or flags when data fall outside of defined parameters. The analytics offered by each provider at no additional cost and regardless of the meter manufacturer include suspected customer leak alerts, reverse flow alerts, other temper alerts, error or invalid read alerts, and AMI network diagnostics. Most of these analytics can be collected by a mobile meter reader in walk or drive-by mode. However, AMI systems collect more frequent reads and produce notifications more quickly. This is particularly useful for timely notifications of continuous flow to indicate potential leaks on the customer side of the meter. Reverse flow and other tamper alerts are standard features offered by the evaluated vendors. The consumption data behind these analytics can be read by many AMR and AMI systems regardless of the meter manufacturer because standard communication protocol have been widely adopted. The ability for a meter reading technology to collect these data over the standard protocol is what vendors typically mean when they confirm compatibility with meters manufactured by another vendor.

For an AMI system to collect more advanced or extended data from a meter, an enhanced protocol is required. Advanced analytics can include meter diagnostics such as register replacement or low battery alarms and empty pipe notifications. Certain types of meters can measure pressure or temperature to help utilities monitor water quality and pressure changes in the distribution system. Remote disconnect or shutoff is another advanced feature that is built into certain meters. In all these cases, the meter manufacturer must give a meter reading technology access to the data for them to be available through the AMI data platform along with the consumption data.

Meter manufacturers are not motivated to release their advanced protocols because it requires additional investment on their part and reduces competitive advantage. On the other hand, meter suppliers will weigh the opportunity costs carefully for larger deployments. This may be an advantage of Consortium-scale purchasing power. For example, Badger's Orion cellular endpoint can read consumption data from Neptune's Mach 10 meters using the standard protocol, but extended meter data cannot be read through Badger's system. The same is true for extended information from Badger meters. However, the two vendors are currently developing the necessary protocol and anticipate interoperability in late 2020. Meter manufacturers will be hesitant to make firm commitments without a clear sales opportunity. Once the Consortium identifies meters and meter reading solutions of greatest interest, specific requests can be sent to the vendors. Inquiries to the AMR and AMI vendors will confirm if they have the ability to collect the extended data from those specific models, and similarly, the meter manufacturers can be asked if they would work with the AMR and AMI suppliers if there were a joint purchasing opportunity to specific sizes. In short, certain meter analytics are only available if the meter manufacturer and the AMI vendor are the same or if the vendors are willing to cooperate.

This is also true for features like remote disconnect. Mueller's remote disconnect meters can only be controlled by Mueller's AMI system; the same is true for Sensus and Badger remote disconnect meters. Certain vendors, including Itron, Neptune, and Zenner, offer remote shutoff valves that connect directly to endpoints and can be controlled at the HES. The remote shutoff feature, whether built into the meter or installed outside of it, is associated with an additional cost. Utilities must determine the use case for advanced capabilities, such as remote shutoff valves or pressure monitoring, because this will inform meter upgrade decisions.

Other types of analytics, such as distribution system monitoring for leaks, pressure, or water quality, can be leveraged with an AMI system, but they require the purchase of sensors with similar limitations around communication protocols and network configuration. Sensus is a Xylem brand, so proprietary sensors from Xylem companies can easily be integrated into the Sensus analytics platform. Mueller offers many proprietary sensors for pressure, leak, and water quality monitoring from various Mueller brands. Badger is currently (in 2020) developing proprietary water quality monitoring capabilities and can incorporate data from LTE-enabled third-party sensors in its analytics platform once transfer protocols are developed. AT&T, Badger's cellular carrier, has strategic vendor partnerships for many types of sensors such as acoustic leak monitors. If there is an interest and use case for leveraging an RF network to connect additional IoT devices in the distribution system, the LoRaWAN option offered by Neptune and Mueller makes it possible to connect any of the hundreds of devices that are LoRaWAN certified. Similarly, Itron's OpenWay Riva network is an open-architecture communication platform that essentially functions as an IT network in the field to support the addition of new applications or devices.

5.2.1.3 Flexibility

Under the flexibility system characteristics, two criteria were used to compare the various vendors: intersystem compatibility and compatibility of the solution with existing inventories of meter registers and encoders in use by the Consortium agencies. This compatibility ensures that solution endpoints can be installed in existing meters without a need to replace registers and increase the capital costs of the project. All vendors indicated their specific compatibility with standard registers and encoders currently (in 2020) in use in North America or with any three-wire American Standard Code for Information Interchange register. Compatibility with existing US meters could not be corroborated by all vendors. Specific registers in use would have to be submitted to vendors to ascertain compatibility. The meter models in Table 17 reflect those already deployed by Consortium agencies and have registers that are compatible with the solutions evaluated. Complete meter register compatibility lists provided by each vendor can be found in Appendix B.

Table 17. Flexibility – Meter Compatibility with Meter Reading Platform

Meter Type	Aclara	Badger	Itron	Mueller	Neptune	Sensus	Zenner
Any 3-Wire American Standard Code for Information Interchange Standard Register	X	X	X	—	—	X	X
Badger Recordall Disc Series (nutating disc) (PD)	X	X	X	X	X	X	—
Master Meter Octave (US)	X	X	X	—	—	X	—
Mueller/Hersey HbMag (EM)	X	—	X	X	—	X	—
Neptune Mach 10 (US)	X	—	X	—	X	—	—
Neptune T-10 (nutating disc) (PD)	X	X	X	X	X	X	—
Sensus iPERL (EM)	X	X	X	X	X	X	—
Sensus SRII series (Oscillating piston) (PD)	X	X	X	X	X	X	—
Zenner All	X	X	X	—	—	X	X

Evaluated solution providers indicated integration capability with existing billing systems used by the Consortium agencies, including Cogsdale, Oracle, Central Square, Tyler, and TruePoint. The development of application programming interfaces (APIs) to interface with billing and customer information systems is widely described as one of the simplest components of AMI implementation. Although there is undoubtedly variability in the software integration fees charged by the AMI vendors (typically measured in thousands of dollars), there was broad consensus across vendors regarding unpredictability around costs charged by the billing vendors with reported swings in the tens of thousands of dollars. Although integration time may be reduced if an AMI vendor and billing vendor have already developed interface protocols, performance testing and data audits required by certain billing vendors are examples of integration requirements specific to each new implementation.

Table 18 includes a summary of meter compatibility and each vendor's billing system integration capabilities as reported by each solution provider. Solutions offer a proprietary MDM at an additional cost. For customer portals, Mueller, Itron, and Zenner partner with third-party vendors such as Smart Energy Water, WaterSmart, or MeterSmart. All others offer proprietary customer portal capabilities.

Table 18. Flexibility – Intersystem Compatibility

Criteria	Meter Compatibility	Data Management Platform and Customer Portal	Billing System Integration Experience
Aclara	Compatible with 18 major meter manufacturers and over 50 register models	Proprietary management platform is AclaraONE endpoint and software; Customer portal (AclaraACE).	Integration experience with all vendors
Badger	Compatible with any meter or encoded register meeting 3-wire American Standard Code for Information communications standard	Proprietary management platform is BEACON AMA; customer portal is EyeOnWater.	Integration experience with all vendors
Itron	Compatible with all water meter registers available in North America	Proprietary management platform is MDM; no proprietary customer portal; preferred partners are Smart Energy Water, WaterSmart, and MeterSense.	Integration experience with Tyler, Oracle, and Cogsdale
Mueller	Compatible with 9 major meter manufacturers and 14 register models; no programming required	Proprietary management platform is Sentryx; does not have proprietary customer portal; preferred partner is WaterSmart but has integration experience with others.	Integration experience with all vendors
Neptune	Compatible with 6 major meter manufacturers and 15 AMR register models	Proprietary management platform and customer portal but also has integration capability with all major customer portals and software companies.	Integration experience with all but Oracle and TruePoint
Sensus	Compatible with all registers that have an industry standard UI1203 communications protocol	Proprietary management platform and customer portal through Sensus Analytics platform. Experience integrating over 25 third-party platforms.	Integration experience with all vendors
Zenner	Compatible with all major AMI ready (3-wire) register	Backend functions as a management system; endpoint may not on occasion capture every vendor's code specific alarm; no proprietary customer portal but has partnerships with several providers.	Integration experience with all but TruePoint

5.2.1.4 Redundancy

The category of redundancy in this context refers to alternative meter reading contingency options, namely the ability to read meters using mobile walk-by and drive-by technology and options for addressing signal propagation challenges. Vendors were also asked to describe options for two-way communication including backhaul for RF systems and confirm technology availability in the Sacramento area. Table 19 summarizes vendor responses. Aclara is the only vendor that does not offer the ability to collect endpoint data via mobile reads; however, it does have a portable DCU that can be situated temporarily in an area experiencing backhaul failures. However, the portable DCU is not designed as a direct replacement to AMR equipment because it would be stationary for a temporary period (e.g., days to weeks if necessary) and only in range of select endpoints.

Table 19. Redundancy – Read Options

Criteria	Mobile Read Capability	Two-Way Communication	Available in Area?	Option Where No Signal is Available
Aclara	No, network design and onboard storage of the endpoints and DCUs provide redundancy.	Licensed 450–470 MHz RF with utility's choice of backhaul.	Yes	Portable DCU mounted in a vehicle can be driven to any location where it can collect from nearby endpoints.
Badger	Yes, endpoints can be read by walk-by or drive-by using an Orion transceiver and a tablet computer.	AT&T carrier; available secondary carrier if needed. Endpoints communicate over the LTE-M cellular network with the option for NB-IoT.	Yes	Traditional AMR/AMI manual reads from Badger meter.
Itron	Yes, endpoint can be read via mobile when programmed in fixed network mode.	Unlicensed star 900 MHz ISM star network with the 902–928 MHz frequencies. Backhaul supports cellular, Ethernet, Wi-Fi, and fiber optics.	Yes	Mobile drive-by and walk-by data collection.
Mueller	Yes, same Mi.Node can do both AMI and local reads.	LoRa unlicensed star 902–928 MHz ISM radio band. System operations internet protocols (cellular, Ethernet, fiber optics, and radio) can serve as two-way communication backhaul between collectors and HES.	Yes	Mi.Tech handheld or the Network Manual Tool on laptops for collection in walk-by or drive-by AMR fashion.
Neptune	Yes, endpoints can be read in mobile AMR and AMI mode.	LoRa and LTE, backhaul can be cellular or Ethernet.	Yes	Install point-to-point radio systems to act as the backhaul from the gateway.
Sensus	Yes, endpoint are the same for walk-by and fixed based solutions.	Carrier grade, nationwide network (FlexNet), with nearly 1,000 MHz (combined) of dedicated frequencies.	Yes	Not dependent on other providers for radio coverage.
Zenner	Yes, endpoints can be read in AMR or AMI mode, but system is designed so data can be retrieved from multiple DCUs if backhaul fails, which is more efficient than retrieving from each endpoint.	Unlicensed mesh network 902–928 MHz; endpoints are manufactured for future LoRa capability; backhaul for DCUs is Ethernet or cellular.	Yes	Current products allow for Ethernet, drive-by, walk-by, or manual readings, but repeaters allow data to be moved from areas where backhaul is available.

5.3 Summary of Differentiators and Takeaways

The objective of this review is to provide a comparison of capabilities and service options so Consortium agencies can determine which offerings are best suited to their business needs and which specifications are most relevant for evaluating results of a propagation study or pilot study. Infrastructure requirements, O&M considerations, equipment warranties, data storage, analytics, intersystem compatibility, and alternative read options were evaluated for each vendor option. A summary of the comparison results and overall takeaways is provided in Table 20.

Table 20. Summary of Differentiators and Takeaways

Criteria	Differentiators and Takeaways
Analytics	**Analytics**: Both AMR and AMI endpoints collect consumption data to provide information about abnormal flow patterns, such as no flow, reverse flow, or continuous flow. AMI systems receive the data in near real-time, which makes the data significantly more actionable. Consumption data and related flags for deviation from defined parameters can be collected by a meter reading technology from many meters using a standard communication protocol with exceptions as noted in the meter compatibility summary. Advanced meter analytics may include built-in meter diagnostics (e.g., low battery alert), monitoring capabilities (e.g., temperature and pressure in newer meters), and control capabilities, such as remote disconnect. The ability of a meter reading technology to process the data requires an advanced communication protocol that may not be provided by the meter manufacturer. Analytics that require additional sensors or third-party data sets (e.g., distribution system leak detection or pressure monitoring) are specific to each meter reading technology and their integration flexibility. **Takeaways**: There is little variation across standard consumption analytics performed by the evaluated vendors. Utilities must evaluate the business case for meter-specific features to determine preferences for meter manufacturers that offer desired functionality. Prospective meter manufacturers and meter reading technology providers will confirm integration capabilities and may consider developing interface protocols when requested by the utility. Integration capabilities are constantly evolving for each meter reading technology; therefore, including vendor integration commitments in contract language is also recommended. The ability to connect a wider range of IoT devices across an AMI system is one advantage of Neptune and Mueller's LoRaWAN options and Itron's OpenWay Riva network.
Compatibility	**Intersystem Compatibility:** Except for Neptune and Mueller, all evaluated vendors' endpoints communicate over the 3-wire American Standard Code for Information Interchange communications standard. Not all vendors can communicate with the meters deployed across the Consortium systems, at least without any modification or programming. All vendors confirmed ability to develop APIs for billing system integration. Out of the 7 vendors, Aclara, Badger, Mueller, and Sensus confirmed integration experience with all billing software solutions currently used by Consortium agencies in 2020. **Takeaways:** Meter manufacturers may consider releasing the advanced protocol to meter reading technology providers if there is a strong business case, which may be another benefit to Consortium-scale meter purchases, as it increases the scale of the opportunity. Meter reading solution providers have not tested every meter and register on the market, so compatibility should be validated before any large purchasing decisions are made. Billing system integration is relatively straightforward, but hidden costs can be avoided by discussing interface requirements and fees imposed by both the meter reading solution provider and the billing system vendor in advance.

Table 20. Summary of Differentiators and Takeaways

Criteria	Differentiators and Takeaways
Data Storage	**Data Storage:** Endpoint data storage capacity ranged from 365 to 400 days of hourly reads across the evaluated solutions with Sensus on the low end and Zenner with nearly 3 times the next highest capacity. Badger does not differentiate between hourly and 15-minute reads for endpoint storage; it stores 42 days regardless of read interval. Endpoint data storage for all other evaluated vendors was proportional to read frequency. DCU storage varied widely from 3 to 365 days for hourly reads, and except for Zenner, the storage was proportional to read interval; Zenner DCU storage is not dependent on read intervals. No data is stored at Neptune's LoRa DCU or Itron's OpenWay Riva router. **Loss Prevention:** Data backup frequency in HES software ranged between daily to weekly for all evaluated solutions. Disaster recovery protocols are standardized on the hosting platform (e.g., AWS or Microsoft) with the exception of Zenner and Sensus, which manage multiple storage sites at different geographic locations. For prolonged outages, vendors cited several safeguards, including the ability to upload data to the HES through mobile collection and automatic backfilling of data once network functionality is restored. **Takeaways:** Utility preferences for data storage and loss prevention are typically driven by IT policies that must be taken into consideration when comparing vendors across this category. Extended storage options are available through HES or data management platforms for an additional fee. SaaS agreements for management of the HES software typically cover basic storage and loss prevention.
Equipment Warranties	**Equipment Warranties:** Meter endpoints are warrantied for 20 years, assuming hourly reads and vendor-specified data transmission intervals. Sensus provides the only warranty that offers full replacement up to 15 years and prorated replacement up to 20 years; the industry standard is full replacement up to 10 years and prorated replacement up to 20. Zenner is the only vendor with a field-replaceable endpoint battery. 15-minute read intervals changed the warranty terms for all the evaluated vendors with the exception of Badger and Zenner. Neptune does not offer 15-minute read intervals, and only Itron's OpenWay Riva solution offers 15-minute read intervals. DCUs, routers, and repeaters are covered by 1-year warranties. **Takeaways:** There are few AMI systems that have been operating long enough to validate endpoint lifespan estimates. Between the battery technology improvements over the last decade and optimal data transmission protocols, vendors are confident enough in expected endpoint battery life to offer 20-year warranties. The terms of these warranties vary little between the evaluated vendors, with only Sensus deviating from the standard 10 full/10 prorated terms. However, vendor testing results have indicated that improved battery technology and optimal data transmission protocols give vendors enough confidence to offer 20-year warranties. For DCUs, routers, and repeaters, 1-year warranties can mitigate the 1%–2% failure rate that is common in new electronic equipment.
O&M Requirements	**Maintenance:** Badger's solution does not require DCUs. The systems that use DCUs require battery replacements every 5 to 7 years. Vendors indicate DCU maintenance is minimal, and antenna cable is one of the most common repairs required after normal wear. Remote firmware updates are available for endpoints in all systems except for Neptune. Neptune endpoints do not require firmware updates and only have one-way communication between the endpoint and DCU. All systems with DCUs install firmware updates remotely while systems are operational. **Takeaways:** There was little difference across reviewed solution providers for DCU maintenance and remote firmware updates. One of the biggest advantages of cellular AMI is the minimal maintenance, although the disadvantage is limited capability to address communication issues if cellular networks are not performing as desired. DCU modems with cellular backhaul must be replaced when LTE becomes obsolete. Utilities can choose alternative backhaul options if cellular uncertainty is a major concern.

Table 20. Summary of Differentiators and Takeaways

Criteria	Differentiators and Takeaways
Read Options	**Read Options:** Alternative options for reading meter endpoints provide redundancy in case of network failures. All systems build redundancy into their network configuration to ensure endpoints can communicate with at least 2 data collection devices. Mesh systems like Zenner's are particularly well equipped to reroute data if areas of the communication network fail because there are essentially unlimited communication pathways. Additionally, all vendors except for Aclara can collect mobile reads using walk-by or drive-by methods in the event of a backhaul failure. Aclara offers a portable DCU that is not designed to move around the system but is useful in the event of isolated backhaul issues. If cellular backhaul is a concern due to connectivity issues, alternatives such as Ethernet or fiber-optic options can be explored. **Takeaways:** The ability to collect data from endpoints using mobile reading technology is a safeguard against communication network failures. Combined with built-in storage at endpoints and DCUs (for applicable systems), along with redundant network configurations, alternative read and backhaul options will significantly minimize the risk of data collection issues.
Required Infrastructure	**Service Models:** Regardless of the type of business model, meter endpoints are owned and maintained by the utility. All evaluated vendors stated that they can offer NaaS agreements, but Mueller, Itron, and Zenner do not currently (in 2020) have any NaaS AMI customers. Sensus, Aclara, and Neptune have a handful of NaaS deployments, and Badger's cellular AMI solution is only offered as a NaaS. All reviewed options manage the HES software through a SaaS contract, and 5 of the 7 evaluated vendors offer on-premises software hosting options; Sensus and Neptune only offer hosted solutions. **Components:** All AMI systems require AMI-compatible meter endpoints. Other than endpoints and cell towers, which are not owned by the utility, Badger's cellular AMI solution does not require any additional equipment. RF systems require installation of data collection and transmission devices throughout the network. These devices include DCUs with antennas, repeaters, and routers. Optimal antenna height ranged from 30 feet to 100 feet, although only Aclara suggested an optimal height higher than 75 feet. The maximum distance from endpoints to data collection devices ranged from 1.5–5 miles, but propagation studies are required to validate for any given system. Itron's OpenWay Riva system uses routers instead of DCUs. Repeaters can reduce the number of DCUs, which are more expensive than repeaters. Neptune and Aclara do not use repeaters because they add system complexity and additional potential points of failure. Mueller, Zenner, and Itron's Choice Connect systems use repeaters as part of their standard configuration, and Sensus uses optional repeaters. **Takeaways:** Aside from Badger's cellular AMI network, NaaS contracts are uncommon. However, they represent a novel approach to managing the long-term costs of network maintenance, which is one of the primary concerns communicated by Consortium agencies. Extended service contracts are offered by all evaluated vendors for network equipment once the standard warranty ends. Vendors also offer varying degrees of managed system contracts to align with customer preferences. As an alternative to NaaS models, these service contracts are useful for reliably budgeting for network maintenance. Propagation study comparisons will allow for evaluation of costs associated with each vendor's proposed equipment configuration.

Section 6 Conclusion and Next Steps

Technical Memorandum No. 2 provides an overview and synthesis of the proven and emerging meter and meter reading technologies that are most relevant to Consortium agencies as developed during the Phase 2, Next Generation Program Options Analysis. The information collected will serve as the basis for subsequent phases in addition to the information collected during Phase 1, Individual Agency Assessment. The primary conclusions and recommendations derived from this quantitative and qualitative information are as follows.

6.1 Meter Selection

To date, Consortium agencies have predominantly deployed mechanical (PD) meters, which is detailed in Technical Memorandum No. 1. Many of these meters have been in place for more than 20 years, which provides the Consortium with confidence that mechanical technologies are proven and reliable. The emerging solid-state meter models can provide comparable or better specifications compared to mechanical models. However, solid-state models currently lack comparable deployment histories and have not yet demonstrated the ability to last as long as mechanical models.

Accuracy – The emerging solid-state models are specified to provide increased accuracy at ultra-low flows over a warranty period that corresponds to both the new meter and repaired meter warranties for mechanical meters. There is no appreciable trend between accuracy warranty periods for mechanical and solid-state meters. Most accuracy warranties cover 15- to 20-year periods. Without further study by Consortium agencies, it is currently (in 2020) unknown how much additional flow could be registered by solid-state models. However, because of the way Consortium agencies structure their rates, a change in registered flow corresponds with a smaller change in revenue. For example, a one percent change in registered flow would correspond with a smaller average 0.4 percent change in revenue across Consortium agencies.

Meter Retail Pricing – There is no appreciable trend between the costs of mechanical and solid-state meters. Some solid-state meters are modestly cheaper than mechanical models, and sometimes, it is the opposite. The biggest differences are between brands, as Zenner and Badger models have the least expensive retail pricing.

Electronics Warranties – There are no appreciable trends in electronics warranties, including those for built-in batteries. The 20-year electronics warranty periods are available for many, but not all, mechanical and solid-state options (though most are prorated for years 11–20). The biggest difference between mechanical and solid-state models is that the registers are integrated into solid-state meters and cannot be replaced in situ if they fail. It should also be noted that solid-state meters may increase the amount of electronic waste that must be properly disposed of.

Meter Reading Compatibility – The Sensus, Badger, Aclara, Zenner, and Itron systems report the ability to support any three-wire American Standard Code for Information Interchange standard register. As a result, many of the meters predominantly used by Consortium agencies can be read by existing meter reading platforms. Advanced protocols, such as low battery warnings and theft detection, offered by meter reading vendors are not widely available. However, it is possible to successfully request advanced protocol integration across vendors if a business case can be made to the vendor.

6.1.1 Recommendation 1: Develop and Employ a Joint Request for Proposals for Consortium-Level Small Meter Purchasing

Significant cost savings could be achieved through joint meter purchasing at the Consortium level. Putting in place a large purchasing contract with common specifications could achieve more competitive unit pricing through economies of scale. The first step in this process will be to compare the meter requirements for each agency and isolate the specifications that are common and those that differ across the agency. The second step will be to prepare technical specifications for a joint RFP. Consortium agencies could consider establishing up to two or three large-scale purchase orders to manage supply-chain risk.

6.1.2 Recommendation 2: Establish A Consistent Meter Database Across Consortium Agencies

In 2020, there are differences between the meter inventory data collected by Consortium agencies. As a result, it is difficult to compare information across the combined dataset to inform decisions about meter selection and replacement timing. Putting in place a consistent data collection and management system at each agency would enable agencies to better use their data for decision-making and to leverage other agencies' data if the Consortium is willing to share information. A Consortium-level deployed meter database would provide Consortium agencies with a powerful foundation for decision-making. Over time, this could lead to more consistent and beneficial decision-making across the region.

6.1.3 Recommendation 3: Establish a Consortium-Wide Meter Pilot Program

Most Consortium agencies assess the potential use of solid-state meters but continue to widely deploy mechanical meters. The City of Sacramento has explored a number of new meters through a bench-based test program. SSWD and others have several types of solid-state meters deployed for evaluation. Putting in place an evaluation program that leverages the tools, capabilities, context, and interests of all Consortium agencies would be a powerful way to assess new technologies, assess the functional lifespans of newer models, and validate their performance under real-world conditions. Establishing a consistent process that combines bench testing, pilot deployments, and data collection (Recommendation 2) would enable Consortium agencies to make more informed decisions more quickly and efficiently about incorporating potential accuracy capabilities into their deployed inventories. This process could connect to a regular update and revision process for the proposed joint RFP process (Recommendation 1).

6.2 Meter Reading

Consortium agencies employ a variety of meter reading methods and vendors, which are detailed in Technical Memorandum No. 1. CHWD and SJWD are in the process of shifting from touch read to AMR. PCWA primarily employs an AMR network but has cellular AMI for four percent of its customers. The City of Sacramento, City of Folsom, and SSWD primarily employ AMI. The SCWA is in the process of expanding its Sensus AMI system.

In 2020, the proven and commonly deployed meter reading systems are offered through RF-based fixed networks or cellular networks. Emerging technologies, such as next generation cellular technologies (e.g., NB-IoT and 5G) and LPWAN technologies like LoRa, will drive future improvements in AMI systems, such as lower data transmission costs, better battery performance, and the ability to connect more IoT devices across an AMI network. Automated meter reading using satellite communication is another emerging option currently used by several rural water systems. However, this technology has limitations in more urban service areas and has not yet been cost-effectively deployed at scale.

The hardware components for fixed network systems have historically been purchased, operated, and managed directly by the agency. AMI solution providers are beginning to offer fixed network systems that are owned, managed, or maintained by the vendor as a service through NaaS models and extended service contracts, which is typically how cellular-based AMI systems are contracted. These configurations are available but not yet widely deployed across municipal water AMI systems.

There are potential advantages to explore through meter reading collaborations across Consortium agencies. There are potential cost savings to be gained through joint purchasing and/or sharing of hardware, software, operations, and maintenance resources. Many Consortium agencies have already deployed meter reading systems. Existing infrastructure across the Consortium service area may be capable of supporting other Consortium agency meter reading systems. A Consortium-level propagation study is recommended to fully assess the most cost-competitive options and potential benefits of shared network infrastructure.

6.2.1 Recommendation 4: Conduct a Consortium-Level Propagation Study

As a next step in the Study, a Consortium-scale propagation study will be conducted to determine the required hardware components to achieve the service requirements for reading the meters in a larger, multi-agency area. Since many Consortium agencies are proximal to one another, there may be opportunities to leverage existing hardware or share new hardware. If multiple agencies use the same AMI system(s), there may be cost-saving opportunities through Consortium-pricing for hardware, software, and service agreements. The consulting team will use the results of the propagation study to collect detailed cost information and assess the benefits of different collaboration opportunities. The cost data will be organized in capital, operations, and maintenance categories.

6.2.2 Recommendation 5: Conduct a Consortium Approach to Piloting Emerging Technologies

Newer meter reading technologies, such as LPWANs, are available but not yet widely deployed. Similar to solid-state meter technologies, some Consortium agencies are positioned to pilot new meter reading technologies without great additional cost. Joint pilot initiatives could help align future AMI deployments across the Consortium.

6.2.3 Recommendation 6: Develop a Consortium-Wide Analytics Program

Deploying AMI meter reading platforms provides a number of benefits beyond the basic ones that relate to the shift from manual to automated meter reading. AMI vendors provide similar analytics capabilities. Taking advantage of these capabilities can require significant effort. By leveraging the experiences and developing common processes, Consortium agencies have the opportunity to assimilate a larger number of benefits more quickly and cost effectively. For example, standardized reporting could lead to a consistent meter-related apparent water loss reporting process.

6.3 Next Steps

The consulting team will solicit a propagation study and add additional data to inform the cost benefit analysis for meter reading collaboration options. The consulting team will also start Phase 3, Meter Testing Program Strategy, which will include a review of each agency's current water meter testing program and available water testing facilities (in-house and regional). Opportunities for Consortium-level collaboration will be researched in this phase to identify the feasibility of joint meter testing options. This will be an opportunity for Consortium agencies to establish common testing protocol and methods, data sharing, and/or joint training programs to improve the consistency and use of test data toward operational and financial efficiencies and future regulatory compliance.

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Appendix A. TAC 2.1 Workshop Summary Document

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1. Consortium member rankings of metering solution characteristics

Each agency was given a total of 21 points to allocate across 6 high-level categories of metering solution characteristics (redundancy, flexibility, responsiveness, accuracy, reliability and simplicity). The following table presents the group's collated responses.

Categories	Aggregated Ranking (across all 7 members)
Simplicity	36
Reliability	32
Accuracy	23
Responsiveness	23
Flexibility	18
Redundancy	15

2. Summary of General Feedback regarding Metering Programs

During the TAC 2.1 Workshop, Consortium Members were asked to discuss their meter programs with at least one other member agency. Each group was asked to capture drivers of meter purchasing decisions and meter reading technology decisions; primary concerns; capabilities they are most excited about; and agency objectives for the Study. The following is a high-level summary of the captured feedback:

Q1. Drivers of meter purchasing decisions

- Reliability and proven history with technology and vendor
- Meter durability and simplicity
- O&M costs
- Redundancy (e.g., backup options for reading meters)
- Fireflow considerations
- Billing system compatibility and compatibility with meter reading technology

Q2. Drivers of meter reading selection

- Complexity and resulting maintenance, including troubleshooting communication issues
- Changing prices in communication options
- Ability to store data for longer periods to help with complaints and problem solving
- Ease of information access
- Ability of system to perform resiliently
- Cross-organization committee which helped to make decisions

Q3. Top concerns

- Is it working and doing what it's supposed to do?
- Disjointed O&M and related concerns about staffing
- Maintenance of assets
- Keeping up with the technology
- Battery life
- Lifecycle costs across different configurations

Q4. Benefits most excited about

- Cost benefit
- Better conservation and reduced water loss
- Improved life of components with batteries and equipment
- Better lifecycle planning
- Greater frequency of data reads
- Regional collaboration around testing

Q5. What you're hoping to get out of the project

- Better regional understanding of how information is being collected and tracked
- Solutions to problems
- Joint meter testing
- When and how to add new technologies
- Joint purchasing
- Support for understanding return on investment (ROI)
- Sharing data for testing
- Better regional collaboration

3. Proposed 5 vendors for a more detailed evaluation

Based on the group's feedback around vendor selection and priority considerations, we have proposed 5 vendors for a more detailed comparative review. As noted during the workshop, we have also made an effort to present you with a balanced spread of communication options and configurations to compare.

Vendor	Communication[1]	Configuration
Neptune - R900®	Cellular and radio frequency	Unlicensed star network 910-920 MHz, LTE option with LoRa enabled endpoints
Mueller - Mi.Net®	Radio frequency	Unlicensed mesh network 902-928 MHz
Sensus FlexNet®	Radio frequency	Licensed star network 900 MHz
Badger - ORION®	Cellular and radio frequency	Unlicensed star network 902-928 MHz, LTE-M (and future 5G) cellular
Aclara - STAR®	Radio frequency	Licensed star network 450-470 MHz

Reasons for not selecting the other identified vendors	
MasterMeter	Similarities to Aclara
Itron	Similarities to Mueller but good backup option due to experience in Western US
Honeywell	Similarities to Mueller and Neptune / Less experience in CA
Kamstrup	Less experience in CA
Zenner	Less experience in CA

4. Proposed evaluation criteria which will be used to compare the shortlisted solution providers

Characteristic	Evaluation Criteria	Isle Notes
Simplicity	Required Infrastructure	Minimum infrastructure required and capturing of contracted services that can be arranged with the vendor, i.e. if network provided is available as a service option and the minimum/maximum number of endpoints per tower are examples to highlight what might be the minimum investment and other considerations.
Simplicity	O&M Requirements	To include notable maintenance requirements for primary components (endpoints, gateways, software)
Reliability	Battery life	Estimated component battery life (endpoints, gateways, etc.)
Reliability	Equipment life	Estimated useful life for major components of system
Reliability	Data storage	Data storage protocols and data loss prevention
Responsiveness	Analytics	Built-in analytics included as turnkey features of system (list)
Flexibility	Compatibility2	Inter-system compatibility and other information systems
Redundancy	Read Options	Options for redundancy in reading technology in case of failure

Information collected for the 8 evaluation criteria will infer cost considerations around total investment and flexibility of service-related costs that utilities may use as a basis of establishing a firm request for proposals in the future.

[1] We would be happy to substitute a vendor that uses satellite communication if desired by the majority of utilities.
[2] Will identify compatibility limitations with brands and types of meters as well as other meter data management platforms.

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Appendix B. Vendor Responses

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Neptune - R900 ® Response

Technology Name: Company Name: Company Contact Name:	Neptune Technology Group Ferguson Waterworks Mike Bortoletto, Sales Manager
Technology Type	
Technology Description	Neptune has many options in regard to technology, and for CHWD we would offer our unmatched R900® solution with the ability to be AMR and AMI all in real-time and in a streamlined process. The built-in ability of Neptune's R900® endpoints to be read in mobile AMR and fixed network AMI mode simultaneously assures AMI network compatibility with mobile AMR backup support, eliminating the significant costs associated with replacing, reprogramming, or paying license fees regardless of reading system needs. Neptune's approach is a build-on rather than a change-out model assuring forward and backwards compatibility while leveraging R900™ technology. **AMR/AMI Migration:** The built-in ability of Neptune's R900® endpoints to be read in mobile AMR and fixed network AMI mode simultaneously assures backward compatibility and forward migration, eliminating significant costs associated with replacing, reprogramming or paying license fees to use these meters and RF endpoints in a fixed network AMI mode. Neptune's approach is a build-on rather than a change-out model assuring future compatibility and leveraging R900™ technology already deployed. **Ease-of-Use:** A fundamental design principle at Neptune is to make our products and systems easy to use. This practice runs through our entire product portfolio, including the R900® endpoint that requires no programming and automatically detects the type of encoder to which it is attached. The ECoder®) R900i™ and ProCoder™) R900i™ with integrated radios are as easy to install as a direct reading meter. And Neptune's software was built on the concept of simplicity to ensure ease of use. By designing our systems for ease of use and interoperability, we help reduce costs, reduce errors, enable data sharing across the utility, and provide for increased efficiencies. **Turn-key US Supplier:** While many companies have moved production offshore, Neptune has increased its investment in its US-based manufacturing. The benefits of this Made-in-America approach are evident in terms of reducing product lead times and creating tighter links between our customers, our design teams and manufacturing. Neptune's core focus is high-quality meters, encoded registers, RF MIUs, reading system software, and customer support. **Value-Added Functionality:** The types of data utilities can generate through the R900 encoded register family and Neptune's supporting software can expand applications far beyond simple meter reading for monthly billing. Hourly consumption profile data over an account's last 96 days, along with alerts for leak, backflow or tamper, help to proactively identify and resolve customer issues – heading off high bill complaints, reducing delinquent payments, and eliminating write-offs. Using Neptune 360 host software, you can leverage detailed meter data to balance water produced versus water consumed, support district metering needs, and track/manage Non-Revenue Water. Customer field presentment of usage history using current Neptune hand held units or Android and IOS compatible tablets or phones is also supported, improving the customer experience. **Product Reliability and Performance:** Neptune's products are rugged, and our warranty indicates that we stand behind what we sell. With a battery life of 20 years, field performance is maximized while maintenance costs are minimized. Neptune's Tallassee, AL factory is ISO 9001 quality certified. This assures our customers will receive only the highest quality products and services. Neptune has built a "Meter Farm" at our factory that allows us to monitor approximately 1,500 meters and meter interface units in various conditions including extreme heat and cold, ultra-violet exposure, moisture, flooded pits, and many other conditions that our products may experience under normal operating conditions. These devices are read and monitored continuously through various types of

Technology Name: Company Name: Company Contact Name:	Neptune Technology Group Ferguson Waterworks Mike Bortoletto, Sales Manager
	gateways and data collectors. This commitment to product testing helps to ensure that they perform as expected in the "real world". **Field Proven Reliability:** All Neptune meters meet or exceed AWWA standards and NSF/ANSI 61 certifications. Neptune is the only North American water meter manufacturer with its own bronze foundry, providing to our customers only lead-free bronze in all its water meters. Neptune's meter endpoints are designed for the harsh environments of pit or vault applications or inside sets. RF MIUs are available in both integrated and stand-alone form factors. **Innovative Technology:** Neptune's MACH 10® solid-state ultrasonic meter features no moving parts to wear out over time. Its high resolution measurement enables capture of extremely low flow rates. It combines solidstate metrology with corrosion-resistant, lead-free, high-copper alloy main case, built to withstand demanding service conditions. The Neptune R900v5 series endpoint with its interleaved messaging supports mobile AMR, fixed base R900 AMI, and the LoRaWAN™ open-standard protocol for AMI. It is the first LoRa® Alliance certified water AMI solution. **Software and Managed Services**: The Neptune® 360™ Cloud Platform, offered as Software-as-a-Service (SaaS) provides utilities with a scalable, reliable, and secure data management solution. **Ferguson's Network-as-a-Service (NaaS**): This provides for an outsourced AMI infrastructure solution including design, build, and ongoing O&M for AMI projects, resulting in the most cost effective total cost-of-ownership (TCO) for network infrastructure over the life-cycle of such projects. Through the LoRAWAN network and the LoRA Alliance organization, the utility will be able to leverage this technology to extend to a variety of other IoT/M2M applications for water/wastewater automation and Smart City initiatives.
Operating Experience	**A. Please provide the number of US water utility deployments, including the smallest and largest size of deployment (number of endpoints and population served).** Since Neptune R900 radio endpoints transmit simultaneously in both AMR & AMI modes, we do not distinguish between AMR and AMI customers. There are 2,900+ water utilities utilizing Neptune's AMR/AMI systems across the US. The City of Cincinnati (250k endpoints and 1.1M people served), the City of Raleigh (200k endpoints and 600k people served), and the City of Atlanta (170k endpoints and 1.2M people served) are all Neptune AMR/AMI water customers. As for the smallest water utility served, there are many that have less than 500 endpoints servicing populations of less than 1,500 people. **B. Please note how many California deployments you have in the water sector.** There are over 60 water utilities in CA utilizing the Neptune AMR/AMI System. We have included a chart of (10) CA Neptune AMI customers below:

Local Neptune AMI/MDMS Accounts

Utility Name	Location	Installation Date	Account Size
Ventura Water	Ventura, CA	2018-Present	31,500
City of Buena Park	Buena Park, CA	2018-2019	19,500
North Marin WD	Novato, CA	2017-2019	21,000
East Valley WD	Highland, CA	2016-Present	24,000
City of Lakewood	Lakewood, CA	2016-2017	20,000
Indio Water Authority	Indio, CA	2015	22,000
City of Simi Valley	Simi Valley, CA	2015	25,000
Indian Wells Valley WD	Ridgecrest, CA	2015	13,000
Rio Linda WD	Rio Linda, CA	2017	5,000
City of Benicia	Benicia, CA	2017	9,600

Technology Name: Company Name: Company Contact Name:	Neptune Technology Group Ferguson Waterworks Mike Bortoletto, Sales Manager
	C. If case studies are available, please provide website or attachments. Ferguson has maintained its own in-house installation team, dedicated to installing Neptune meters and AMR/AMI technologies. We have successfully deployed many meters and/or AMR change out projects, ranging from basic touchpad reading to mobile/drive-by meter systems to sophisticated multicollector fixed network radio technologies. For the past fourteen years, the Ferguson meter installation team has been completing meter change-out projects throughout the Upper Midwest. We have now expanded our reach beyond the Upper Midwest and are providing installation services in other areas of the country, including 43 of the 50 states in the country. We have proven experience in the installation of both residential and commercial grade meters and AMR/AMI units in a variety of environments, ranging from interior basement/mechanical room applications, to exterior-mounted Meter Interface Units (MIUs) to sidewalk/yard pit meter installations. We are currently over 1 Million endpoints installed and counting. The link to a most current case study is: https://www.neptunetg.com/resources/case-studies/benicia.
Simplicity	
Required Infrastructure	**Minimum infrastructure required and service options.** **A. Do you offer a network as a service option?** Yes, we can offer both a utility owned solution or Ferguson-owned solution for CHWD. **B. What is the minimum, maximum and optimum/standard requirement for antenna height? Would limitations on antenna height impact the number of collectors required for adequate coverage?** We would need to run a propagation study to best determine this for CHWD. With that said minimum height would be 35' as for a maximum the higher the better for this solution and could impact the overall amount of infrastructure needed. **C. Acknowledging significant variation which will be determined by a system propagation study (due to many factors such as building density, topography and vegetation), please provide a minimum, maximum and optimal range from the endpoints to the gateways.** There is no minimum range. While the maximum possible range between a data collector and endpoint in the R900 system is greater than 15 miles, this distance is not likely to be achieved in the real-world nor is it the optimal range for a robust AMI network design. It is more useful to approach this question by considering the number of gateways required to meet the performance requirements for a given area and the cost associated with each gateway. Neptune utilizes sophisticated propagation modeling that incorporates the specific variables for the utility's coverage area to determine the optimum infrastructure placement, and therefore the optimum range. Propagation modeling incorporates such factors as geographic and topographic parameters of the endpoint locations, proposed sites of data collectors, and antenna height. Once the modeling is complete, a proposal will be provided to the utility outlining implementation and infrastructure requirements. **D. How does your network achieve redundant coverage of endpoints?** Use of multiple Gateways to build in redundancy is key. However, asset height and type of networks can vary from solution to solution. Overlapping gateway reception provides a redundant communication path for end-devices, contributing to higher message success rates. The network design criteria typically result in endpoints communicating to 2 or more gateways. **E. Any additional information regarding options to minimize infrastructure complexity is welcome.** The use of the R900® LoRaWAN network may be the best way to minimize infrastructure for CHWD. For a utility owned option, our R900 IoT gateway provides superior deployment flexibility while maintaining simplicity. The Gateway is a pre-configured, carrier grade device which requires minimal maintenance over its operating life. Ferguson's NaaS option nearly eliminates complexity from the standpoint of CHWD by

Technology Name: Company Name: Company Contact Name:	Neptune Technology Group Ferguson Waterworks Mike Bortoletto, Sales Manager
	handling all aspects of design, O&M and replacement of network infrastructure for the life of the NaaS contract.
O&M Requirements	**A. Please summarize notable maintenance requirements for primary system components.** Ferguson's proposed Network as-a Service (NaaS) AMI network solution does not require the City to utilize personnel for the installation, operations, and ongoing maintenance of the data collector infrastructure. Neptune will be responsible for all aspects of the AMI network design and O&M for the defined lifecycle of the AMI contract. This also includes the cloud-based network and application servers supporting LoRaWAN™ and any network infrastructure upgrades over the life of the AMI project. **B. What is the typical maintenance of a gateway over the life of the system?** Not much maintenance is needed for a Gateway once operational, potentially a firmware update to address any new features or firmware enhancements and defects. **C. Do you offer over-the-air (through the headend and software) firmware updates?** For LoRa NaaS or a customer owned and deployed LoRa network with the R900 IoT Gateway, firmware updates can be applied to address any new features, firmware enhancements and defects.
Reliability	
Battery Life	**Please provide component battery life (endpoints, gateways, etc.) assuming scenarios for both hourly and 15-minute read frequencies.** The R900 MIU is warranted for 20 years (10 full + 10 prorated). In order to support a 20-year expected life, the R900 endpoint provides a single mode of operation with predefined transmission intervals. This allows the expected life to be accurately calculated and deterministic since the number of transmissions is fixed and known.
Equipment Life	**Please provide estimated useful life for major components of system.** The expected life of the R900 AMI Collectors is 10-years, at which point they would need to be replaced one time. The R900 endpoint includes the industry standard 20-year warranty (10 full + 10 prorated) and is estimated to live for 23-years.
Data Storage	**A. Please provide data storage protocols and data loss prevention safeguards.** Neptune's Head End System is hosted via Amazon Web Services and covered by their disaster recovery policies and resources. Database and log transaction files backups are performed every day in a seven day rotation. These are stored to a volume directly attached to the database server. These volumes have multiple replicas of them built into AWS' cloud infrastructure. Daily and weekly instance images (including the OS) are being taken and stored to our provider's object storage. Daily images are kept for two days and weekly for two weeks. The object storage is replicated across multiple datacenters. **B. Please provide any additional information regarding resiliency during emergencies and disaster-proofing.** In the event of a network/gateway outage or some other condition where the MIU reading packet is not received, the R900 MIU features additional mechanisms to recover missed hourly reading intervals. First, each LoRa fixed network message contains historical reading information to provide reading redundancy. This information is automatically backfilled if a reading interval is not received at the head end system. Secondly, the R900 MIU supports the retrieval of 96 days of reading intervals through the standard RF-activated data logging capability. In the event of a prolonged network outage or other condition which causes the R900 MIU to not communicate with the LoRa network, this information can be uploaded to the head end system through synchronization of mobile data collection hardware.

Technology Name:	**Neptune Technology Group**
Company Name:	**Ferguson Waterworks**
Company Contact Name:	**Mike Bortoletto, Sales Manager**

Responsiveness

Analytics

Please list built-in analytics included as turnkey features of system, e.g. leak detection, pressure monitoring, reverse flow alarms, tampering alerts, etc.

Neptune-managed system with no installation required

Cloud-based solution in a world-class data center with the highest level of security and disaster recovery/redundancy

24/7 software system monitoring.

Retain data ownership in a system designed exclusively for water utilities,

Integrate and access Data Analytics across departments — helping your utility achieve goals and objectives.

Identify potential leaks, excessive consumption, and reverse flow to proactively resolve issues faster.

Migrate easily from mobile to fixed network in real time.

Aid Non-Revenue Water reduction, conservation, and rate planning

A single platform across devices that can be accessed anywhere at any time!

Flexibility

Compatibility

Inter-system compatibility with components and information systems.

A. Please list meter types and brands with which your technology is compatible. Identify compatibility limitations with brands and types of meters.

<table>
<tr><th>Manufacturer</th><th>AMR Compatible Register Model</th></tr>
<tr><td>AMCO</td><td>Digital</td></tr>
<tr><td>AMCO</td><td>Absolute Encoder</td></tr>
<tr><td>Badger</td><td>ADE</td></tr>
<tr><td>Badger</td><td>HR E|LCD</td></tr>
<tr><td>Hersey/Mueller</td><td>Translator</td></tr>
<tr><td>Neptune</td><td>E-CODER</td></tr>
<tr><td>Neptune</td><td>ProRead</td></tr>
<tr><td>Neptune</td><td>ProCoder</td></tr>
<tr><td>Neptune</td><td>MACH 10</td></tr>
<tr><td>Sensus</td><td>ECR II</td></tr>
<tr><td>Sensus</td><td>ICE</td></tr>
<tr><td>Sensus</td><td>iPearl</td></tr>
<tr><td>Sensus</td><td>Electronic Register</td></tr>
<tr><td>Sensus</td><td>OMNI</td></tr>
<tr><td>Elster</td><td>InVision (SP)</td></tr>
</table>

B. Do you provide a proprietary data management platform and customer portal or do you have preferred third party partners? Yes, Neptune has its own proprietary management platform. Neptune also has its own customer portal, but can also partner with Watersmart, Dropcountr, and most other major customer portal software companies.

C. Please verify compatibility/experience with the following billing systems:

- Cogsdale Yes
- Oracle Yes
- Central Square Yes
- TruePoint Yes

Technology Name: Company Name: Company Contact Name:	Neptune Technology Group Ferguson Waterworks Mike Bortoletto, Sales Manager
Redundancy	
Read Options	**Please detail options for redundancy in reading technology in case of failure, e.g. can the same transmitter be used for drive-by or walk-by reads?** The built-in ability of Neptune's R900® endpoints to be read in mobile AMR and fixed network AMI mode simultaneously assures backward compatibility and forward migration, eliminating significant costs associated with replacing, reprogramming or paying license fees to use these meters and RF endpoints in a fixed network AMI mode. Neptune's approach is a build-on rather than a change-out model assuring future compatibility and leveraging R900™ technology already deployed.
Communication	**A. What kinds of two-way communication networks are your systems enabled for (e.g., 3G, 4G, 5G, LTE-M, LoRa, Sigfox, etc.)** LoRa and LTE **B. Is your preferred communication technology available in the Sacramento area?** Yes **C. In areas where there is no signal (cellular or radio) what options do you offer?** We can install point-to-point radio systems to act as the backhaul from the Collectors to the head-end if cellular and/or Ethernet is not available.

Mueller - Mi.Net® Response

Technology Name: **Company Name:** **Company Contact Name:**	**Mi.Net** **Mueller** **Kevin Cornejo**
Technology Type	
Technology Description	The Mueller Mi.Net system uses a LoRA Communication protocol over the 902-928Mz spectrum. Using this chirping spread spectrum protocol we lower the noise floor allowing farther and clearer communication. The Mi.Net System is also upgradable to a LoRAWAN Class B low latency Open Architecture Network to allow for true smart city functionality this occurs with an OTA (over the air) firmware update without the need to change out the existing meter radios. Our Collectors are a Multi-Network designed to allow for a full system conversion of all deployed traditional AMI network items into a LoRAWAN Class B network. This provides our customers to the confidence of owning their own network while allowing interoperability between devices, such as parking meters, smart street lights, etc… and this functionality allows other agencies or departments to use the same established network to route data through. The Mueller Mi.Net platform also comes with a state-of-the-art software platform, Sentryx, this platform allows data from multiple sources into a common head end, such as Real Time Distribution Pressure Monitoring, Distribution Leak Detection, Remote Flushing, Water Quality Sensors, Valve Actuations, well as 3rd party data sets. The Sentryx system also has real time meter revenue alerts, reports, and account level alerts functionality. The Mi.Net System with our patient 2-way on demand communication allows for the system to query a meter register, or group of registers and return those values in 12 seconds, this one of a kind functionality allows for our Remote Disconnect Meter to be activated in seconds to open or close a water service. The Mi.Net System by MUELLER is the fastest and most versatile AMI system on the market today.
Operating Experience	**A. Please provide the number of US water utility deployments, including the smallest and largest size of deployment (number of endpoints and population served).** a. 25 Million Meters Sold b. AMR/AMI 1200 i. 950 AMR ii. 250 AMI iii. 5+ Million Endpoints c. 220K Remote Disconnect Meters d. Largest Customer ~380,000 services e. Smallest Customer less than ~250 services **B. Please note how many California deployments you have in the water sector.** a. We have multiple deployments with multiple versions of AMI and AMR. Currently there are 4 AMI customers 2 with our Licensed Product and 2 with our Unlicensed Broad-Spectrum open protocol product. We have several more AMR customers as well as product in almost every utility in the state of California. **C. If case studies are available, please provide website or attachments.** a. https://muellersystems.com/resource-library/case-studies/ b. https://www.waterworld.com/water-utility-management/smart-water-utility/article/14072177/an-investment-in-quality-of-life c. https://www.wwdmag.com/advanced-metering-infrastructure-ami/modern-meter-reading
Simplicity	
Required Infrastructure	**Minimum infrastructure required and service options.** **A. Do you offer a network as a service option?** a. Varies depending on system selected but usually, i. Collector

Technology Name: Company Name: Company Contact Name:	Mi.Net Mueller Kevin Cornejo
	ii. Endpoint iii. Encoded register b. Our Multi-Network Collectors (MNC) are modular meaning easy repair or replacement. The MNC is usually mounted at ladder height while the antenna may be 100ft above it. Our Network Operations Center (NOC) in Atlanta is included in our hosting fees they ensure the read rates, provide for data traffic rerouting, and perform remote diagnosis, repair and support. Since the system is supported by the NOC and the designs are modular with an extended equipment warranty, a network as a service for maintenance and repair is not something typically not needed with our design however if desired, we can on a case by case basis. Also, we can hang our endpoint on a 3rd party LoRAWAN Network offered through Cox, Comcast, Mylander, Senet, and others where they provide complete network as a service. Or we can provide collectors to have our customers be their own LoRAWAN provider. **B. What is the minimum, maximum and optimum/standard requirement for antenna height? Would limitations on antenna height impact the number of collectors required for adequate coverage?** a. Yes, the antenna height does have an impact on coverage. Especially in the City of Trees. Providing Antenna heights for a propagation study is the best way of ensuring adequate counts and range. 30-50' would be optimal if you get too high with the trees you have a hard time with the canopy and cars. Have a system that utilizes repeaters in this environment would also be beneficial. **C. Acknowledging significant variation which will be determined by a system propagation study (due to many factors such as building density, topography and vegetation), please provide a minimum, maximum and optimal range from the endpoints to the gateways.** a. 3 to 5 miles on average but we have some as far a 8 miles. No minimum. **D. How does your network achieve redundant coverage of endpoints?** a. Mueller Systems understands and complies with this requirement. We approach the architecture, redundancy and other assurances differently than most other systems. This is done to assure best performance at the lowest lifecycle cost. First, we perform a comprehensive radio propagation study to determine what hardware is needed and where it should be placed to provide solid coverage and a level of redundancy. Each endpoint is assigned to a specific collector (but can be rerouted via the NOC or customer if needed) and may use repeaters to reach the assigned collector. These assignments are not necessarily based on geography but rather radio path strength and reliability. b. Part of the service and ongoing support of a hosted Mi.Net system, includes 24/7 system monitoring by our Network Operations Center (NOC) where sophisticated software reads and interprets communications and network performance metrics and displays points of concern on the nine-foot tall monitor, alerting engineering staff. Many times, issues are resolved before utility staff even suspect a problem. c. If a network issue should occur, such as a collector or repeater failure, and the radio path is interrupted or other network issue that prevents data from being forwarded to the host servers for any given period, the Mi.Node endpoints will store data for 511 days. The path to the host may be routed through other infrastructure assets. Once a new path is achieved or the disruption is corrected the stored data will automatically backfill as soon as the system communications have recovered. We have found this to be a highly reliable level of assurance for our network users. **Any additional information regarding options to minimize infrastructure complexity is welcome.** See above response.

Technology Name: Company Name: Company Contact Name:	Mi.Net Mueller Kevin Cornejo
O&M Requirements	**A. Please summarize notable maintenance requirements for primary system components.** a. Preventive maintenance requirements are minimal. Each Mi.Net Multi-Network Collector (NMC) is sealed in order to stay watertight and deter tampering with the unit. Preventive maintenance is covered by Mueller Systems under the hardware service agreement. Typically, any maintenance on the unit is provided by Mueller Systems at no additional charge if the customer has a hardware maintenance contract. **B. What is the typical maintenance of a gateway over the life of the system?** a. See Above **C. Do you offer over-the-air (through the headend and software) firmware updates?** a. The Mi.Node endpoint and MNC is capable of receiving Over-The-Air (OTA) firmware updates that will allow the Mi.Node endpoint radios to be reprogrammed to operate in fixed base mode with the endpoints being routed to a Mi.Hub data collector. This migration can be done in phases or only in specific regions allowing.
Reliability	
Battery Life	**A. Please provide component battery life (endpoints, gateways, etc.) assuming scenarios for both hourly and 15-minute read frequencies.** a. Endpoints are designed to last 20 years with hourly reading. Mi.Net functionality can go down to 5, 15- or 30-minute intervals reverting back to hourly automatically after 1 week for 5 minute interval and 2 weeks for 15 minute and 30 minute intervals. Dropping down below an hour interval is usually only used in cases of investigations and meter right sizing and generally only needed for short periods. We can turn off the revert function and it would be impacted by the interval quantity per hour i.e. 15 minutes would be 4 time an hour and reduce the life 20/4= 5 years +/-. This is the case with all power cells.
Equipment Life	**A. Please provide estimated useful life for major components of system.** a. Major components of the system can be expected to be replaced once within the 20 year life span of the Endpoint/ Radio.
Data Storage	**A. Please provide data storage protocols and data loss prevention safeguards.** a. All data is host by Amazon Web Services- Government Service Standards and all safe guards and data integrity follow Amazons policies and guarantees. **B. Please provide any additional information regarding resiliency during emergencies and disaster-proofing.** a. The system has multiple safeguards to prevent the loss of stored data. In the event of a system failure, the system remains at the point of failure. When restarted, the system will continue on from that point. All message queues remain intact and will begin sending and receiving messages once the system has been restarted. All message logs from the meter are always saved in addition to the storage of the meter data in the Mi.Host database. The data can always be reprocessed from the messages should a catastrophic database event occur. All data is stored in RAID 10 to ensure data integrity and access in the event of drive failure. In the case of system failure all data in the database is backed up with full database base backups 2x per week, differential backups every other day and log backups every hour. This will ensure that data is secure and backed up in the case of failure. i. Mi.Node Holds 105 days of hourly reads. (Auto back fills) ii. The MNC (Collector) Holds 90 days of hourly reads of all reporting Mi.Node Radio/ Endpoints/ MTU's iii. AWS Government Standards for data.
Responsiveness	
Analytics	**Please list built-in analytics included as turnkey features of system, e.g. leak detection, pressure monitoring, reverse flow alarms, tampering alerts, etc.**

Technology Name: Company Name: Company Contact Name:	Mi.Net Mueller Kevin Cornejo
	Below is an extensive description of the alerts and flags which are available within the system, some of which are generated at the register or resident in the endpoint and others are monitored within the user interface. All alerts and flags are entirely configurable for virtually any variable (time, volume, etc.), tracked by the user interface and can be sent via email to staff by utilizing a simple scheduler for identifying the specific alerts and assigning them to various groups or individuals based on a wide range of variables. There are fourteen different alert categories that can be generated by a node, meter or software. Although most alerts have variables which may be adjusted, the alert descriptions below are based upon the standard configurations. Isle Utilities may revise the parameter variables to meet specific needs for individual meters, by group or globally. The available alert conditions are: 1. **Unable to Read Device**: The MIU has not received any response from the register when interrogated (timed out attempting to read the register). This could indicate a wiring issue between the register and node, the meter has been removed or the register is faulty. 2. **Device Read Failure**: The MIU receives a response from the register but is unable to fully interpret the string of data from the register (such as a digit error). This indicates a faulty register and will require replacement. Invalid data or holes appear in the hourly reads received each day. 3. **Wheel Location Error**: Indicates that the MIU was able to read the meter but the reading contained a "?". This is industry standard procedure for mechanical encoder registers to report a "?" when the wheel position is ambiguous and cannot be properly encoded. To avoid reporting an incorrect reading, a wheel error may occur when the meter wheel position is between digits. It can also occur if the wheel is broken and unable to get valid readings. Generally, this is a transient condition that resolves itself when wheels advance due to consumption. If the condition persists it could potentially require replacement of the register. 4. **Tamper Detection**: This is a condition where the current register serial number does not match the value of the register identified during the install process. This value is stored in nonvolatile memory in the MIU and compared with the register identifier each time the register is interrogated, when the ID in memory does not match, an alert is generated. 5. **No Flow Detection**: Standard, this alert is generated after 21 continuous days of no forward flow reads. This could indicate a system-side failure, closed valve or a tamper issue where a meter was disconnected, removed or bypassed. Complementing the No Flow Detection is the Soft Disconnect feature in the host user interface which can detect water flow at an unoccupied property or for a vacationing homeowner. In these scenarios the No Flow Detection alert may be turned off. 6. **Soft Disconnect**: Indicates consumption on a meter that should not register any use. Typically used for inactive metered accounts and may be scheduled during specific times/dates or just ongoing. 7. **Reverse Flow Detection**: Reverse flow is indicated when the register moves in reverse (decrements) and is detected for a set number of consecutive hours. This could indicate a reverse flow condition that could contaminate the public water supply or could be an incorrectly installed meter (generally detected shortly after an installation or replacement) also if a consumer has reversed the meter to reduce their bill (tampering). In systems without backflow preventers some reverse flow may occur due to main line pressure changes, surges, etc. 8. **Register or Chamber Tamper**: When using a Mueller Meter equipped with a Mueller Systems SSR register, an alert will be generated when magnetic separation is detected between the register and the meter body or measuring element or if a

Technology Name: Company Name: Company Contact Name:	Mi.Net Mueller Kevin Cornejo
	magnet is placed near the meter in an attempt to slow or stop the meter. This is triggered by tampering with the meter by removing the register or measuring chamber from the meter or placing a magnet near the meter. 9. **Magnetic Tamper**: When using a meter equipped with a Mueller Systems SSR register, an alert will be generated to warn of magnetic tampering. 10. **Small Leak Detection**: This Small Leak Detection function allows for leaks typically smaller than 1 CF or 10 gallons to be detected over a 21-day monitoring period. The Mi.Node endpoint does not measure an amount less than 1 CF or 10 gallons per hour so to detect this condition, the endpoint calculates a pattern over several readings. The system logs at least 12 readings where more than three (3) consecutive readings increase 1 CF or 10 gallons. This indicates a low flow such as dripping faucet or running toilet. This is performed by ignoring periods of high consumption and looking for periods with average low consumption. 11. **Large Leak Detection**: This is a condition where continuous flow has been detected during a moving 95-hour window (i.e. no read interval of zero use). The internal count is reset on any zero flow or reverse flow condition. 12. **High Flow Rate Detection**: This is used to detect when flow through the meter is higher than expected. This is turned off by default since it requires configuration by the user with desired values based on size of meter and the application. 13. **Provisioned Consumption Threshold**: This alert is used on an individual account basis, when needed, to identify when the metered use is outside of the expected use parameters. 14. **Battery Health**: Indicates when the capacitor voltage drops below a specified value and duration. When sensing a low capacitor level, the MIU will automatically go into sleep mode for 24 hours to allow the capacitor to slowly recharge using the battery. During this time no data will transmit or receive but the node will otherwise continue to operate normally. Standard operation resumes once the voltage rises above the threshold level. **In the Software Managing Alerts** Each alert has its own default settings but can be changed if desired. The response from the attached register and the consumption pattern is evaluated each hour when the register is interrogated to determine if an alarm/alert condition exists (trigger or set) or if the conditions indicate the alarm/alert is no longer present (clear). The actual operation for alert generation and updating of thresholds is handled during the logging operation only. Any on Demand read will not be used in the threshold calculations. Each alert has its own default settings but can be changed if desired. The response from the attached register and the consumption pattern is evaluated each hour when the register is interrogated to determine if an alarm/alert condition exists (trigger or set) or if the conditions indicate the alarm/alert is no longer present (clear). The actual operation for alert generation and updating of thresholds is handled during the logging operation only. Any on Demand read will not be used in the threshold calculations. The available settings for each alert are: <table><tr><td>Alert Generation On/Off</td><td>Option to make the specific alert active or inactive. This message can be included during the installation message.</td></tr><tr><td>Urgent Notification</td><td>If urgent notification is on, the alert will be sent on the top of the hour. If it is off, the alert will be sent on the same message as the reading, during the next daily report. This is typically set for those conditions that require continuous monitoring.</td></tr></table>

Technology Name:	**Mi.Net**
Company Name:	**Mueller**
Company Contact Name:	**Kevin Cornejo**

Notify Every Interval	If this option is on, the alert will be sent every hour until it is no longer valid (a.k.a. until the alert clears). If off, the alert will only be sent when the condition first occurs.
Generate Alert on Clear	By selecting on, an alert will be generated when the alert clears (a.k.a. the alert is no longer valid). This is recommended to be on so the utility personnel is notified when the alert is cleared.
Various Thresholds	Each alert has certain thresholds and periods as default. These can be changed as desired by staff. It is common to tweak settings over time as the utility develops experience using the system. This gives utility staff the ability to set priorities and prevent alerts from becoming “noise” in the system.

Alert Priority Levels

Priority level and reporting capabilities for tamper detection are set to a factory default but are remotely configurable by the utility staff. If desired the MIUs can be programmed to immediately wake up and send alerts through the network when triggered. Lower priority alerts may also be established which would cause the MIU to log an event and send the data along with its normal consumption message.

All alerts may be made immediately viewable by utility personnel logged onto the system and can also be configured to send email or text alerts according to a built-in scheduler application. This will contact utility personnel and/or homeowners and notify them of the specifics of an alert condition. Alerts can be configured to send email/text alerts only during regular business hours. Utility personnel can be identified to have alarms sent to different people depending on alarm type, shifts, day of the week, etc.

Additional Software features:

- **Remote Disconnect and Reconnect Meters**- Turn on and turn off service with in seconds.
- **Leak Monitoring**- Adding in Echologics leak Monitoring for Distribution side leaks. Accurate to with in 3 to 6 feet with no water surfacing. No about your leaks before they surface or cause shut downs with Echologics DX.
- **DMA**- District Metering Area. Be able to calculate water loss by zone with the use of zone primary meters.
- **Pressure Monitoring**- Be able to monitor Distribution System to transient pressures events in near real time.
- **Remote Flushing**- Activate remote flushing stations in problem areas on command.
- **Water quality Monitoring**- Monitor you water quality remotely, for total chlorine, free chlorine, turbidity, Ph, and others.

Flexibility

Compatibility

Inter-system compatibility with components and information systems.

A. Please list meter types and brands with which your technology is compatible. Identify compatibility limitations with brands and types of meters.

We have provided a Meter Compatibility Table below showing the degree of compatibility of our Mi.Node endpoints with all makes and models of water meters currently available in the US market.

Technology Name: **Company Name:** **Company Contact Name:**	**Mi.Net** **Mueller** **Kevin Cornejo**

Manufacturer	Register Model	Degree of Compatibility	Functionality
		1 - No programming req'd 2 - Routine programming of MIU or meter req'd 3 - Technically feasible, non-routine mod 4 - Infeasible	1 - All features operational 2 - Some functions inoperable (describe) 3 – Under development (describe)
Badger	ADE	1	1
Badger	E-Series	1	2 (a)
Badger	HRE	1	2 (a)
Diehl Metering	Hydrus	1	3 (d)
Hersey	Translator	1	1
Hersey	SSR	1	1
Kamstrup	FlowIQ	1	2 (a)
MasterMeter	AccuLinx	1	2 (b)
Metron	OER	1	2 (c)
Neptune	E-coder	1	2 (a)
Neptune	Pro-read Auto-Read	1	1
Performance	ETR	1	1
Sensus	ICE	1	1
Sensus	iPerl	1	3 (d)

(a) Limited to 9 digit reading
(b) Limited to 6-digit reading
(c) Limited to 5-digit reading
(d) Full 8-digit reading with extended protocol including all alerts

B. Do you provide a proprietary data management platform and customer portal or do you have preferred third party partners?

a. Water Smart is our preferred Customer Presentment partner.

C. Please verify compatibility/experience with the following billing systems:

- Cogsdale- Yes
- Oracle- Yes
- Central Square- Yes
- TruePoint- Yes
- Mueller Systems has the flexibility to work with the utility and the Cogsdale CIS and other vendor to integrate with the billing system. Through requirement gathering workshops, Mueller Systems works to identify the data elements that need to be passed between systems in order to develop interfaces to the utility's requirements and specifications.

<table>
<tr><th>Technology Name:
Company Name:
Company Contact Name:</th><th>Mi.Net
Mueller
Kevin Cornejo</th></tr>
<tr><td colspan="2">Redundancy</td></tr>
<tr><td>Read Options</td><td>Please detail options for redundancy in reading technology in case of failure, e.g. can the same transmitter be used for drive-by or walk-by reads?
Yes the same Mi.Node/ Endpoint/ Radio/ MTU can do both AMI and local reads.</td></tr>
<tr><td>Communication</td><td>A. What kinds of two-way communication networks are your systems enabled for (e.g., 3G, 4G, 5G, LTE-M, LoRa, Sigfox, etc.)
All system communication utilizes the unlicensed 902-928 MHz Industrial, Scientific, Medical (ISM) radio band with LoRa (Long Range) technology making for a simple, smart design. From the collector to the head-end system operations software, various IP protocols (Cellular, Ethernet, Fiber Optic, and Radio) can serve as two-way communication backbones/ Back haul. Mi.Net offers the ability to communicate within seconds with a single meter endpoint or groups of endpoints for the purposes of retrieving stored consumption data, sending commands, and changing operating parameters.
The Mi.Net System and Mi.Nodes/Radio/Endpoints/MTU’s can be flashed over to a 3rd party or customer owned LoRAWAN Class B network. <u>There are differences in latency between Class A and Class B LORAWAN.</u>
a. In addition to collecting scheduled reads automatically, the Mi.Net two-way AMI system supports the ability to retrieve <u>data on-demand within 12 seconds</u> with the click of a button, remote disconnect and reconnect capability for residential meters, right sizing of meters, customer specific usage detection and alert programming that is fully configurable over-the-air. Move-in/move-out reads, as well as implementing or changing watering restriction programs can be easily performed over the network. Remote Firmware Upgrade (RFU) capability of all system components, including radio endpoints, helps to ensure that meters installed now can be upgraded to support new features and provide the same level of advanced support as systems implemented years later and may be done from the host desktop.
B. Is your preferred communication technology available in the Sacramento area?
a. Yes it is available for deployment not for review at this time. Maybe with in the next few months.
C. In areas where there is no signal (cellular or radio) what options do you offer?
a. The Mi.Net System described in this proposal was designed as a two-way AMI network. However, there are existing tools in place that allow our system to load the Mi.Tech handheld(s) with routes of missed reads for either manual or walk-by radio reads or to load a laptop utilizing the Network Manual Tool (NMT) with a route for use as a drive-by (disaster recovery) method in the event the network collectors are disabled. This process is built into the Mi.Host UI.
b. Utilities can load meters to be read to either a Mi.Tech handheld or the NMT for collection in walk-by or drive-by AMR fashion. The process for accomplishing this is described below.
The manual read cell is created when the billing function “Process for Missing Reads” is performed or manual read cells can be manually created from Tools, Reporting, Manual Readings in Mi.Net.
The cell can be split as it is downloaded and loaded onto multiple Mi.Tech handhelds or multiple NMT (laptops).
When reading using the Mi.Tech shows the distance from the meter to read in feet, while the NMT offers a map based view.
The handhelds can read the non-reporting meters in close proximity with the install radio. The NMT can read them with the maintenance radio. The NMT can be set to automatically retrieve the read if within X feet, making the read collection work in drive-by fashion.</td></tr>
</table>

Technology Name: Company Name: Company Contact Name:	Mi.Net Mueller Kevin Cornejo
	• If the meter does not read with the radio, the reading can be entered manually into the handheld or NMT. • Once all handhelds and NMT's are complete and the cells are uploaded, the billing process "Process for finalization" can be run, pulling the obtained reads into billing. When using the NMT (laptop) in connect to a maintenance radio and GPS locator, the process for collecting reads in drive-by fashion is as follows. • From the NMT open the edit task dialog box and hit the download manual reading worksheet • Open the task view window and show only the locations that are on the list. • Uncheck the show complete tasks so only the locations you still need to visit show on the map. • Check the auto send if within 300 feet (this number is configurable by Isle Utilities). This automatically sends a read meter over the RF and will get the reading if the node can communicate and has a readable register. • If not, a box pops up asking the user to type in the reading. • Once the task list is empty, return to edit tasks and upload the readings to the server. As a Company meter reader driving the vehicle drives the route with a GPS locator, the NMT will automatically send on-demand read requests to the unread meters within the route and populates the reading field. The vehicle is shown on the screen along with unread meters so the driver can track his or her progress. The method described above is utilized for capturing billing reads. Interval data is generally provided by utilizing the "Force Upload" feature of the NMT. If a meter can be accessed via any network equipment a force upload can be initiated from the NMT which will upload all interval data directly to the Mi.Host server. Additionally there are tools that allow the NMT to utilize a mobile Mi.Hub collector to initiate force uploads in the field and then retrieve the information to the vehicle where it is then uploaded to Mi.Host via cellular connection.

Sensus FlexNet® Response

Technology Name: Company Name: Company Contact Name:	FlexNet AMI Solution Sensus USA Inc. Dawn Groves
Technology Type	
Technology Description	**Provide a technical description of your AMI solution, specifically summarizing the network configuration options (e.g. cellular, RF, etc.) and characteristics which set your offering apart from other providers in the AMI space. Please keep this to a 300-word summary or less.** Sensus' AMI solution is differentiated from competitive offerings by its superior reach, flexibility, security, and ability to support multiple applications on a single network. Our point-to-multipoint, primary-use, FCC-licensed RF network is exclusively reserved for FlexNet customers. Interference from unauthorized devices is regulated and prohibited by the FCC. While other AMI solutions share RF spectrum, Sensus believes that a utility grade network should not have to share spectrum with unauthorized devices, such as baby monitors. Sensus' dedicated spectrum results in absolute control of the network, now and in the future. With its point-to-multipoint design and high-power transceivers, FlexNet requires significantly less network infrastructure than competitive offerings. Less infrastructure results in lower costs, not only upfront, but in the years of maintenance and support that follows. Another commercial benefit of the FlexNet solution is its interoperability with third party meters, devices, and applications. This enables utilities to choose their preferred products. FlexNet supports meters from the manufactures listed in **Attachment A**: **Compatibility Guide**. The FlexNet Head End System can be integrated with any third-party application through standardized interfaces such as CMEP or MultiSpeak. Additionally, Sensus has proven our commitment to design new products with both forward and backward compatibility in mind**. We maintain backward compatibility with all FlexNet-enabled AMI solution components for the 20-year life expectancy of your system** by testing and verifying backward compatibility prior to releasing new products. We regression test every new version of our FlexNet Head End System against legacy FlexNet Head End Systems and meters to ensure this compatibility. As a result, **no endpoint is left behind**. If new AMI capability is needed, it can be added to the existing infrastructure through software updates. There is no need to replace infrastructure. FlexNet is designed to grow with you as your needs evolve over time.
Operating Experience	**A. Please provide the number of US water utility deployments, including the smallest and largest size of deployment (number of endpoints and population served).** Sensus has over 5000 customers, 1100 of which are currently using the FlexNet AMI solution in North America. Approximately 800 of these deployments support a water solution. Water deployments range from fewer than 500 endpoints to more than 600,000 endpoints. FlexNet's point-to-multipoint architecture allows for virtually unlimited scaling regardless of the utility type, as seen through FlexNet customers that support over 10 million endpoints. Through design and our existing utility base, the Sensus solution is adaptable to all geographic conditions, both natural and man-made, including mountains, urban canyons, and suburban and rural environments. Our proven technology provides utilities in diverse weather conditions (heat, cold, extreme wind) with peace of mind about the solution stability in a time of need. **B. Please note how many California deployments you have in the water sector.** Sensus actively supports more than 200 water customers in the state of California; more than 50 are AMI base solutions. Through intentional design, Sensus can support both AMR to AMI customers with the same endpoints. This allows utilities to transition to AMI from

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	AMR at their own pace with no additional endpoint costs, complex configurations, or firmware updates. No other vendor can make that claim. **C. If case studies are available, please provide website or attachments.** For convenience, Sensus has attached three case studies related to current utility concerns; meter accuracy, water reduction, and conservation programs. • Eastern Municipal Water District Improves Meter Read Accuracy • Fountain Valley Case Study • Redwood City Leverages FlexNet Features for Innovative Conservation Program Additional case studies and testimonials from water utilities are available at: https://sensus.com/resources/case-studies/topic/water/.
Simplicity	
Required Infrastructure	**Minimum infrastructure required and service options.** **A. Do you offer a network as a service option?** Yes, Sensus offers a network as a service (NaaS) option for the communication network, as well as a software as a service (SaaS) model for the head end system. The NaaS offering provides all the benefits of a Sensus FlexNet communication network and managed by Sensus. Sensus will own, manage, monitor, and maintain the FlexNet communication network and infrastructure. Sensus is responsible for warranty, maintenance, and support of the base stations and FCC-licensed radio spectrum. Sensus is responsible for any and all interference and mitigation of spectrum, should any arise due to unforeseen circumstances. Sensus will perform network optimization and tuning to ensure that the FlexNet communication network is operating at peak performance. Part of network optimization and tuning includes looking at stale meters, Read Interval Success (RIS), RF channels, and overall network health, capacity, and performance. We will change meter configuration and channel configuration to ensure optimal performance for each channel and frequency. Sensus will also perform regular scheduled maintenance on each base station, and will respond to any network-related incidents that may occur in the field. We will monitor all FlexNet components around the clock from our Network Operations Center (NOC) to ensure proactive management and identification of incidents and problems that may occur. Sensus will manage and maintain the base station firmware and other software required to operate the Sensus base station applications. The Sensus Security team and experts will manage, monitor, and maintain the security of base stations. Sensus will own, manage, and monitor the cellular backhaul connectivity with other service providers, such as AT&T and Verizon. Sensus will own the cellular modem and backhaul, in this case, and will maintain all ownership and responsibility for this connection and troubleshooting with the service provider, which includes direct access to their top-level Tier 3 support personnel. **NaaS benefits and outcomes** • Reduce the risk of system and network misconfiguration by shifting responsibility to Sensus. • Reduce IT and operational costs required to manage, monitor, and maintain the FlexNet communication network. • Provide predictable costs for budgetary planning. • Improve security on the FlexNet communication network through having the network managed and monitored by Sensus security experts and personnel. • Increase availability and uptime of the FlexNet communication network, reducing outages and system downtime. • Improve operational efficiency by leveraging Sensus expertise.

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	FlexNet Managed Services Sensus can offer additional managed services for the FlexNet communication network, referred to as FlexNet Managed Services. This service provides the operational management, monitoring, and maintenance of the FlexNet infrastructure and communication network. The utility maintains ownership rights and responsibilities for the network, and Sensus provides the service to manage, operate, monitor, and maintain the FlexNet infrastructure. Sensus also tunes and optimizes the network to gain maximum performance and capacity. This will free up resources for the utility and allow them to repurpose these individuals to more strategic activities. In addition to the IT and operational cost savings, FlexNet Managed Services provides experts in the FlexNet solution that maintain maximum performance, capacity, reliability, and availability. Rely on Sensus' team of experts, who have been providing this service for some of our largest customers for the past six years. **Software as a Service** The SaaS offering provides all the benefits of a Sensus FlexNet communication network by placing the FlexNet head end in Sensus' private, cloud-based solution. When using a SaaS model, Sensus would purchase and provide all of the hardware and software required to operate the FlexNet head end, and would manage the application and servers in our world-class data centers. Customers do not need to invest additional expenditures such as IT hardware and software, additional office space, and specialized IT resources, such as security or database administrators. They can achieve the required business outcomes with the lowest total cost of ownership and complete peace of mind. With a SaaS solution, Sensus will monitor the utility's servers around the clock to ensure high availability and reliability. The data center team performs all hardware maintenance and software patch installation, updates, and upgrades, to ensure that customers can access the latest features. In addition to administering standard security testing procedures, Sensus' certified cybersecurity partners perform quarterly third-party audits and security testing to ensure that all information is safe. The Sensus SaaS solution eliminates the need for customers to maintain a separate disaster recovery environment through its geographically separated data center locations. The SaaS offering for the FlexNet head end includes: • Sensus purchases and owns the FlexNet Head End System software and license, as well as all third-party software required to run the application • Sensus manages, maintains, and monitors software and server hardware. • FlexNet software maintenance, including patches, updates, and upgrades (which are scheduled with customers). • Production and Disaster Recovery environments are included. • Standard technical support. The baseline SaaS offering includes Service Level Agreements (SLAs) for uptime and availability of the FlexNet head end application. **SaaS benefits and outcomes** • Reduced IT and operational costs. • Reduced risk associated with system configuration and maintenance. • Reduced risk in planning for business continuity through disaster recovery. • Reduction of environmental impact (carbon footprint).

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	• Increased availability and system performance through dedicated network and servers. • Increased and strengthened security of IT systems. • Accelerated time to market with new technologies. • Increased operational efficiency leveraging Sensus' Network Operations Center. • Predictable and more level cost structure. **Application Managed Services** Sensus also can provide Application Managed Services for its customers. In this optional Application Managed Services offering, Sensus would provide all personnel to manage, monitor, and maintain the FlexNet Head End System on behalf of its customers in our world-class data centers. The utility would own the hardware, head end system license, and all third-party software and licensing, which provide the capital expenditures that may be required by the utility. This service frees the utility to focus on more strategic activities. Sensus would provide the service to manage the hardware, servers, and software, and to ensure maximum performance and availability for the head end system. Sensus uses the same people, process, and tools in providing the Application Managed Service that are used to provide SaaS. The only difference is the ownership model and how the utility wishes to spend the capital budgetary dollars. **B. What is the minimum, maximum and optimum/standard requirement for antenna height? Would limitations on antenna height impact the number of collectors required for adequate coverage?** Sensus' approach is not to dictate fixed antenna height details and force a utility into a specific model, but rather to perform a propagation study to determine the ideal antenna locations, antenna heights, and type of antennas. **C. Acknowledging significant variation which will be determined by a system propagation study (due to many factors such as building density, topography and vegetation), please provide a minimum, maximum and optimal range from the endpoints to the gateways.** **Full Endpoint Coverage** Range is a relative reference point, as it is dependent upon transmission strength, radio equipment, endpoint and infrastructure locations, and terrain. FlexNet Base Stations transmit at 25 watts of power to the endpoints and endpoints report to the base station with up to 2 watts. The power differentiation is compensated by very sensitive components in the base station; no buddying or endpoint hopping (which degrades the performance of the network) is required in a point-to-multipoint system. Sensus' propagation study will take into account terrain (including vegetation, buildings, and topography), endpoint locations, infrastructure locations, redundancy requirements, and transmission power. **Superior Propagation Study** For our propagation analysis, Sensus uses CRC-Predict, the most widely used propagation model in the suite of radio wave prediction algorithms available in Mentum Planet. CRC-Predict is a deterministic model based on Physical Optics, a form of wave theory. Predictions are based on a detailed simulation of diffraction over terrain (including clutter), and include an estimate of local clutter attenuation. As a result, predictions of coverage gaps and interference areas are based on your particular terrain and are more likely to be accurate. Traditional approaches to radio-wave propagation that are empirical in nature are limited and cannot account for the infinite variety of landscapes. CRC-Predict is superior because it fits realworld measurements to curves and then applies the curves to similar geographic areas.

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	D. How does your network achieve redundant coverage of endpoints? **Network Redundancy** While FlexNet Base Stations have a very low failure rate and come with battery backup for continued support during power loss, Sensus believes it is important to design redundancy into the critical infrastructure of the system. Network redundancy is a standard practice in the network design. Sensus' solution is to place network infrastructure strategically throughout the utilities territory such that each endpoint can communicate with at least two base stations while still managing infrastructure volume and, ultimately, cost. With continuous overlapping base station coverage, there is no timely route rebuilds necessary to reach an endpoint when a segment of the network is offline. **Any additional information regarding options to minimize infrastructure complexity is welcome.** **Correct Infrastructure location and configuration** As part of the propagation study, Sensus requests not only the endpoint locations, but also utility owned infrastructure, such as poles, water tanks, buildings, and any other structures owned. While conducting the propagation study, we aim to reduce costs by: • Using customer-owned sites to avoid third-party leases. • Considering installation of a pole or other infrastructure that carries a one-time, upfront investment. • Minimizing infrastructure – Point-to-multipoint requires much fewer collectors than other systems. This savings is not only in initial costs but also service expenses over the life of the project. The propagation study will yield options relative to endpoint coverage, network duplication and the associated costs of each scenario. **Utility Growth** Many utilities grow in size and endpoint volume over the course of the lifespan of the project. While some growth is planned for in the initial propagation study, Sensus recommends not investing in additional infrastructure to accommodate a perceived planned growth. Rather, we recommend investing in the infrastructure needed when the grown actually occurs. This strategy enables a utility to better manage their investment and timing of the investment. Sensus will perform subsequent propagation studies upon request. The point-to-multipoint design does not require massive modifications, but rather compliments the existing design. **Shared Infrastructure** The point-to-multipoint design allows neighboring FlexNet utilities to share infrastructure to further reduce costs. Sensus welcomes the opportunity to discuss this option in greater detail, should it appeal to the utility.
O&M Requirements	**A. Please summarize notable maintenance requirements for primary system components.** Head End Maintenance Under the Sensus SaaS offering, Sensus would perform all head end maintenance on behalf of the utility. A licensed, utility-owned solution would require the utility to perform standard maintenance. The following table compares the SaaS solution with a licensed solution and provides an overview of the expected maintenance.

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TABLE 1: SENSUS AND CUSTOMER RESPONSIBILITIES FOR OWN AND OPERATE VS. SAAS MODELS

Own and Operate		Software as a Service (SaaS)	
Customer responsibilities	Sensus responsibilities	Customer responsibilities	Sensus responsibilities
Database		Database	
Configure and manage equipment (non-RNI) Configure and manage network addresses Configure and manage Virtual Private Networks (VPNs) Configure and manage standard time source (Network Transfer Protocol (NTP) or GPS) Configure and manage security access points Respond to relevant alarms and notifications	Assist in configuring connection from base stations to licensed RNI server Assist in configuring standard time source (NTP or GPS) Respond to customer incidents when customer calls technical support	None	Configure and manage non-RNI equipment in data center Configure and manage network addresses in data center Configure and manage Virtual Private Networks (VPNs) Configure and manage standard time source (NTP or GPS) Configure and manage security access points Respond to relevant alarms and notifications
Storage area network		Storage area network	
Respond to alarms and notifications Investigate issues using log files Manage vendor if physical storage is offsite Configure and verify that regular backups are occurring	None	None	Respond to alarms and notifications Investigate issues using log files Manage vendor if physical storage is offsite Configure and verify that regular backups are occurring successfully
Database		Database	
Define data retention policy Archive relevant data Purge old, irrelevant, and excess data Monitor space and capacity requirements Respond to database alarms and notifications Install database software upgrades and patches Migrate data during installation and upgrades	May perform or assist with installation of database patches, updates, and upgrades if customer pays for service Perform standard technical support troubleshooting of RNI application or database when customer calls for assistance	None	Define data retention policy Archive relevant data Purge old, irrelevant, and excess data Monitor space and capacity requirements Respond to database alarms and notifications Install database software upgrades and patches Migrate data during installation and upgrades

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RNI application		**RNI application**	
Create and manage user accounts Support application users Install application upgrades and patches	May perform or assist with installation of application patches, updates, and upgrades if customer pays for service Perform standard technical support troubleshooting of application when customer calls for assistance	Create and manage user accounts Support application users	Install RNI application patches, updates, and upgrades when customer requests per change management process Perform standard technical support troubleshooting of application when customer calls for assistance
Operating system and third-party software		**Operating system and third-party software**	
Install operating system and other third-party software patches, updates, and upgrades Perform system hardware maintenance, or delegate and monitor maintenance personnel with tasks such as monitoring system performance, capacity, and availability	May perform or assist with installation of system patches, updates, and upgrades if customer pays for service Perform standard technical support troubleshooting of system when customer calls for assistance	None	Install operating system and other third-party software patches, updates, and upgrades Perform system hardware maintenance and monitor system performance, capacity, and availability Perform standard technical support troubleshooting of system when customer calls for assistance
Security		**Security**	
Configure and manage security policies Install security-related software and hardware upgrades and patches for operating system, database, and applications Respond to alarms and notifications	May perform or assist with installation of security patches, updates, and upgrades if customer pays for service Perform standard technical support troubleshooting of RNI application or database when customer calls for assistance	None	Configure and manage security policies Install security-related software and hardware upgrades and patches for operating system, database, and applications Respond to alarms and notifications

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Business continuity			Business continuity	
Develop and implement a disaster recovery plan Monitor system performance trends Monitor for significant equipment and infrastructure faults Identify problems and tasks required to perform required repairs; delegate to appropriate personnel Replicate all systems (hardware and software) to a separate location, if available Perform complete system switchover to disaster recovery location, if available	May consult with customer to create a business continuity plan or procedures if customer pays for service May assist with switchover of systems to disaster recovery location if customer pays for service Perform standard technical support troubleshooting of system when customer calls for assistance during a disaster situation		None	Develop and implement a disaster recovery plan Monitor system performance trends Monitor for significant equipment and infrastructure faults Identify problems and tasks required to perform required repairs; delegate to appropriate personnel Replicate all systems (hardware and software) to a separate location Perform complete system switchover to disaster recovery environment

B. What is the typical maintenance of a gateway over the life of the system?

Under the Sensus NaaS offering, the utility would not be responsible for any network infrastructure. A utility-owned solution would require the utility to perform standard maintenance. The following table provides an overview of the expected maintenance.

TABLE 2: SENSUS AND CUSTOMER RESPONSIBILITIES FOR OWN AND OPERATE VS. NAAS MODELS

Own and Operate			Network as a Service (NaaS)	
Customer responsibilities	Sensus responsibilities		Customer responsibilities	Sensus responsibilities
Backhaul			Backhaul	
Typically only upon failure and cannot be performed through FlexNet head end – troubleshoot or reset the backhaul connection	None		None	Typically only upon failure and cannot be performed through FlexNet head end – troubleshoot or reset the backhaul connection
Base station			Base station	
Semiannual site visit to replace filters and inspect base station for signs of physical damage to antenna, coax, and the unit. Replacement of batteries approximately every seven years. Automated battery conditioning is typically performed on a four-month cycle, so no special maintenance is required.	None		None	Semiannual site visit to replace filters and inspect base station for signs of physical damage to antenna, coax, and the unit. Replacement of batteries approximately every seven years. Automated battery conditioning is typically performed on a four-month cycle, so no special maintenance is required.

C. Do you offer over-the-air (through the headend and software) firmware updates?

Yes, Sensus offers over-the-air firmware updates. The FlexNet firmware solution supports the management of firmware versions across the entire deployment. The FlexNet Head

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	End System stores firmware details of every endpoint and accessed through the GUI. Multiple versions of firmware are supported without impacting the operation of the system. Sensus' flexible firmware update delivers a secure, reliable, and timely solution to deliver the firmware image to a single endpoint, a group of endpoints, or an entire endpoint population without impact to any other critical functions of the overall AMI solution. The management of firmware update is performed using real-time, efficient tools, ranging from firmware version reporting to interactive firmware update status. All FlexNet-enabled endpoints are supported in the Sensus firmware download solution; both Over the Air (OTA) and as a field visit. The actual firmware download is generally run as a low priority, background operation while normal operations continue to run. This ensures there is no measureable impact on read success or system operation during the firmware upgrade. The firmware design and firmware download solution are designed to not impact any of the states in the endpoint. All read values and alarm conditions are retained, as well as the current state/position of the remote disconnect switch/valve. No additional actions are required by the utility after the completion of a firmware download Sensus uses a total replacement approach for upgrading firmware files. Updates are sent to the SmartPoint communication module as individual packets. The head-end notifies each endpoint individually participating in the firmware download. The head-end then initiates packet delivery, which is performed securely as a broadcast to accelerate firmware download when multiple endpoints are included. Endpoints participating in the program accept the packets; endpoints not in the program ignore the packets. The head-end broadcasts the entire firmware image multiple times and uses other mechanisms to fill potential packet gaps. This increases the success rate by which a SmartPoint has hears and receives every packet needed to build the complete firmware image. **Note**: A success threshold can be defined to stop the download after a designated percentage of meters have completed the process. After all the packets are received at the SmartPoint, a Cyclic Redundancy Check (CRC) is performed, validating the image received. Once instructed by a SmartPoint's unique Cipher Block Chaining Message Authentication Code (CBC-MAC) signature, the SmartPoint redirects the image to the proper location for flashing. The image received by the SmartPoint could be for the SmartPoint itself, the meter's metrology, an electric Zigbee board, or even a demand response endpoint, such as a thermostat. The unique message prevents unauthorized firmware download images from being flashed. In addition to the CRC and CBC-MAC validations, all firmware download messaging can be encrypted using AES256 encryption. The end result is a very secure solution with no corrupted or bricked endpoints. Firmware download is controlled through roll-based permissions. Users with proper permissions can initiate, monitor progress, and view results of the firmware upgrade through a web-based UI. A history of all jobs and their outcomes are available for long-term tracking and auditing.
Reliability	
Battery Life	**Please provide component battery life (endpoints, gateways, etc.) assuming scenarios for both hourly and 15-minute read frequencies.** **Endpoints** Batteries in the iPERL and ally meter and the pit mount and wall mount SmartPoint are warrantied for 20 years when configured for hourly reads and experience normal use. Warranty covers full replacement for the first 15 year and is prorated for an additional 5 years.

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Years	Replacement Price
1 – 15	0%
16	30%
17	40%
18	50%
19	60%
20	70%
>20	100%

Meters and SmartPoints configured for interval reads less than one hour are warrantied for one year.

Base stations

FlexNet base stations use 120v or 240v line power. In the event of a power failure, the base station is equipped with battery backup power. Standard battery configuration is two 12-volt, 40-amp-hour EnerSys XE-40 batteries featuring PB/SN chemistry (lead-acid batteries). These batteries are Absorbed Glass Mat (AGM)-sealed to prevent fumes and hydrogen venting, which can cause corrosive damage to electronics in an enclosed NEMA-4 cabinet, such as the cabinet used for the M400B base station. As an extra precaution, the batteries are well sealed in 4-mil polypropylene bags in case there is a leak.

Under normal operating conditions, the FlexNet base station consumes 38 watts at idle and 50 watts at a transmit duty cycle of 17%. KWh per day is 0.912 for idle, and 1.2 for transmit as noted. Battery run time is typically 20 hours idle and 8 hours at 17% transmission. These calculated values have been exceeded in real-world field conditions, as the FlexNet Base Station transceiver is seldom in a 17% transmit mode for water solutions.

Equipment Life

Please provide estimated useful life for major components of system.

The FlexNet system and all of its components are designed for a minimum of 20 years of useful life. Sensus is firmly against end-of-life policies that prematurely shorten the life of an AMI system. We work hard to not leave any endpoints behind as we make our AMI system even better, as we have proven by continuing to support the original AMI endpoints still in service today. Many competing providers cannot make this claim and have required costly upgrades to enable new functionality at the utilities' expense.

Data Storage

A. Please provide data storage protocols and data loss prevention safeguards.

The data is critical to the utility business environment; loss of data is not acceptable. Sensus built many safeguards into its solution to prevent a catastrophic loss of data starting with the endpoint.

In the Network

In the event the network is not available, the endpoints store more than one month of hourly interval reads. The data from the endpoint can be pushed or requested when the network service returns. Traditional drive-by and walk-by solutions can pull data should the data be needed for the network is restored.

If the backhaul between the FlexNet base station and FlexNet head end is not available, the base station will store all received messages. When the backhaul connection is restored, the base station will push the stored messages and new messages to the head end for processing.

The base station stores approximately 30 days of messages. In the event the backhaul cannot be restored within the 30 day window, the stored messages can be pulled locally off the base station and injected directly in the FlexNet head end for processing.

At the Head End

The head end uses standard IT recommendations. RAID environments are used for data base performance and data redundancy at the drive storage level. It is also recommended that the FlexNet head end relation database be regularly backed up.

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	It is strongly encouraged to have a disaster recovery system at a remote location in the event of a catastrophic failure at the primary production data center. To reduce data loss potential it is recommended that incoming data is streamed to both production and Disaster Recovery (DR) sites. The Sensus SaaS solution will manage all data redundancy requirements for the utility, including a geographically dispersed DR site. **B. Please provide any additional information regarding resiliency during emergencies and disaster-proofing.** In environments with more extreme weather conditions like Tornado's and Hurricanes, Sensus recommends putting base station equipment on resilient infrastructure. Water towers, buildings, and properly built poles are great examples.
Responsiveness	
Analytics	**Please list built-in analytics included as turnkey features of system, e.g. leak detection, pressure monitoring, reverse flow alarms, tampering alerts, etc.** More and more utilities expect their systems to do more than just meter reading and billing. To meet and exceed these demands, Sensus invests significant resources into expanding our solution capabilities beyond metering. **Endpoint Data** Sensus meters, SmartPoints, sensors, base stations, and head end collect and store vast amounts of information and make that data available to applications. Whether it is meter reads, alarming conditions like tampering, reverse flow, minor leak, and major leak, pressure values, temperature, tank levels, or any other sensor data, the data is available for analytical purposes **Sensus Analytics** Sensus analytics is a platform where analytical applications are made available to the utility. The current suite of applications include alarm management, pressure profile application, customer portal, usage management, leak detection, hidden revenue generator, and Service management application. Other applications are in the roadmap; and Sensus is working with key water customers to continue to define priority and need. **Xylem Brands** Xylem boasts a strong history of making strategic acquisitions aimed at adding further value to our utility-focused offerings. Xylem's well-known global brands have served the water market for many decades with products sold in more than 150 countries. The company listens, learns and adapts to local environments, working in true partnership with the customers they serve. With deep application expertise in the water industry, Xylem focuses on producing highly efficient water technologies that use less energy, reduce lifecycle costs and provide environmental benefits to users and the communities in which they operate. Through our parent company and its brands, Sensus can offer smart solutions beyond metering and AMI that will further position utilities for the future. For a full list of Xylem brands, please visit https://www.xylem.com/en-us/brands.

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EmNet provides network modeling and optimization solutions that enable municipalities to manage the urban water cycle, and wastewater and stormwater systems.

Valor monitors every meter in your system to help reduce water loss and protect your revenue.

Xylem's Flygt brand provides customers with a complete range of products and solutions for moving water and wastewater.

Pure Technologies is a world leader in the development and application of innovative technologies for inspection, monitoring and management of critical infrastructure.

Focused on supporting pipe network operators in monitoring their infrastructure and optimizing their operations with patent-protected hardware, wireless data transmission and software services.

Wachs Water helps utilities optimize control of their aging water distribution infrastructures, which reduces the consequences of failure and improves water quality.

Flexibility

Compatibility

Inter-system compatibility with components and information systems.

A. Please list meter types and brands with which your technology is compatible. Identify compatibility limitations with brands and types of meters.

Metering Compatibility

Sensus' commitment to interoperability is evident in its compatibility with third-party water meter registers. Most encoded (electronic) registers on the market today use the Sensus meter data standard developed in the 1980s by Sensus, and therefore most are compatible with the FlexNet water SmartPoint communication module. The Sensus transmitter is able to communicate with all registers that have an industry standard UI 1203 protocol.

Sensus is also compatible with most encoded commercial meters on the market, and continues to add new meter compatibility every year.

Please refer to **Attachment A: Compatibility Guid**e for details.

B. Do you provide a proprietary data management platform and customer portal or do you have preferred third party partners?

Sensus does have data management capabilities, customer portal, and other solution applications available through its Sensus Analytics platform. However, FlexNet is designed to be interoperable and can therefore integrate with any third party system of your choice. You may choose to take advantage of the benefits of the Sensus Analytics platform or choose other products based on their merits, function, and cost. For utilities that choose not to use the Sensus solution, the FlexNet Head End can be integrated with just about all MDM, customer portal, and other water solution applications.

Standardized Integration

In addition to the native smart water capabilities of the FlexNet system, we can integrate the FlexNet system with third-party products and applications using MultiSpeak or CMEP interfaces.

- CEMP is a file export for batch type process, and
- MultiSpeak for real time interactions

Both can be used as the same time and offer options for integration into any 3rd party software.

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	Third Party Vendors The Sensus Professional Services team is well-versed in the integration of FlexNet with other third-party platforms and systems. We have rolled out more than 1100 FlexNet deployments, integrating the FlexNet system with a variety of applications. Our recent integrations include: • NISC • Siena, ABB • DataVoice • Milsoft • Pyxis • Savage ODS • SEDC • PayGo • Jomar • iVue OMS • Sensus Analytics • SmartGrid CIS • ESB • ESInitial • Itron MDM • UISOL • IBM ESB • Allete CIS • GE OMS • MeterSense • eMeter • Oracle • Siemens • Energate • OATI • Daffron **C. Please verify compatibility/experience with the following billing systems:** • Cogsdale • Oracle • Central Square • TruePoint Yes, with thousands of deployments, Sensus' Professional Services team is well-versed in integrating FlexNet with many different billing systems, such as those listed above.
Redundancy	
Read Options	**Please detail options for redundancy in reading technology in case of failure, e.g. can the same transmitter be used for drive-by or walk-by reads?** Sensus uses the same SmartPoint for walk-by, drive-by, and fixed based solutions. All are supported simultaneously and do not require any special configuration or conditions. Even under a full fixed based deployment, each meter can still be read locally. Many customers find this advantageous as they can start installing meters before the fixed based network is deployed.
Communication	**A. What kinds of two-way communication networks are your systems enabled for (e.g., 3G, 4G, 5G, LTE-M, LoRa, Sigfox, etc.)** FlexNet is a carrier grade, nationwide network, with nearly 1,000 MHz (combined) of dedicated frequencies housed within nearly 650 FCC private spectrum licenses. By contracting with Sensus, WSSC instantly gains access to an exclusive use wireless network for accomplishing its AMI, Smart City, and IoT goals. • Benefit: Control of the RF noise floor within the network for the life of the system. • Value: Operating as the sole source of RF activity within the network provides the owner reduced risk associated with: • Reliability – read, alarm, and critical data messages are not competing with RF traffic associated with devices operating on unlicensed and shared networks. • Predictability – protected by the FCC, and managed by Sensus; the FlexNet network is dedicated to the utility exclusively for the life of the system. • Scalability – configurable modulations, upgradable firmware, and long range coverage provide flexible options for adapting to change. • Power – the FCC allows Sensus to operate with a maximum of 2-watt power output in the SmartPoint transceiver. The 2-watt output, in addition to a low noise flow, enables RF to propagate up to 20 miles in most topologies.

Technology Name: Company Name: Company Contact Name:	FlexNet AMI Solution Sensus USA Inc. Dawn Groves
	The FCC-licensed, primary-use frequencies also allow the FlexNet communication network to use much more sensitive receivers. Range and reliability are enhanced because of the frequencies, the advanced receiver design, and a noise floor on the FlexNet communication network that is much lower than that of unlicensed spectrum (ISM band). **B. Is your preferred communication technology available in the Sacramento area?** Yes, Sensus invested in nationwide access to a large frequency band. The band is large enough to support all water customers in the Sacramento area in addition to the other utility types (electric or gas). Each FlexNet utility will have its own spectrum without interference from any neighboring utilities' networks. **C. In areas where there is no signal (cellular or radio) what options do you offer?** Sensus currently holds 655 FCC licenses, obtained over the last 13 years. Because Sensus owns its own RF technology and frequencies, Sensus is not dependent on other providers for radio coverage. Sensus will perform a propagation study with the expectation of covering 100% of the meter population. With far reaching radio technology Sensus is very successful in 100% coverage. In cases where coverage cannot be cost justified by the utility, walk-by and drive-by solutions are available.

*Sensus has provided additional documentation which is provided separately in Appendix D.

Badger - Orion® Response

Technology Name: Company Name: Company Contact Name:	BEACON Advanced Metering Analytics Badger Meter Brian Helphand
Technology Type	
Technology Description	The BEACON® AMA managed solution from Badger Meter brings a new level of utility-optimizing information to light, combining the power of intuitive software with proven ORION® AMI cellular technology to provide greater visibility and control over utility management. Built on the time-tested ORION system for interval data capture and two-way communication, the BEACON AMA system delivers a simple yet powerful end-to-end solution. The BEACON AMA software suite puts meter-reading data to work to address the utility's demands for actionable information and to improve operations in the process. BEACON AMA includes: • Customizable dashboards to deliver information in a format matched to match the utility's requirements. • Unique alert conditions to define and monitor exceptions. • Consumer engagement tools including online access and smartphone apps to enable access to individual customer information. • Secure, hosted platform with API feature to easily share data across utility applications • Automatic software updates. • Integration with the utility's billing system. • **Faster leak detection:** Customizable alerts using the interval read data that allow your utility to define exceptions, including continuous flow, to more quickly identify and fix problems. • **Water conservation clarity:** Quantify the effects of water conservation efforts—on a utility basis, or by water customer. • **Easier compliance reporting:** Achieve regulatory compliance by using the system's interval read data to configure and print required reports through the system. • **Enhanced customer service:** Easy-to-use data tools put the power of consumption data at your fingertips by allowing rapid response to customer inquiries and quick resolution or elimination of some billing issues. The EyeOnWater® consumer engagement tool and smartphone apps provide water customers with easy access to their consumption data. Customers will be able to view activity and gain a greater understanding of usage and the value provided. • **Superior level of security:** Badger Meter is ISO 27001 certified and SOC2 compliant.
Operating Experience	A. Over 1,000 utilities use BEACON AMA with our Orion cellular endpoint. While in various stages of deployment, these utilities currently range in size from just a few endpoints to over 150,000 endpoints and serve populations of up to 500,000. B. Approximately 8% of our customer base is located in California. In addition, twenty case studies and ten customer testimonial videos are located on the BEACON AMA website.
Simplicity	
Required Infrastructure	**Minimum infrastructure required and service options.** **A. Do you offer a network as a service option**? BEACON AMA is a Network as a Service system delivered via the existing carrier-grade LTE-M LPWAN (Low Power Wide Area Network) as defined by the 3GPP international standards organization.

Technology Name: Company Name: Company Contact Name:	BEACON Advanced Metering Analytics Badger Meter Brian Helphand
	B. What is the minimum, maximum and optimum/standard requirement for antenna height? Would limitations on antenna height impact the number of collectors required for adequate coverage? Our AMI endpoints communicate encrypted meter data over the existing LTE-M, no utility owned antennas or infrastructure is needed. **C. Acknowledging significant variation which will be determined by a system propagation study (due to many factors such as building density, topography and vegetation), please provide a minimum, maximum and optimal range from the endpoints to the gateways.** Building density, topology and vegetation affect all radio frequencies in the same manner. Some materials such as cement, wood and glass absorb a portion of a radio transmission's power. Some materials such as metal, the power. Please see the Understanding RF Propagation of AMR/AMI Systems for an overview of the conditions that affect proper data transmission. To mitigate environmental impact on data transmission, the Federal Communications Commission (FCC) allows the cellular carriers to install equipment with higher transmission power and with higher sensitivity receivers than the custom communication networks supplied by traditional AMI network equipment. The LTE-M technology's lower radio frequency band further increases signal propagation. To provide more exact detail and at no cost to the utilities, Badger Meter can initiate and cellular coverage analysis (CCA). We simply need an account address file to begin this process. **D. How does your network achieve redundant coverage of endpoints?** With cellular networks supporting first responders, the FCC regulates cellular networks to minimal outage schedules and redundancy requirements.
O&M Requirements	**A. Please summarize notable maintenance requirements for primary system components.; B. What is the typical maintenance of a gateway over the life of the system?** With our infrastructure-free system, utilities are not required to purchase, install or maintain gateways. Over the 20-year expected life of our cellular-based system, utilities are not required to replace gateways every 5-10 years as required by traditional AMI systems. **C. Do you offer over-the-air (through the headend and software) firmware updates?** Over-the-air firmware updates are automatic with BEACON AMA.
Reliability	
Battery Life	**Please provide component battery life (endpoints, gateways, etc.) assuming scenarios for both hourly and 15-minute read frequencies.** Our LTE-M cellular endpoints collect 15-minute reads with a battery designed for a 20-year life.
Equipment Life	**Please provide estimated useful life for major components of system.** Based on the most challenging conditions (temperature, submergence), the LTE-M endpoints are designed for a 20-year life. The LTE-M network is designed for 20+ years and backed by Badger Meter's 20-year network warranty.
Data Storage	**A. Please provide data storage protocols and data loss prevention safeguards.** Our LTE-M endpoints store 42-days of 15-minute reads and alerts. In cases where data transmissions are not confirmed by the head-end software, such as cars parked over meter boxes, data is automatically back filled. BEACON AMA is hosted by Amazon Web Services (AWS) and is ISO 27001 certified and SOC-2 compliant. **B. Please provide any additional information regarding resiliency during emergencies and disaster-proofing.** Cellular networks are the best solution for a utility's resiliency plan to meet the American Infrastructure Act. Per FCC regulations, cellular networks support first responders and are normally among the first networks to come back on-line after natural disasters.

Technology Name: Company Name: Company Contact Name:	BEACON Advanced Metering Analytics Badger Meter Brian Helphand
Responsiveness	
Analytics	**Please list built-in analytics included as turnkey features of system, e.g. leak detection, pressure monitoring, reverse flow alarms, tampering alerts, etc.** Badger Meter has designed the BEACON AMA dashboard to eliminate the need to proactively run reports to confirm if there are systems issues, or not. Examples include: leaks, continuous flow, reverse flow, no usage, endpoint tampers, theft (encoder removal, magnetic tamper), encoder and endpoint communication issues, high consumption, low consumption, high temperature, and low pressure. Utilities and their end customers can set email or SMS text message leak alerts. Utilities can use analytics tools to manage customer outreach for leaks and portal/smartphone app usage. Utilities can setup District Meter Areas (DMA) to manage and address non-revenue water issues, control valves for residential meters with integrated shut off valves to safely address non-payment issues, set a high consumption limit and a water reduction goal to address conservation goals and pressure and temperature events via meters with integrated sensors.
Flexibility	
Compatibility	**Inter-system compatibility with components and information systems.** **A. Please list meter types and brands with which your technology is compatible. Identify compatibility limitations with brands and types of meters.** All of Badger Meter's AMR/AMI endpoints communicate over the 3-Wire ASCII communications standard defined for the North American water industry. We have not tested every meter/register on the market, but any meter/encoded register meeting the standard should be compatible. For the list of tested meters/registers, please refer to our installation manual. **B. Do you provide a proprietary data management platform and customer portal or do you have preferred third party partners?** BEACON AMA is our proprietary data management platform. Our EyeOnWater software includes a customer web portal as well as iOS and Android smart phone applications. Both systems are included in our offering at no additional cost. BEACON AMA provides web service commands supporting the development of Application Program Interface (API) to automatically transfer data to/from third party data management platforms, customer engagement systems, billing, work order management, GIS, asset management, hydraulic modeling, etc. **C. Please verify compatibility/experience with the following billing systems:** • Cogsdale • Oracle • Central Square • TruePoint Since introducing BEACON AMA in 2014, Badger's interface analysis group have completed hundreds of billing interfaces. As of 2019, interfaces have been completed for Cogsdale (3), Oracle (1), Central Square (5), and TruePoint (2).
Redundancy	
Read Options	**Please detail options for redundancy in reading technology in case of failure, e.g. can the same transmitter be used for drive-by or walk-by reads?** Our primary service provider is AT&T but Badger Meter also has an option to use a secondary carrier if ever needed. In addition, our LTE-M endpoint can be read by walk-by using an Orion transceiver and a tablet computer for getting a current and for troubleshooting.

Technology Name: **Company Name:** **Company Contact Name:**	**BEACON Advanced Metering Analytics** **Badger Meter** **Brian Helphand**
Communication	**A. What kinds of two-way communication networks are your systems enabled for (e.g., 3G, 4G, 5G, LTE-M, LoRa, Sigfox, etc.)** Our endpoints communicate over the LTE-M cellular network with the option for NBIOT. As defined by the 3GPP international standards organization, LTE-M and NBIOT are part of the 5G standard. **B. Is your preferred communication technology available in the Sacramento area?** Yes, many utilities in the area are using our LTE-M endpoints including Sacramento Suburban Water District. **C. In areas where there is no signal (cellular or radio) what options do you offer?** BEACON AMA supports traditional AMR/AMI solutions from Badger Meter and manual reads for locations without cellular signal.

Aclara - RF® Response

Technology Name: Company Name: Company Contact Name:	Aclara RF Aclara Technologies LLC Dave LaJeunesse
Technology Type	
Technology Description	**Provide a technical description of your AMI solution, specifically summarizing the network configuration options (e.g. cellular, RF, etc.) and characteristics which set your offering apart from other providers in the AMI space. Please keep this to a 300-word summary or less.** Aclara RF is a simple and efficient AMI network. We use a point-to-multipoint network topology to facilitate two-way communication between the endpoint and the headend. Meter Transmission Units (MTUs) communicate via AES 256-bit encrypted messages over an FCC licensed 450-470 MHz radio frequency to strategically located Data Collector Units (DCUs) which then use a backhaul of choosing to bring the encrypted data to the AclaraONE headend. MTUs connect to a water meter of choice as Aclara RF is water meter agnostic. Read rates can be configured for 15-minute, 20-minute, 30-minute, 60-minute, 2-hour, 4-hour, 6-hour, and daily reads. The default setting is 60-minute intervals and can be configured over-the-air. On-demand reads are supported as well as extended alarms. MTUs have a 20-year battery life, store up to 96 days of interval data, and offer a variety of mounting and connection options. DCUs are typically located at utility assets with a choice of mounting hardware and include a NEMA 4X rating. DCUs provide another layer of redundancy with onboard storage that supports up to 28 days of reads. Backhaul options include cellular, ethernet, Wi-Fi, etc. DCUs also provide network health monitoring. Continuing the theme of simple efficiency, Aclara DCUs are designed for minimal maintenance with battery replacements once every 5 five years and over-the-air upgrades. AclaraONE presents AMI data to utility representatives via a customizable dashboard. Network health and monitoring are displayed for analysis and making informed decisions. AclaraONE can integrate data from other utility software sources and is designed to be a centralized platform for all AMI data, thus the moniker AclaraONE (One Network for Everyone). Aclara also understands growth and the Aclara RF AMI is specifically designed to accommodate expansion for future smart infrastructure solutions such as pressure monitoring and leak detection.
Operating Experience	**A. Please provide the number of US water utility deployments, including the smallest and largest size of deployment (number of endpoints and population served).** **B. Please note how many California deployments you have in the water sector.** **C. If case studies are available, please provide website or attachments.** Aclara has 144 total Aclara RF water deployments ranging in size from a few hundred water meters to over 840,000 (NYCDEP). 22 out of the 144 deployments are located in California. Case studies can be found at www.Aclara.com.
Simplicity	
Required Infrastructure	**Minimum infrastructure required and service options.** **A. Do you offer a network as a service option?** **B. What is the minimum, maximum and optimum/standard requirement for antenna height? Would limitations on antenna height impact the number of collectors required for adequate coverage?** **C. Acknowledging significant variation which will be determined by a system propagation study (due to many factors such as building density, topography and vegetation), please provide a minimum, maximum and optimal range from the endpoints to the gateways.**

Technology Name: **Company Name:** **Company Contact Name:**	**Aclara RF** **Aclara Technologies LLC** **Dave LaJeunesse**
	D. How does your network achieve redundant coverage of endpoints? Any additional information regarding options to minimize infrastructure complexity is welcome. Aclara offers the Aclara Owned Network (AON) as our network as a service option. With this option, Aclara will own the infrastructure while the utility will own the endpoints. Aclara typically models the network with DCU antenna heights and locations specified by the utility. A higher antenna height allows for RF signals to travel further with less interference, decreasing the number of required DCUs to obtain the same coverage with a restricted antenna height. Redundancy is achieved with strategic placement of DCUs throughout the territory. Point-tomultipoint topology allows MTUs to transmit to more than one DCU and eliminate single points of failure throughout the network.
O&M Requirements	**A. Please summarize notable maintenance requirements for primary system components.** **B. What is the typical maintenance of a gateway over the life of the system?** **C. Do you offer over-the-air (through the headend and software) firmware updates?** Aclara's MTUs are designed for a 20-year battery life and require minimal maintenance. DCUs are also relatively maintenance free and only require battery exchanges approximately every 5 years. Software and firmware upgrades can be performed over-the-air.
Reliability	
Battery Life	**Please provide component battery life (endpoints, gateways, etc.) assuming scenarios for both hourly and 15-minute read frequencies.** Estimated battery life for Aclara MTUs is 20 years with field proven results. Estimated battery life for DCUs is 4-5 years.
Equipment Life	**Please provide estimated useful life for major components of system.** Aclara's network components are all designed to have a 20-year useful life and meet specifications for a minimum of 15-year lifespans.
Data Storage	**A. Please provide data storage protocols and data loss prevention safeguards.** **B. Please provide any additional information regarding resiliency during emergencies and disaster-proofing.** Hosted Aclara solutions use Microsoft servers with Microsoft security and loss prevention protocols. Additional Aclara security and backup protocols include annual certifications and testing, trainings, and assessments. Aclara's security and data procedures can be provided upon further agreements. Aclara's network is designed with resiliency and redundancy in mind. New York City Department of Environmental Protection (NYCDEP) can attest to the resiliency of Aclara's solution. During hurricane Sandy, NYCDEP only suffered minimal losses of their Aclara network and were able to leverage incoming data to assist in rescue efforts by identifying evacuated areas based on usage. The full story has been included as an attachment for your review in addition to the highlights in the graphic below.

Technology Name: Company Name: Company Contact Name:	Aclara RF Aclara Technologies LLC Dave LaJeunesse
	
Responsiveness	
Analytics	**Please list built-in analytics included as turnkey features of system, e.g. leak detection, pressure monitoring, reverse flow alarms, tampering alerts, etc.** Aclara RF with AclaraONE software provides analytics for consumption (negative, continuous, zero, high, and abnormal) as well as network health monitoring (battery life alerts, tamper alerts, etc.). Leak detection and pressure monitoring can also be achieved using the AclaraONE software. Included in the Attachments is a document entitled, "AclaraONE Events, Alarms, and Report Views" that provides further detail with screenshots. Optional smart infrastructure solutions such as ZoneScan can provide further insights into leak detection on your distribution lines.
Flexibility	
Compatibility	**Inter-system compatibility with components and information systems.** **A. Please list meter types and brands with which your technology is compatible. Identify compatibility limitations with brands and types of meters.** **B. Do you provide a proprietary data management platform and customer portal or do you have preferred third party partners?** **C. Please verify compatibility/experience with the following billing systems:** • Cogsdale • Oracle • Central Square • TruePoint Aclara's water solution is meter agnostic. Aclara has included a meter compatibility list as an attachment. The Aclara solution includes the AclaraONE headend and software which offers Aclara's MDM. Aclara also offers a consumer engagement solution called Adaptive Consumer Engagement (ACE). Aclara ACE is a customer portal designed to integrate seamlessly with AclaraONE. Aclara has experience integrating with many billing systems and can achieve integration via flat-file, Aclara standard APIs, proprietary third-party APIs, and more. Throughout Aclara's experience, we have been very successful with third party software integrations.

Technology Name: **Company Name:** **Company Contact Name:**	**Aclara RF** **Aclara Technologies LLC** **Dave LaJeunesse**
Redundancy	
Read Options	**Please detail options for redundancy in reading technology in case of failure, e.g. can the same transmitter be used for drive-by or walk-by reads?** Redundancy is achieved through the network design and on-board storage of the MTUs and DCUs. Aclara's GIS team specifically designs the DCU layout so that each endpoint is covered by multiple collectors. In the unlikely event a DCU fails, the on-board storage in the MTU will keep up to 96 days of hourly data (dependent upon the read-rate configuration) and the DCU will store up to 28 days of collected data.
Communication	**A. What kinds of two-way communication networks are your systems enabled for (e.g., 3G, 4G, 5G, LTE-M, LoRa, Sigfox, etc.)** **B. Is your preferred communication technology available in the Sacramento area?** **C. In areas where there is no signal (cellular or radio) what options do you offer?** Aclara's two-way communication network operates on a licensed 450-470 MHz radio frequency with your choice of backhaul. As an option, Aclara offers a portable DCU (pDCU) which functions like a standard fixed DCU mounted in a truck or other vehicle. The pDCU can be driven to any location where it can then collect from any nearby meter transmission units.

*Aclara has provided additional documentation which is provided separately in Appendix D.

Zenner – Stealth Reader Response

Technology Name: Company Name: Company Contact Name:	Stealth Reader Zenner USA
Technology Type	
Technology Description	**Provide a technical description of your AMI solution, specifically summarizing the network configuration options (e.g. cellular, RF, etc.) and characteristics which set your offering apart from other providers in the AMI space. Please keep this to a 300-word summary or less.** The Stealth Reader system is a full 2-way communicating, self-configuring & healing, mesh style, meter-reading network. Stealth's level of redundancy enables full failover in case of a system failure. All radios in Stealth System use Frequency-Hopping Spread-Spectrum (FHSS) communications capable of utilizing all 2,000+ channels within the unlicensed ISM frequency bandwidth (902-928MHz). The Stealth System does not require any pre-programmed routing or network programming at any point within the system. It accomplishes these tasks automatically. Each endpoint acts as a repeater, designed to move data throughout the system. The Stealth Network is capable of reconfiguring itself to "hop" around both temporary and permanent obstacles. Data is able to take multiple paths to the gateway, ensuring delivery of data with every transmission. Inexpensive, battery operated repeaters are used to bridge gaps in deployments. A/C Powered repeaters can be used for bridging gaps and reducing latencies within the network as well. Using a patented communication system, the Stealth Mesh Network can distribute new firmware upgrades over the mesh without affecting reading percentages or battery life. Each endpoint retains its readings for up to a year and the Stealth Gateway retains readings it has collected for more than a year. In the event of a loss of power or connectivity to a gateway, it will continue to collect data for up to a month on battery power. When initiated, Endpoints establish 2-way communications to the closest gateway. This becomes their prime communication path. Should communications with the primary gateway fail, each Endpoint will reroute itself, automatically, to the next closest gateway. In this way, each endpoint can fail-over to another portion of the network should their primary communication link to the mainframe computers ceases functioning. This makes a Stealth Reader deployment a fully redundant, self-healing, self-configuring 2-way system.
Operating Experience	**A. Please provide the number of US water utility deployments, including the smallest and largest size of deployment (number of endpoints and population served).** AMI – 250 Utilities fully functioning networks • Largest: American Water, Oak Hill, WV 32,000 endpoints • Smallest: Paradise, MT 105 endpoints fixed Mesh network **B. Please note how many California deployments you have in the water sector.** 10 Deployments in California **C. If case studies are available, please provide website or attachments.** No written testimonials, but can provide video testimonials on request.
Simplicity	
Required Infrastructure	**Minimum infrastructure required and service options.** **Minimum infrastructure:** • Gateway • Stealth Endpoint **A. Do you offer a network as a service option?** If this question refers to the customer not owning the infrastructure, Zenner has options.

Technology Name: Company Name: Company Contact Name:	Stealth Reader Zenner USA
	B. What is the minimum, maximum and optimum/standard requirement for antenna height? Would limitations on antenna height impact the number of collectors required for adequate coverage? • Minimum of 5 feet for infrastructure. • Maximum 200+ (not a real maximum, but additional height not necessary.) • Optimum – in densely wooded areas, above the tree line 50-60 feet high. • Optimum – Above obstacles where possible, prefer 35-60 feet high. • Limitations due to height- This is heavily determined by the terrain and obstacles at the deployment site. In general, in a dense mesh, height can normally be lower. In a very spread out mesh, height is a benefit as to gaining range to more distant endpoints or repeaters thus reducing the number of hops required. **C. Acknowledging significant variation which will be determined by a system propagation study (due to many factors such as building density, topography and vegetation), please provide a minimum, maximum and optimal range from the endpoints to the gateways.** As long as the gateway can reach one of the endpoints or repeaters, the Stealth mesh will transfer data. Stealth Mesh networks pass data in multiple paths, simultaneously. Zenner builds in redundant pathways of communications within each Stealth Mesh Network. Vegetation, buildings or topography, which create big challenges to line-of-site network, do not affect the Stealth Mesh Network due to the multiple paths of communications back to the collector. In regards to minimum, maximum and optimum range of the endpoints to the gateway, with the Stealth Reader system operating as a mesh, this item does not directly apply. Endpoints can hop different paths back to the gateway, so the limitations found in line-of-sight systems do not apply to this system. To answer this in a line-of-sight context would have the following: • Minimum – as close as is required. Some distance is preferred, but endpoints can be right next to the gateway if necessary. • Maximum, Optimum – This varies depending on the placement of endpoints and type of install: pit, basement, post, wall mounted. Endpoint: • Maximum seen in the field 1.36 miles (7181 ft). • Optimum: 0.3 miles (1584 ft) Powered Repeater / Gateway: • Maximum seen in the field 14.2 miles (74,976 ft). • Optimum: 1 mile (5280 ft) **D. How does your network achieve redundant coverage of endpoints?** The data path is not determined by predefined routes. Within a mesh each data packet can take multiple paths back to the gateway. When received, the first message for a specific endpoint and timestamp is inserted in the database. If a gateway goes down completely, the endpoints will fail over to another gateway to pass data. The endpoints will continue on that mesh until it can hear from the original gateway again. **Any additional information regarding options to minimize infrastructure complexity is welcome.** Stealth Reader gateways are installed at utility owned properties: water tanks, pump stations, office buildings. At some utilities they have agreements with the city to install on traffic light posts and other sites, but that is rare. In even rarer situations, the utility can opt to have the power company do a pole-drop where required. That being said, Zenner makes

Technology Name: Company Name: Company Contact Name:	Stealth Reader Zenner USA
	great effort to design a Stealth System around the available utility owned gateway locations while minimizing the infrastructure to fit the utilities expectations and needs. Additionally, powered repeaters or battery repeaters can be used to reduce latencies and increase the number of endpoints reporting to a single gateway.
O&M Requirements	**A. Please summarize notable maintenance requirements for primary system components.** • Endpoints: Encoded registers are usually used, and no maintenance required; • Battery repeaters – no maintenance unless antenna cable or connector become damaged • Powered repeaters and Gateways – Primary battery replacement if they become low due to power outages. Possible antenna cable or connector maintenance if damaged. **B. What is the typical maintenance of a gateway over the life of the system?** Minimal maintenance is required. Items to maintain are just battery cells and antenna cables/connectors. **C. Do you offer over-the-air (through the headend and software) firmware updates?** The system receives firmware updates over the air or via handheld if the customer chooses. During the firmware update process, reporting and battery life are not affected. Firmware updates are installed as a low priority message to the endpoints and only passed when there is available bandwidth. All endpoints pass on the parts of the firmware they have loaded to their neighbors, even when they do not have the complete firmware. This speeds up the propagation of the firmware throughout the mesh while keeping transmissions from bogging down.
Reliability	
Battery Life	**Please provide component battery life (endpoints, gateways, etc.) assuming scenarios for both hourly and 15-minute read frequencies.** Each Stealth MIU comes with a 10yr full/10yr prorated warranty. Under normal pit conditions, a utility can expect between 13-14yrs of battery life from each MIU. What does make the Stealth MIU unique within the industry is its replaceable batteries. During proration, should an endpoint fail due to batteries, the utility will have the option of utilizing the warranty or performing a battery replacement (2020 cost of $25). Based on how the Stealth System stores information, the battery life of components is not affected by moving from 1 hour to 15 min read interval. Each MIU can be programmed to read down to 5 min time intervals and store the information without consuming additional battery power. Other system components have the following battery life expectations: • Gateway-Up to 15yrs with Field Replaceable Batteries • AC Repeaters-Up to 15yrs with Field replaceable Batteries • Battery Repeaters-5yrs with Field replaceable Batteries • MIU Repeaters-13-14yrs with Field replaceable Batteries
Equipment Life	**Please provide estimated useful life for major components of system.** 20 to 30 years under normal conditions
Data Storage	**A. Please provide data storage protocols and data loss prevention safeguards.** Endpoints will retain up to 365 days of hourly data on board. The Gateways will retain more than a year of data for all components, including endpoints, within the mesh. The backend system retains all data indefinitely. Currently, 3 years of data is available for immediate reporting with 7+ years of offline archived data being saved for additional reporting. **B. Please provide any additional information regarding resiliency during emergencies and disaster-proofing.**

Technology Name: Company Name: Company Contact Name:	Stealth Reader Zenner USA
	All data collected is stored within the Zenner mainframe computers located in Addison, TX, with 3 additional, geographically spaced, redundant site locations. This insures that, should a regional disaster occur, your utility's information remains available.
Responsiveness	
Analytics	**Please list built-in analytics included as turnkey features of system, e.g. leak detection, pressure monitoring, reverse flow alarms, tampering alerts, etc.** Alarms built into the endpoints include; leak, tamper (both garbled data and no data), battery, reverse flow, initial reading. Built into the Gateways include antenna feedline alert, backhaul issue, power supply, low battery (primary and secondary). Additional reports: • Consumption based reports – Usage Reports, High & Low Audits (User definable) • Exception Reports-Leak, Tamper, Reverse Flow, Low Battery (User definable) • Network Manager System Reporting & Functionality Monitoring-Network Manager provides the capability to monitor the network diagnostically and report on system health all the way from the Gateway to each individual endpoint.
Flexibility	
Compatibility	**Inter-system compatibility with components and information systems.** **A. Please list meter types and brands with which your technology is compatible. Identify compatibility limitations with brands and types of meters.** • The Stealth Reader endpoints work with all major AMI ready (3-wire) registers. • The Stealth Reader endpoint also works with pulse (open collector) registers. • Current limitations are that the endpoint may not, on occasion, capture every vendors' code specific alarms. **B. Do you provide a proprietary data management platform and customer portal or do you have preferred third party partners?** Yes, our backend systems function as a MDMS as well. For a customer portal we currently have a partnership with several providers. **C. Please verify compatibility/experience with the following billing systems:** • Cogsdale • Oracle • Central Square • TruePoint Zenner has worked with Central Square. Other billing providers Zenner has worked with include: • United Systems Technologies (UTSI) • Munibilling • Utility Data Systems • Harris Computer (In Hance) • Caselle (Civic Systems) • Oak Bay Technologies • Tyler Technologies • BSA Software • Thoroughbred Systems • BIAS Software

Technology Name: Company Name: Company Contact Name:	**Stealth Reader** **Zenner USA**
	• Vision Software • Inoprise • Local Government Corp • Sequoyah Software • Cambridge Technology • AVR • RVS • Keystone • Software Solutions • Fathom • Locin • Redline Data Systems • Intedata • Vision Government Solution • Pelorus • Zenner in-house engineering has the ability to write interfaces with any provider willing to work with us. *Zenner offers remote shut-off, leak detection, pressure monitoring for use within its Stealth Mesh Network and Stealth Drive-by Systems.
Redundancy	
Read Options	**Please detail options for redundancy in reading technology in case of failure, e.g. can the same transmitter be used for drive-by or walk-by reads?** Since the system is designed to keep operating through component and backhaul failures by moving information to and storing it within available collectors, the requirement to operate as both a fixed base and Drive-by/Walk-by AMR system, becomes unnecessary. In worst case scenarios, the utility can go directly to each collector and download current reading into a laptop for retrieval and return to the office. This saves the utility from the need to send personnel out into the field and performing the arduous task of driving the entire system in the event of a failure. Should a utility, for whatever reason, wish to switch back to a drive-by system, there is no need to switch out endpoint. All endpoints are shipped with the two firmware versions preloaded; mesh and drive-by.
Communication	**A. What kinds of two-way communication networks are your systems enabled for (e.g., 3G, 4G, 5G, LTE-M, LoRa, Sigfox, etc.)** The 2-way mesh RF communications is not a publically known technology. However, Stealth Endpoints come manufactured with IoT (LoRa Based Internet of Things) capability preloaded for a future move toward that capability. The current backhaul for the gateways is Ethernet or cellular (3G, 4G, LTE). **B. Is your preferred communication technology available in the Sacramento area?** Yes, Stealth communication backhaul options are available in the Sacramento areas. With an eye toward a move to open protocal infrastructure, the infrastructure for the Stealth Reader system is currently set up for a future move to IoT (LoRa, Sigfox, etc) as these public networks become available. Near-term, 6-9 months out, Stealth products also include cellular endpoints. **C. In areas where there is no signal (cellular or radio) what options do you offer?** Current products allow for Ethernet, Drive-by, Walk-by or manual readings. If feasible, we can move information from areas where backhaul is not available to areas where it is. We can accomplish this through low-cost repeaters in the network.

Itron Response

Technology Name: Company Name: Company Contact Name:	**TBD – Itron will propose multiple technologies** **Itron Inc.** **Cam Paulson**
Technology Type	
Technology Description	Itron has been providing AMR/AMI systems for more than twenty years. Itron's OpenWay Riva solution is based on our proven ChoiceConnect Fixed Network, first introduced in 2005 and our OpenWay solution first introduced in 2006. In 2015 Itron began development work to enable our water and gas communication modules to utilize Itron's fully standards-based multi-purpose IPv6 network. Both systems are RF-based, utilizing the unlicensed 900 MHz ISM band for communication between the endpoint and collector/router. ChoiceConnect measures, collects, and analyzes usage at the customer, utility, and system levels while providing the collected data to utility users for customer service, conservation support, advanced operational analysis, custom reporting, and improved revenue protection. The solution is the perfect balance of high-reliability collection automation and long-term storage and analysis functionality. It integrates seamlessly with the utility's billing system and other existing enterprise applications, such as a CIS and other IT systems. This proven Itron solution targets a utility's most pressing needs. OpenWay Riva is the latest generation of Itron's proven OpenWay solution, which began as an AMI solution for electric utilities and has expanded to provide coverage and communication for battery-powered devices such as water meter modules and sensors of all types. The underlying communications platform of the OpenWay Riva solution is powered by an open IPv6 architecture co-developed with Cisco, the leader in the field. It functions like an IT network in the field, allowing multiple services to coexist over the network while standardizing security and simplifying network management. The OpenWay IPv6 architecture allows water utilities to simplify the process and control the costs of expansion, including: • The addition of new applications and devices. • Expanding in to Smart City/ Internet of Things (IoT) use cases such as new and distributed resources, streetlights, LNG fueling stations, shared networks with nearby utilities, and more.
Operating Experience	**A. Please provide the number of US water utility deployments, including the smallest and largest size of deployment (number of endpoints and population served).** Itron has deployed more than 22 million water communications modules in North America with over 5.5 million meters automated with ChoiceConnect, representing 130 customers. We have an additional 1.8 million water modules representing a dozen customers that have either selected or are in the initial stages of implementation of our OpenWay Riva solution. Itron has delivered automated metering projects to hundreds of utilities and municipalities – projects ranging from small pilots of hundreds of endpoints to massive, multi-million endpoint rollouts. Our largest water projects is the City of Houston with 450,000 endpoints serving 2.2 million customers, and City of Baltimore with 425,000 endpoints serving 1.8 million customers. **B. Please note how many California deployments you have in the water sector.** Itron currently has about 20 network customers in the state of California. **C. If case studies are available, please provide website or attachments.** Please see attached case studies (Supplementary data Appendix D).
Simplicity	
Required Infrastructure	**Minimum infrastructure required and service options.** **A. Do you offer a network as a service option?** Yes. Itron offers the option to deploy customer systems as On-Premise (installed), in the Itron Cloud (SaaS), or as a Network as a Service (NaaS) configurations.

Technology Name: Company Name: Company Contact Name:	TBD – Itron will propose multiple technologies Itron Inc. Cam Paulson
	B. What is the minimum, maximum and optimum/standard requirement for antenna height? Would limitations on antenna height impact the number of collectors required for adequate coverage? For Itron's ChoiceConnect network, the CC100 minimum antenna height is 25' and max is 175'. The optimum height is 75' to 100'. For Itron OpenWay Riva, the minimum antenna height is 25' and max is 50'. 40' is optimal. With both systems, if limited to a 25' height, the overall count of required equipment would Increase. **C. Acknowledging significant variation which will be determined by a system propagation study (due to many factors such as building density, topography and vegetation), please provide a minimum, maximum and optimal range from the endpoints to the gateways.** Itron allows for coverage predictions for up to two miles for ChoiceConnect 100 as well as OpenWay Riva. While there are many variations to consider, in our most typical variations we will see consistent coverage out to ~0.5 miles. **D. How does your network achieve redundant coverage of endpoints?** The Itron Global Network Design Center team develops hundreds of network designs every year for utilities around the world. Itron's network design approach is a sophisticated, highly mature, and extremely thorough multistage process. Part of this process includes ensuring redundancy in the network based on customer requirements as well as topographical obstacles. Network redundancy is provided by ensuring overlapping coverage of the field area routers or collectors. OpenWay Riva can dynamically operate in star and mesh configurations. For water only utilities the typical network design would have the water module connecting directly to the CGR in a classic "star" configuration. (This is the same type of configuration used in ChoiceConnect.) If the water module is unable to connect directly to a CGR, it can connect through a neighboring water module. In a multi-commodity utility, electric and water, deployment of OpenWay Riva the water modules can communicate through the electric meter mesh network. **E. Any additional information regarding options to minimize infrastructure complexity is welcome.** Itron solutions support mobile AMR for remote areas that may make a network less desirable. We are also developing cellular endpoints that can communicate where RF may not be available.
O&M Requirements	**A. Please summarize notable maintenance requirements for primary system components.; B. What is the typical maintenance of a gateway over the life of the system?** The ChoiceConnect Network is designed to have minimum maintenance requirements. Collectors and repeaters have a backup battery that should be replaced every 5 to 7 years. No further preventative maintenance is required. Openway Riva similarly has no typical maintenance requirement outside of the need to replace the backup battery in the Cisco CGR every 5 to 7 years. The water endpoints have an operational life of 20 years, including battery, and require no maintenance. **B. What is the typical maintenance of a gateway over the life of the system?** As noted above, the only typical maintenance in both systems to be proposed, is the replacement of backup batteries every 5 to 7 years. In addition, firmware updates will be pushed by Itron as needed. **C. Do you offer over-the-air (through the headend and software) firmware updates?** Yes. Both the ChoiceConnect and the OpenWay Riva networks support firmware updates to the network equipment over-the-air. Upgrades may also be accomplished in the field at meter locations if necessary and are configurable at customer request. Itron endpoints will continue normal operation while downloading software or firmware updates until instructed to switch to

Technology Name: Company Name: Company Contact Name:	TBD – Itron will propose multiple technologies Itron Inc. Cam Paulson
	a new version, and additionally will automatically revert to the previous operational version should a failure be detected.
Reliability	
Battery Life	**Please provide component battery life (endpoints, gateways, etc.) assuming scenarios for both hourly and 15-minute read frequencies.** ChoiceConnect: The 100W+ is optimized to store and transmit time-synchronized hourly interval data to the Collector for the life of the system while delivering a 20+-year battery life. OpenWay Riva: The OpenWay Riva Water Module provides a 20 year or greater battery life when used in any of the standard modes, including intervals programmed for 15, 30, or 60 minutes.
Equipment Life	**Please provide estimated useful life for major components of system.** Itron water endpoints are designed with an industry-leading 20-year life including battery to be installed and operate with no maintenance for the life of our system. Network infrastructure life will vary depending on the technology selected; however, the designed lifetime of an Itron system is 15 -20 years.
Data Storage	**A. Please provide data storage protocols and data loss prevention safeguards.** Itron water modules store multiple days of interval data that can be retrieved at any time. They continue to record even if the network is down, allowing data retrieval once the network is operational. **ChoiceConnect:** Itron's 100W+ ERT module takes a time synchronized hourly interval reading at the top of every hour. In the Fixed Network mode the read includes the ERT ID, the ERT type, the most current meter register value, the last 7 time-synchronized consumption intervals, leak acoustics from leak sensor if installed with the ERT module, and any alerts: communication error flags, reverse-flow and system leak status flags, low battery alarms. Data is stored in the ERT, Collector, Fixed Network software and Itron Analytics software. The 100W+ ERT module stores 40 days of hourly interval data, the Collector stores 5 days of hourly interval data, the Fixed Network software stores 400 days of hourly interval data and Itron Analytics software is used for long-term data storage and analysis. Itron normally quotes 5 years of storage but can store for longer periods for an additional nominal fee. **OpenWay Riva:** OpenWay Riva water modules are connected to the water meters and record consumption and meter events/alarms at the utility's desired interval. The water module transmits its data two (2) to four (4) times per day through a CGR. Because the CGRs are routers, not collectors, when a CGR receives the transmissions from the water modules, the data is immediately routed via one of many backhaul options available through the CGR to the data center. The OpenWay Riva network is a true IPv6 field area network so once the data is received at the data center, the data is routed to the appropriate headend software application based on the IP address of the device sending the data. Long-term data storage and reporting is handled by Itron Analytics. Itron Analytics was designed to deliver our customers the value from the more granular and frequent collection of data through our network solution without the complex Meter Data Management Software applications designed for electric utilities. Itron Analytics provide use case-based Apps, easy reporting capabilities and long-term data storage. Itron Analytics makes data available through published API's, web services, flat file exports, etc., with the goal of providing our customers the most value from the data collected whether through Itron or third party applications. **B. Please provide any additional information regarding resiliency during emergencies and disaster-proofing.** Itron Global Managed Services maintains a Business Continuity Program for its systems. This includes backups of files and periodic testing of restore capabilities. Disaster Recovery is available at additional cost and can be quoted based on the requirements desired by the utility.

Technology Name: **Company Name:** **Company Contact Name:**	**TBD – Itron will propose multiple technologies** **Itron Inc.** **Cam Paulson**
Responsiveness	
Analytics	**Please list built-in analytics included as turnkey features of system, e.g. leak detection, pressure monitoring, reverse flow alarms, tampering alerts, etc.** Itron AMI systems support numerous tamper detection capabilities. The endpoints support such tampers as reprogramming attempt, register error, invalid read, reverse flow, suspected customer-side leak. Some of the modules support extended alarms provided by the meter register. Itron's optional acoustic leak sensor which is compatible with our AMI systems, detects leaks in the distribution system.
Flexibility	
Compatibility	**Inter-system compatibility with components and information systems.** **A. Please list meter types and brands with which your technology is compatible. Identify compatibility limitations with brands and types of meters.** Itron has the broadest water meter compatibility in the industry. Our modules are compatible with virtually all water meter registers available in North America. We have attached our "Water Meter and Telemetry Module Compatibility List" as a response for this question. **B. Do you provide a proprietary data management platform and customer portal or do you have preferred third party partners?** Itron is the industry leader in Meter Data Management (MDM) solutions with our proprietary solution "Itron Enterprise Edition" (IEE). The vast majority of IEE MDM solutions implemented by Itron have been at electricity utilities. We have found that most water utilities can meet their needs for storage and analytics with Itron Analytics. Itron has an optional IEE MDM MDUS-compliant software suite available which includes a more sophisticated level of data Validation, Estimation, and Editing and other meter data management functions. If the utility desires this added functionality we would recommend MeterSense. Itron has partnered with SEW for a customer portal that also provides some analytics for the utility. WaterSmart and MeterSense also have customer portals that Itron would recommend. **C. Please verify compatibility/experience with the following billing systems:** • Cogsdale • Oracle • Central Square • TruePoint Itron has interfaced with numerous billing systems through standard APIs. We do not officially track all billing systems with which we have interfaced, but have experience with Cogsdale and Oracle among many others. Of the hundreds of systems we have deployed we have never had an issue with the ability to interface with the billing system.
Redundancy	
Read Options	**Please detail options for redundancy in reading technology in case of failure, e.g. can the same transmitter be used for drive-by or walk-by reads?** **ChoiceConnect:** Network redundancy is built into the system with most of the 100W+ ERT modules being read by more than one Repeater or CCU, and all Repeaters being heard by multiple CCUs. In the event a CCU or Repeater is unavailable due to power outage or other failure, a communication path is typically still available for data collection from another CCU. This alternate communication path is always available and requires no action on the part of the network management system to switch over between network paths. Once restored, the Collector receives the data from the ERT and passes it to the headend. A request can be sent to the ERT module to retrieve historical data. Each Collector also stores 5 days of data for up 100,000 ERTs.

Technology Name: Company Name: Company Contact Name:	TBD – Itron will propose multiple technologies Itron Inc. Cam Paulson
	OpenWay Riva: The Adaptive Communication Technology that is utilized by our OpenWay Riva communications platform provides redundancy with its ability to dynamically select the most optimal path to the Cisco Connected Grid Routers (CGR). If the endpoint's primary CGR is down, it will automatically find another CGR. The CGRs are spaced to allow for failover; if one CGR goes down, the endpoint can temporarily use a nearby CGR to communicate its data. This creates a fault tolerant network where any endpoint can communicate with any available CGR on the system. The CGR is a router rather than a collector and does not store the data (data is stored in the endpoint); it is immediately transmitted to the headend. The OpenWay Riva Water Module stores 160 days of hourly data and 40 days of 15-minute interval consumption data as well as meter events and alarms. This allows the utility to request on-demand reads with the OpenWay Operations Center software from an individual, group, or all water modules to provide all requested data; thus, the data is never lost in the system. Both ChoiceConnect and OpenWay Riva transmitters (water modules) can be read via mobile when programmed in fixed network mode.
Communication	**A. What kinds of two-way communication networks are your systems enabled for (e.g., 3G, 4G, 5G, LTE-M, LoRa, Sigfox, etc.)** ChoiceConnect and OpenWay Riva work on the Industrial, Scientific, and Medical (ISM) band, within the 902-928 MHz frequencies. Often called the "unlicensed" band, these frequencies in fact are tightly regulated by the Federal Communications Commission (FCC); however, do not require a license to operate. Itron uses the 900 MHz ISM unlicensed band because it offers a wide frequency band allowing the ability to operate across multiple channels to provide assured connectivity with the highest bandwidth. Itron's network is a very adaptive and noise-tolerant solution. The system's frequency-hopping, dithering, and interference-avoidance occur automatically within seconds, with no need for input or even monitoring by the utility. Itron has deployed over 130 million endpoints in this spectrum; and we have not encountered a single scenario of radio noise or interference that could not be successfully overcome by our technology. Backhauls supported include cellular from public wireless carriers, direct Ethernet and Ethernet-enabled devices such as Wi-Fi, fiber, or private IP-based networks. **B. Is your preferred communication technology available in the Sacramento area?** Itron's ISM band is available in the Sacramento area. **C. In areas where there is no signal (cellular or radio) what options do you offer?** ChoiceConnect (100W) and OpenWay Riva (500W) transmitters fully support mobile drive-by and walk-by data collection if cellular backhaul from network devices is unavailable. **Mobile Collection System (MC3):** The Itron MC3 with SRead technology, can handle everything from basic consumption reads to the collection of interval data and performing other two-way communications to water, sensors and other devices such as service control valves and switches. The Itron MC3 Radio is the world's most popular high-volume mobile meter reading radio for drive-by and capable of processing over 10,000 consumption reads a minute. The vehicle roof mounted 5dBi gain antenna with 1-watt transmission power is optimum for reading and interrogating Itron endpoints driving through neighborhoods at speeds of 35 mph. The MC3 system configuration can be permanently mounted or be portable thus eliminates the need for a dedicated vehicle by being small enough to easily transfer among drivers as necessary. Itron's MC3 radio represents the lowest possible cost-per-read solution available. It is the most popular and highest performing drive-by solution in the world. The MC3 Radio is USB-connected and interoperates with a Windows 10 PC/tablet/laptop. The built-in GPS provides accurate navigation location to the application running on the PC. Itron recommends and has certified the Panasonic FZ-M1 tablet and CF-31 laptop with sleds that seatbelt to the vehicles passenger seat. Both are ultra-rugged and designed for the rigors of field use and handling.

*Itron has provided additional documentation which is provided separately in Appendix D.

Informational Data Technologies, LLC – Satellite Field Unit Response

Technology Name: Company Name: Company Contact Name:	IDP Pressure Model G1+ (Satellite Field Unit) Informational Data Technologies, LLC (IDT) Nick Polsinelli
Technology Type	
Technology Description	Used for simultaneous reading of a single water meter and line pressure. With standard programming, the device wakes up hourly and transmits a water meter and pressure reading once per day via satellite. The device has the ability to receive over-the-air commands to control a remote shutoff valve. The unit has the ability to transmit a meter reading to a separate remote reader or device and can be reprogramed to report at different intervals.
Operating Experience	A. The current deployment is 11,000 total installed. The installation size ranges from one single unit to 3,000 plus. The primary customer base is in the Midwest, with a small international deployment. There is a small installation in California that is expected to grow over the next 12 months.
Simplicity	
Required Infrastructure	Minimum infrastructure required and service options. A. Yes; IDT utilizes a geosynchronous satellite constellation as the network to provide telemetry and data delivery. B. The antennae are onboard the device and no external equipment is required. C. Each device is connected directly to the meter. The distance can be adjusted as needed by lengthening or shortening the cable provided at installation. D. While not redundant, the satellite device will continue to attempt a successful message transmission in the event there is interruption or interference. The device is self-contained and is designed to be “plug-and-play,” with the average time to install of 5 minutes.
O&M Requirements	A. Regulatory maintenance is not necessary. B. Typically, the most maintenance a system will be required to do is to replace batteries between 5-10 years after initial installation. C. Troubleshooting and updates are sent over-the-air and in most cases, no hands-on service is required.
Reliability	
Battery Life	The battery life fluctuates depending on the number of daily reports. The minimum battery life expectancy is 3,650 transmissions.
Equipment Life	The satellite constellation is designed to be operational at least 15 years from launch, however the anticipated longevity is 20 years plus. The current IDP system was launched in 2015 and the previous system was operational for 20 years (from 2000 to 2020).
Data Storage	A. All data is stored on the satellite network’s gateway as well as an offsite data storage facility. B. As the system is satellite based, the transmissions are not dependent on cellular or radio availability.
Responsiveness	
Analytics	Leak detection, pressure monitoring, remote shut-off are available through the customer portal – a web-based platform.
Flexibility	
Compatibility	Inter-system compatibility with components and information systems. A. IDT has proven compatibility with major meter brands including pulse, although a digital readout is preferred. IDT will test any new or unique meter brands/models if the prospective system so chooses.

Technology Name: **Company Name:** **Company Contact Name:**	**IDP Pressure Model G1+ (Satellite Field Unit)** **Informational Data Technologies, LLC (IDT)** **Nick Polsinelli**
	B. All data is available through a web-based customer access platform. C. Billing software compatibility is provided on a case-by-case basis to determine if direct communication or API is needed to provide data.
Redundancy	
Read Options	The devices are satellite-based so the redundancy of reads is built in as a “retry” transmission until the reading is successful.
Communication	A. Inmarsat satellite constellations are used for all two-way communication with the IDP G1+ Field Unit. B. Satellite communication is not hindered by location or population density. C. There are no domestic areas where satellite service is unavailable.

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Appendix C. AMI Technology Factsheet

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Each shortlisted vendor was contacted and informed on the project. The following technology factsheet was sent to the shortlisted AMI vendors in order to gather a better understanding of their system's capabilities and service options, including high-level information on their system compatibility, operation and maintenance requirements, indicative costs etc.

AMI Technology Factsheet
Phase 2: Meter Replacement Program Planning Study

Technology Name: **Company Name:** **Company Contact Name:**	
Technology Type	
Technology Description	Provide a technical description of your AMI solution, specifically summarizing the network configuration options (e.g. cellular, RF, etc.) and characteristics which set your offering apart from other providers in the AMI space. Please keep this to a 300-word summary or less.
Operating Experience	A. Please provide the number of US water utility deployments, including the smallest and largest size of deployment (number of endpoints and population served). B. Please note how many California deployments you have in the water sector. C. If case studies are available, please provide website or attachments.
Simplicity	
Required Infrastructure	Minimum infrastructure required and service options. A. Do you offer a network as a service option? B. What is the minimum, maximum and optimum/standard requirement for antenna height? Would limitations on antenna height impact the number of collectors required for adequate coverage? C. Acknowledging significant variation which will be determined by a system propagation study (due to many factors such as building density, topography and vegetation), please provide a minimum, maximum and optimal range from the endpoints to the gateways. D. How does your network achieve redundant coverage of endpoints? Any additional information regarding options to minimize infrastructure complexity is welcome.
O&M Requirements	A. Please summarize notable maintenance requirements for primary system components. B. What is the typical maintenance of a gateway over the life of the system? C. Do you offer over-the-air (through the headend and software) firmware updates?
Reliability	
Battery Life	Please provide component battery life (endpoints, gateways, etc.) assuming scenarios for both hourly and 15-minute read frequencies.
Equipment Life	Please provide estimated useful life for major components of system.
Data Storage	A. Please provide data storage protocols and data loss prevention safeguards. B. Please provide any additional information regarding resiliency during emergencies and disaster-proofing.
Responsiveness	
Analytics	Please list built-in analytics included as turnkey features of system, e.g. leak detection, pressure monitoring, reverse flow alarms, tampering alerts, etc.

AMI Technology Factsheet
Phase 2: Meter Replacement Program Planning Study

Technology Name: **Company Name:** **Company Contact Name:**	
Flexibility	
Compatibility	Inter-system compatibility with components and information systems. A. Please list meter types and brands with which your technology is compatible. Identify compatibility limitations with brands and types of meters. B. Do you provide a proprietary data management platform and customer portal or do you have preferred third party partners? C. Please verify compatibility/experience with the following billing systems: • Cogsdale • Oracle • Central Square • TruePoint
Redundancy	
Read Options	Please detail options for redundancy in reading technology in case of failure, e.g. can the same transmitter be used for drive-by or walk-by reads?
Communication	A. What kinds of two-way communication networks are your systems enabled for (e.g., 3G, 4G, 5G, LTE-M, LoRa, Sigfox, etc.)? B. Is your preferred communication technology available in the Sacramento area? C. In areas where there is no signal (cellular or radio) what options do you offer?

Appendix D. Supplementary Data

This appendix is provided separately.

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Appendix C. Technical Memorandum No. 3 – Meter Testing

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SUBMISSION DRAFT

Meter Replacement Program Planning Study

Technical Memorandum No. 3
Meter Testing Program Strategy

October 2020

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AMI	**Advanced Metering Infrastructure** includes the installation of a meter data collection network and the backhaul of metering data to a meter data management system. Generally described as fixed network.
AMR	**Automatic Meter Reading** is the automated collection of meter reads that still requires a meter reader to visit a property or be near a property. Generally described as drive-by radio meter read data collection but could be touch read also.
AWWA	**American Water Works Association**
Access	**Access** is a database management system (DBMS) from Microsoft that combines a database engine with a graphical user interface and software-development tools**.**
Bench	**Bench** is a meter accuracy testing apparatus that is usually purchased from a manufacturer, such as Mars or Ford, and can be manual or automated.
CCF	**Hundred Cubic Feet** (748 gallons)
CHWD	**Citrus Heights Water District**
City of Sac	**City of Sacramento**
Consortium	**Water Meter Replacement Program Consortium** includes Carmichael Water District, Citrus Heights Water District, City of Folsom, City of Sac, Fair Oaks Water District, Golden State Water Company, Orange Vale Water Company, Placer County Water Agency, the Regional Water Authority, Sacramento County Water Agency, Sacramento Suburban Water District, and San Juan Water District.
Crossover	**Crossover** is the flow rate at which a compound water meter moves from the positive displacement side (low flow) to the turbine side (high flow) of the meter. This flow is typically less accurate than flow rates on either side.
CRUC	**Customer Retail Unit Cost** is the average retail customer water commodity charge of a utility.
cu ft	**cubic feet (7.48 gallons)**
Excel	**Excel** is a spreadsheet software from Microsoft.
Folsom	**City of Folsom**
gal	**gallon**
gpm	**gallons per minute**

GPS	**Global Positioning System**
Intermediate Meter	**Intermediate meters** are meters that are 1.5 and two inches in size**.**
Large Meters	**Large meters** are meters that are three inches and larger in size.
M22	**M22** is the AWWA Manual on "Sizing Water Service Lines and Meters" (Third Edition, 2014).
M36	**M36** is the AWWA Manual on "Water Audits and Loss Control Programs" (Fourth Edition, 2016).
M6	**M6** is the AWWA Manual on "Water Meters-Selection, Installation, Testing, and Maintenance" (Fifth Edition, 2012).
MRP	**Meter replacement program** is a proactive program for replacing water meters as they near the end of their life.
On site	**On site** refers to the meter box or vault on the customer's premises.
PCWA	**Placer County Water Agency**
PD	**Positive displacement** pertains to a mechanical meter type that consists of either a nutating disc, oscillating piston, turbine, or vertical turbine to measure flow.
PDF	**Portable Document Format** is a type of computer file format.
R&R	**Remove and replace**
SCWA	**Sacramento County Water Agency**
SJWD	**San Juan Water District**
Small Meters	**Small meters** are meters that are 5/8 through one-inch in size.
SOP	**Standard operating procedure**
SSWD	**Sacramento Suburban Water District**
Study	**MRP Planning Study**
Validated Audit	**Validated audit** is the M36 Annual AWWA Audit validated by a Certified California Water Audit Validator.

Meter testing is an integral part of water meter asset management because it helps water agencies better understand real water losses by both volume and value (costs) and make informed decisions about when to replace deployed meters. Changes in meter accuracy over time are influenced by several factors, including the type of meter, volumetric throughput, water quality, and more. Changes in meter accuracy will differ by agency, but there can be regional trends (meter type or water quality, for example).

Appropriately developed meter testing programs will provide Consortium agencies with the information they need to extract maximum value from their deployed meter inventories. The costs of agency meter testing programs will be justified relative to the value they provide. Metering requires substantial investments in hardware, software, and staff support. The accuracy data provided by meter testing can enable an agency to time its meter replacements in an efficient manner. Meter testing will provide agencies with data for determining and managing regulated water loss processes.

The purpose of Technical Memorandum No. 3 is to provide Consortium agencies with recommended improvements to their meter testing programs. Opportunities for consortium-level collaboration including the feasibility of joint meter testing options are presented. Meter testing standards and methods are discussed, and recommended region-wide procedures are provided.

Small Meter Testing (1-inch and smaller)

Consortium agencies do not currently have well-defined schedules for small meter testing but should prioritize doing so. City of Sacramento, Folsom, PCWA, and SJWD have in-house test capabilities for small meters. City of Sacramento, Folsom, PCWA, SSWD, and SJWD have bench-tested small meters in recent years. Existing data does currently provide these agencies with some insights into how the performance of their deployed meters changes over time. However, all agencies need to collect additional data in order to develop statistically significant relationships between accuracy, age, and total registered flow. The cost of small meter testing is justified through the ability of Consortium agencies to track meter accuracy degradation over time and use this information to replace meters at the most appropriate time. The investment will enable agencies to develop and demonstrate efficient small meter replacement schedules that minimize revenue lost through meter inaccuracy relative to both the cost of meter testing and meter replacement.

Recommendation 1 – Conduct accuracy testing consistent with AWWA standards of randomly selected deployed meters at 95 percent confidence levels with an initial focus on meters in the 10-25 year age range and 2-6 million gallon (mg) total registered flow range. Within the next five years, each agency should aim to develop statistically significant accuracy estimates for 11-15, 16-20, and 21-25 year age intervals. Agencies should also aim to develop statistically significant accuracy estimates for 2-3 mg, 3-4 mg, 4-5mg, and 5-6 mg total registered flow intervals. This will enable agencies to establish more accurate and statistically defensible small meter replacement criteria and water loss estimates.

Intermediate Meter Testing (1.5 and 2-inch)

Most consortium agencies do not have testing schedules for intermediate testing. Though it is possible to bench test intermediate meters, on-site testing is the recommended method so that all deployed intermediate meter can be tested on a four or five-year rotation. Because many of the Consortium's deployed intermediate meters are older positive displacement models without test ports, it is currently difficult to implement on-site testing. The cost of intermediate meter testing is justified through its role in enabling Consortium agencies to maintain the accuracy of their deployed meters. The test results will demonstrate whether or not agencies are recovering the cost of testing in terms of recovered potentially lost revenue from inaccurate intermediate meters. With this information, agencies will be able to adjust their testing rotation moving forward to balance the costs of meter testing compared to the potential revenue recovery it provides.

Recommendation 2 – Agencies are recommended to place intermediate meters on a four or five year testing rotation. The meters should then be rebuilt or replaced based on the results of testing. If, in the first couple years, the cost justification for annual testing shows that the meter can be shifted to a different schedule, then agencies can adjust accordingly. The methods described here can be used to determine if more or less frequent intervals can be adopted.

Large Meter Testing (3-inch and larger)

SSWD, Folsom, PCWA, and SJWD currently test large meters on fixed schedules. SSWD, Folsom, and PCWA are the only agencies that own and operate large meter test equipment at present (August, 2020). Only SJWD currently tests all meters on an annual basis. The cost of large meter testing is justified through its role in enabling Consortium agencies to maintain the accuracy of their deployed meters. Agency data indicated that deployed meters generate sufficient revenue (on average) to justify annual testing.

Recommendation 3 – Large meters should be selected for annual testing per a recommended standard operating procedure provided in this report. If, in the first couple years, the cost justification for annual testing shows that the meter can be shifted to a bi-annual program, then agencies can adjust accordingly. Conversely, if agencies elect to use more infrequent test intervals (i.e. three years or more), then the methods described here can be used to determine if more frequent intervals (such as one or two years) should be adopted as recommended here.

The annual test counts and estimated costs of the recommended meter test program for small, intermediate, and large meter categories are shown in the table below and further detailed in Appendix B:

Annual Meter Testing Quantities & Costs by Agency for Recommended Sampling

Agency	Small Meters		Intermediate Meters		Large Meters	
	Test Count	Estimated Annual Cost	Test Count	Estimated Annual Cost	Test Count	Estimated Annual Cost
City of Sac	383	$5,021.56	1,799	$242,540.57	1211	$571,356.00
SSWD	381	$5,046.13	607	$116,196.16	224	$142,086.40
SCWA	383	$7,021.67	762	$95,762.86	167	$73,480.00
Folsom	378	$6,930.00	214	$26,902.86	86	$37,840.00
CHWD	377	$6,911.67	297	$37,274.29	43	$18,920.00
PCWA	381	$6,832.60	244	$30,005.03	58	$24,748.00
SJWD	371	$6,618.64	84	$10,184.09	14	$5,994.24

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Consortium Opportunities

There are two test benches among Consortium Agencies that are recommended for joint meter testing. The City of Sacramento facility can test up to 12 small meters in parallel as well as larger meters up to 16-inches in size. They can also test up to five 1.5-inch or 2-inch meters at a time. The Folsom facility can test up to 8 meters in parallel as well as larger meters up to 2-inches in size. Given its size and capabilities, the City of Sacramento test facility would be a good option for CHWD, SCWA, and SSWD to test their small and intermediate meters.

On-site testing can be performed either by agency staff or a third-party contractor. Several Consortium agencies employ the use of third-party contractors for meter testing. It is recommended that the Consortium develop a qualified vendor list and employ the on-site testing standard operating procedure provided in this memorandum. This will provide agencies with consistent testing and potentially economical pricing.

Consistent information management processes for meter test data and deployed inventory will also enable agencies to share and benefit from one another's data. A consistent database is recommended among consortium agencies that could potentially be linked together for comparisons of meter accuracy test results associated with age, total registered flow, model, type, and other factors.

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Section 1 Phase 3 Introduction

1.1 Study Overview

The Meter Replacement Program (MRP) Planning Study (Study) presents a unique opportunity for neighboring water agencies in the greater Sacramento area to explore potential benefits of working together. Water MRP Consortium (Consortium) agencies understand that the utilities of the future will operate in a different paradigm—one that is largely built on public and stakeholder trust, along with cooperation and collaboration with adjoining entities with common interests and economic benefit.

The purposes of the Study are as follows:

- Develop a water meter replacement strategy for participating water agencies.
- Determine the feasibility and a strategy, as appropriate, for long-term, full, or partial integration of MRPs for participating water agencies.

Figure 1 shows the range of potential individual versus cooperative development and implementation of water meter and water meter reading technology replacement for the participating water agencies.

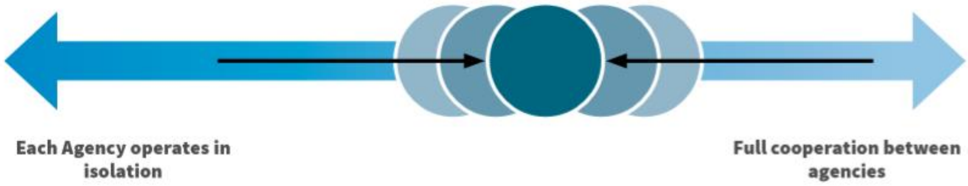

Figure 1. The purpose of the Study is to determine how participating water agencies can sensibly integrate their metering programs over time.

Agencies participating in the Study include the following:

- Citrus Heights Water District (CHWD)
- City of Folsom (Folsom)
- City of Sacramento (City of Sac)
- Placer County Water Agency (PCWA)
- Sacramento County Water Agency (SCWA)
- Sacramento Suburban Water District (SSWD)
- San Juan Water District (SJWD)

Agencies that are members of the Consortium but are not directly participating in the Study include the following:

- Carmichael Water District
- Fair Oaks Water District

- Orangevale Water Company
- Regional Water Authority

1.2 Introduction to Phase 3

The general purpose of Phase 3 of the MRP Study was to review each agency's current water meter testing program and available water testing facilities (in-house and regional). Opportunities for Consortium-level collaboration were researched in this phase to identify the feasibility of joint meter testing options and existing and potential costs. Meter testing standards and methods were discussed, and recommended region-wide procedures were offered.

The following three key questions were addressed in this Study phase:

1. What is a meter testing program? A testing program consists of the following six major elements:
   a. **Purpose.** Why conduct meter accuracy testing in the first place? What goals will be achieved? How can the test results be used to make better meter replacement decisions? How will test results be used to produce more accurate American Water Works Association (AWWA) Manual M36 water audits?
   b. **Approach.** How many small meters of each size will be tested? What small meter testing frequency should be implemented? Should small meters be tested on a test bench? What flow rates will be used? How many large meters will be tested and at what frequency for each size? What is the testing priority basis—annual volume and revenue per meter? Will all meters be tested on site? How many test units are needed? What will the plan cost in terms of capital and annual recurring costs? What is the anticipated test cost per meter for each size?
   c. **Staffing.** What type and number of staff will be needed to achieve the testing goals?
   d. **Equipment.** What type and amount of equipment will be needed?
   e. **Data Management.** How will meter accuracy test data be collected and managed? Can the data be easily stored in and extracted from the testing equipment? What format for data storage will be used—Microsoft Excel or Access? What data is needed from the meter testing form for data analysis to characterize meter accuracy by size for the whole system?
   f. **Analysis.** What data analysis is needed for meter population characterization by size? What data analysis is needed for an annual AWWA Manual M36 water audit? What data analysis is needed for making decisions on meter replacement?
2. Why is a meter testing program important?
   There are many reasons to test water meters of all sizes. Testing methods vary by meter size. Small meters are generally tested on a calibrated, certified test bench. Large meters are generally tested in place in the meter box or vault. Meter tests should be

conducted on a sample of new small meters to assess compliance with purchase specifications and warranty and on a sample of deployed small meters to assess compliance with AWWA standards to determine meter accuracy degradation and to characterize the overall meter population by size for AWWA Manual M36 water audit purposes. Large meters should be tested on site in a prioritized manner with recurring frequency based on billed monthly use and revenue. Large meter accuracy testing data should also be used to characterize accuracy for the whole large meter population by size for auditing and meter replacement planning purposes. Large meter warranty periods are much shorter than those for small meters.

a. Equitable revenue recovery

   Accurate metering is required to spread revenue requirements equitably among all customers. Many utilities use metered water demand to estimate wastewater flow for billing. Inaccurate meters result in typical under billing for both water and wastewater.

   Customer demand

   Accurate customer metering is essential for evaluating spatial and temporal variations in demand for production and distribution system hydraulic modeling, component right-sizing, and asset management. With automatic meter reading (AMR) and advanced metering infrastructure (AMI) systems, accurate metering is necessary for accurate hourly interval data used for system management, water conservation, and customer use monitoring through internet portals.

   Water loss

   Because California requires annual AWWA Manual M36 water audits, accurate customer metering is necessary to populate the top-down audit spreadsheet and to use results to track trends in water loss for both apparent and real losses. Real losses are primarily distribution system leaks, which are calculated from water supplies and customer-metered water demand. Overestimating customer meter accuracy results in a calculation of higher real losses. As a result, resources could be expended in looking for leaks that do not really exist. California is likely to set leakage limits in legislation based on AWWA Manual M36 water audit results. Customer metering accuracy inputs are critical to calculating system leakage.

3. What are the various meter testing methods?

   a. Bench testing

      Bench testing involves the use of a certified commercial meter test bench. Multiple manufacturers of this type of testing apparatus and associated measurement software exist. Many Consortium agencies own and operate their own meter test benches, although accuracy testing can be contracted to a private entity. It may be possible for a Consortium agency to cost-effectively offer its facility to test meters for those agencies that do not have their own test benches. Test benches can be used for small and large meter accuracy testing but are typically used for single-family residential and small commercial meters sized two inches and smaller. Meters larger than two inches are generally tested in the field with comparison meters known to be accurate.

b. On-site testing

On-site testing can be done for all meter sizes but is generally accomplished for large meters using portable comparative meters. Large meters typically have test ports to simulate customer demands at different flow rates and to determine their accuracy at these field rates. Having portable testing equipment precludes removing a large meter; installing a new or temporary meter; preserving the meter without affecting the accuracy response; hauling the meter to a test bench; testing the meter on the bench; and re-installing it if repairable within standards.

1.3 Historical Basis for Meter Testing and Updated Importance for Auditing

The AWWA periodically adopts and updates water policies associated with water utility operations and best practices. It adopted its first policy on metering and accountability in 1969 and recently updated the policy in January 2019. The entire policy can be found on the AWWA website. Key elements related to this project are below:

> The AWWA recommends that every water utility accurately meter all water taken into its system and all water distributed from its system at its customers' points of service.... Data collected from accurate metering is essential for wholesale and retail customer billing, system performance studies, facility planning, and the evaluation of conservation measures. An effective metering program relies upon selecting and managing the proper metering technology and data collection for the customer's consumption patterns; including determining the proper size, type, and installation of meters and periodic accuracy testing, repair, maintenance and replacement of all meters.

Reasons for accurate water metering are as follows:

1. Income generation from water sales.
2. Equitable water and sewer cost allocation (cost of service).
3. Encouragement of water conservation.
4. Water system demand information collection (temporal/spatial).
5. Hydraulic analysis, planning, and infrastructure sizing.
6. Water system auditing.
7. Customer demand. This affects customer complaints and utility credibility.

Some states have regulations specifying how utilities must establish cost of service water rates and balance revenue between fixed charges and commodity charges. Some states also have established drought management programs that increase unit commodity charges when resources increase in scarcity and decrease in availability.

In addition to the adoption of broad, industry-wide policy statements, the AWWA also publishes manuals of practice authored by volunteers who work in the water industry. AWWA Manual M6, Water Meters: Selection, Installation, Testing, and Maintenance (Fifth Edition), offers the detailed history of water metering and best practices for meter management. Some language from AWWA Manual M6 regarding meter testing is presented below:

> Whether required by a regulatory agency or voluntarily performed by the water utility, it must be stressed that meter maintenance is the only means by which revenue is equitably obtained to operate the water system. It requires the necessary time and study to determine the optimum frequency and best practices for testing meters for the most efficient and economic results.
>
> Since meter accuracy degradation can be very gradual, prudent testing intervals, perhaps supplemented by data analytics, can detect significant meter accuracy problems long before large-scale meter failure or significant revenue loss occurs. Prudent testing intervals may vary greatly, depending on water quality, usage patterns, and the specific meter types and designs in use in any given utility system. Test interval decisions can also be driven by the rates charged for water (or water and wastewater) services and by water accountability requirements.

In addition to providing equitable and accurate revenue recovery for each customer, meter testing programs also play an important role in determining and managing water losses. An estimate of overall customer metering inaccuracy is required in AWWA Manual M36 water audits. California mandates annual AWWA Manual M36 water audits. If the meter accuracy is understated, the resulting Real loss calculation will be overstated and possibly incorrect.

Meter accuracy test data is used to develop relationships between low, intermediate, and high test flow accuracy and meter age and cumulative flow for each meter size and type. Development of representative best linear fit of the data can be used to assess meter accuracy by size for the entire deployed meter population. Through the use of individual meter age and volumetric (calibrated tank) throughput, developed linear equations can be applied to each deployed meter to estimate existing accuracy. Meter inaccuracy volumes for each meter can be used to calculate the value of the lost water using existing, utility-specific water rates and sewer rates, if applicable. Cost of meter replacement can be compared with annual sums of the value of lost water to determine the economic optimum time for meter replacement or the number of years it will take to repay the meter replacement cost for each meter.

A systematic meter testing program demonstrates to customers that the utility has taken a proactive stance on water system maintenance so the customers can witness the level of maintenance that a water system staff performs to keep water safe and at a reasonable cost to all. Regulatory agencies in many locations, such as the State of California, have taken an interest in minimizing water waste and maximizing efficient use. Water loss audits are now required by several states to have proper accounting in place for responsible water use. Some bonding companies have begun to use water audits to rate a bond's risk level for water system improvements for water utilities.

1.4 Methods of Meter Testing

There are several ways to test water meters for accuracy. The AWWA Manual M6 (Chapter 5) describes how water meters can be tested. It is strongly suggested that meter technicians read this chapter to gain knowledge on the specific elements of a water meter test. Under the standard operating procedures (SOPs) described in this technical memorandum, suggestions are offered on how to test a meter and include specific flow rates for testing various sizes. Two accuracy test methods are considered in this technical memorandum because both are widely accepted by water systems nationwide, and participating agencies have used and continue to use both methods. The two methods are (1) the use of a standardized meter test bench and (2) the use of a calibrated portable test meter in the field to test meters on site.

Bench Testing

The use of a test bench by a water utility to test a water meter for accuracy has been widely accepted as the preferred method to test small water meters (defined as one inch or smaller). Larger water meters can also be tested on a test bench but present certain time and resource issues, such as the removal of the meter, preservation of internal wet conditions, field replacement with an interim or new water meter, and re-installation of the tested meter if accuracy results allow.

A meter test bench is made up of hardware in which meters can be clamped into meter settings (sometimes called a "meter horn") in a series so that several meters can be tested at the same time. The meter bench is constructed and set up so that meters are installed plumb and level and not tilted to one side or another. This is because some meter measuring elements are affected by gravity and, by tilting the meter body in a setting, the nutating disc or piston that operates as water flows through the meter body can be slowed by gravitational pull, especially under low flow conditions.

Water is introduced into the meter bodies and then travels into a rotameter (defined as a concentric diverging upflow graduated cylinder) that has a weighted disc that moves up along the graduated indexes as the flow velocity increases. A control valve is used to manually vary the flow velocity, allowing the disc to reach a certain flow indicated on the indexes. The water is directed into volumetrically calibrated tanks. When the tank fills to a certain volume level, as indicated on the side of the tank, the control valve is closed. Meters will be installed into the individual setters. The water is introduced to purge the line of air at a low flow. There is usually a bleed valve after each setter so each installed meter can be "zeroed" before testing. For some older benches, the meter will be manually read because they cannot be zeroed. Meters are then read and recorded on a log. After the test tanks are drained and the drain valve is closed, the flow testing begins, usually with the low flow test. At the end of the low flow test, each meter is read, and results are logged before the next higher flow rate test is conducted.

Some test benches are automatic, meaning that a computer controls many of the testing functions. The clamping of the meter is performed hydraulically. The meters are read, and data readings are entered into a computer. After that, testing starts via a computer, and the flow rate is measured electronically and monitored by a computer instead of manually by the rotameter. The volumetrically calibrated tanks sit on load cells so the water is weighed (gravimetric) and the volume is recorded (volumetric). Some modern benches take into account the temperature of the water because the temperature affects the gravity of the water and, therefore, the mass of the water. This allows for exact measurements.

The primary challenge with bench testing is that the meters must be removed from the customer's meter setting and replaced. The meter to be tested should be removed, preserved wet, and transported back to the meter testing facility where the meter bench is located, and tested. Care must be taken to keep the meter wet inside during transport. Dry meters often become stuck and cause the meter to misread during testing. Low flow tests for small meters are better controlled at the test bench. On-site small meter testing can be used, but the meter technician must be able to handle service valve issues where the valves do not function correctly and the on-site test can be compromised. In addition, the time involved with on-site testing and the inconvenience of having a customer without water service during the on-site test can be outweighed by installing a new meter and taking the old meter to the meter testing facility for testing.

Bench testing can also be performed on intermediate and large meters. The elements of large meter bench testing are similar to small meter bench testing. The meter is installed in a setting, and water flows in and out of the meter into a volumetrically calibrated/gravimetric tank large enough to contain the water used for testing. However, the tanks and pipes must be much larger. The size and cost of the installation of a larger test bench and calibrated tanks are often the barriers to a utility using large test benches. In addition, the area that the large meter test bench occupies must be dedicated to only large meter testing. A utility that performs large meter testing via a test bench must have enough large meters to test to justify the capital and operating costs of a large test bench.

On-Site Testing

Testing meters on site eliminates the need to replace and transport meters to the bench testing location. Large meters often have built-in test ports that will allow for on-site testing, provided that the utility has a portable meter tester. Some large meters are too large to remove on a regular basis to take to the meter testing facility for testing when the meters can be isolated on site and flow tested in place. It is difficult and time-consuming to move a large meter without damaging it.

Therefore, on-site testing using a portable calibrated test meter offers a suitable alternative that can be relied on for accurate results as long as a strict protocol is followed for testing. One issue is where to put the volume of water used to conduct the test. This can be solved by locating a drain to a sanitary sewer or storm drain where water can be discharged safely. All agencies will need to dechlorinate the water during discharge, especially if the water goes into a storm drain.

The process for on-site testing is as follows. The meter is first isolated so that the water going through the meter also passes through the test meter. The test meter must be calibrated (i.e., tested regularly for accuracy and documented) and of sufficient size to handle a range of flow rates. Sometimes, the higher flow rates recommended by AWWA Manual M6 for a large meter size are not attainable due to the limitations of the on-site circumstances or the capacity of the test meter. Because no set standards for on-site testing exist, each utility must define the testing protocol elements to be used for on-site testing.

Testing small meters on site is an alternative that can be used by some utilities. A calibrated portable test meter needs to be employed under the strictest conditions to maintain the integrity of the flow tests. Various on-site flow tests can be used for small meters. The meter can be removed on site, the fittings can be installed to set up the meter for testing, the test meter hose can be plumbed into the setting, and then the testing can be performed. Once completed, the meter can be re-installed. Other methods involve connecting a test meter to a hose bib or laundry sink and running water. This can work as long as no plumbing fixture leaks occur inside the home and no additional water is used during the test.

1.5 Methodology

Phase 3 was accomplished in four sequential activities that involved iterative collection, clarification, and updating of information. The four activities were discovery, organization of information, analysis, and documentation.

The discovery activity included developing a survey instrument to pose questions to metering managers and to collect information about existing meter testing goals and programs of each agency. Interviews were held on site with visitation and photographs taken of existing testing facilities and equipment. Organization of information included strategic sequencing of interview responses, identification of data gaps, and follow-up questioning for clarification. Data analysis involved assessing existing testing practices and costs. Existing procedures were compared with AWWA standards and manuals of practice with industry-wide best practices. Economics of meter testing by agency were collected and analyzed to determine potential economies of scale to share local testing resources.

This technical memorandum, as well as the subsequent review and discussion of the document, details the considerations and analyses that make up Phase 3 of the Study. Meter testing issues, policies, procedures, economics in terms of capital and operational costs, and opportunities for regional sharing of facilities and procurement are critical elements of the Study and warrant the separate work phase and discussion documented herein.

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Section 2 Agency Interviews on Meter Testing and Audit Programs

2.1 Interview Survey

As part of exploring the meter testing practices of the seven Consortium agencies, the project team created a set of common interview questions for each agency to help determine and document each agency's current position on water meter testing. The questions were designed to establish if each agency had a meter testing program, how that program was implemented and operated, and if the program met specified and identified goals. Results of annual AWWA Manual M36 water audits were also collected, analyzed, and reported relative to apparent losses primarily associated with customer metering inaccuracy.

The questionnaire was used as a guide to prompt initial responses. Standard questions were asked, but allowances were made to add comments specific to each agency. The answers were tabulated and compiled into a Microsoft Excel spreadsheet for quick reference and easy comparison. In many cases, digital photographs were taken of each agency's meter test benches and field testing equipment (if applicable). Each agency was asked about meter testing policy, training of technical staff, and testing processes; if an SOP was in place; the type of budget each agency had; what the agencies expect to gain from a meter testing program; and provided a quick assessment on immediate perceived meter testing needs. The Microsoft Excel spreadsheet is included as Appendix A, Interview Summary. The following is a discussion of the survey results.

2.1.1 Meter Testing Program

All seven participating agencies have or had a program to test meters to some extent, although some were more extensive than others. The majority do not have a "formal" program that follows defined SOPs. The programs that exist contain techniques and practices passed along over several years with minor changes added periodically. The participating agencies that do have SOPs for testing focus on large meters being tested in the field. Intermediate and smaller meter testing methods were not part of the SOPs supplied for review (with the exception of PCWA).

Agency meter count data from the deployed meter inventory was taken from data contained in Technical Memorandum 1. The meters were classified by size, and those counts were input into the Microsoft Excel spreadsheets used to compile the summary of the interviews and cost data. Three meter sizes are defined in the specific categories below as small, intermediate and large. Specific sizes in AWWA manuals are typically small (5/8 through two inches) and large (greater than two inches). For Phase 3 analyses, small meters are 1 inch or less, intermediate meter sizes are 1.5 and two inches, and large are 3 inch or greater. Intermediate meters are not formally defined by AWWA, but in the vast majority of water utilities in the US, the term has been applied to 1.5" and 2" meters.

As a part of this Phase 3 review, the agency-specific annual validated water audits required by the State of California per AWWA Manual M36 were also consul ted to gain more perspective on each agency's metering practices.

2.1.2 Types of Testing Performed

Four of the seven participating agencies have meter test benches (i.e., City of Sac, Folsom, PCWA, and SJWD). Out of the four that have benches, the City of Sac can test the largest range of meters; up to 16-inch in size. The City of Sac's small meter bench is a "24-stand" meter bench (24 one-inch meters can be tested simultaneously) and is automated. However, due to issues with head loss, currently only 12 small meters can be tested at a time. Automated test benches generally have a computer that controls the flow tests (low, intermediate, and high flows per the definition in the AWWA Manual M6) depending on the size of the meter batches being tested. The computer program typically records the test results for each flow test. The readings for each meter are entered into the computer by the meter technician to calculate the meter accuracy before and after each test run, and then the individual accuracy for each test is calculated. The meter test records are stored in a database on the test bench computer. The format of the database is proprietary to the meter bench manufacturer and was created as such to offer a "bias free" meter accuracy report as a PDF. The water used for the testing is delivered to a volumetrically calibrated/gravimetric tank where the water is weighed as part of the volume calculation.

The large meter test bench can accommodate several large meters for testing at the same time (all must be the same size and type) and can also be used for Intermediate meters. The tests are volumetric and gravimetric. The test bench is automatic, which is similar to the small meter test bench, just larger. In addition, a 10-inch spool mag-style meter also measures flow and flow rates in series with the meters being tested.

The other three agencies with test benches can only test smaller meters, typically 5/8 to one-inch meters. These smaller benches are "four-stand" benches (four-meter capacity). Folsom can test eight at a time. For at least one test bench, fittings can accommodate 1.5- and two-inch meters, but fittings appear to require testing one at a time, and the attainable higher flow rates are limited. One bench is an older Ford test bench and uses rotameters for manual flow monitoring and volumetrically calibrated tanks only (no gravimetric capability). The other two are newer and are volumetric and gravimetric with automatic controls. Further discussion on the test benches is included in Section 6, Recommendations for Meter Testing by Agency, of this technical memorandum.

Large meters are typically defined by the Consortium as three inches and larger. Meter types (e.g., compound, turbine, fire line meters) were not categorized by the agencies for interval testing purposes. Four of the seven agencies test three-inch and larger meters with their own staff in the field (in place in the meter vault) using a calibrated portable meter tester on site or employ a third-party, private firm to test meters in the field. Some use a combination of outside meter testing and in-house staff to test large meters in the field. One agency performed large meter testing years ago but did not establish or perform a regular testing program. The number of meters tested annually varied from agency to agency, with some agencies stating clear testing intervals (years between testing) by sizes. One agency tests all their large meters annually. The four agencies that test meters in the field appear to have similar field testing practices and procedures (based on the agency-provided sample meter test sheets) with minor differences. These agencies follow the AWWA-prescribed test flow rates by meter size in the AWWA Manual M6 (Chapter 5) for low, intermediate, and high test flows used to compare the tested meter accuracies with AWWA standards.

Intermediate meters are defined in the Study as 1.5- and two-inch meters. Meter types (compound, turbine, and displacement meters) were not categorized by the agencies for testing interval purposes. One agency lumped intermediate meters with small meters, typical of AWWA Manual M6 definitions. Most of the agencies do not have a "regular defined" program for testing intermediate meters. One agency stated that they test these meters about every 10 years. It was perceived by some agencies that the reason for not testing these meters is that the meter or setting does not usually have a test port and, therefore, field testing is not performed. To test meters without test ports, a meter technician must remove the meter and take it to the meter testing facility for testing on the meter test bench, requiring adaptors and fittings to accommodate the size meter for testing. Only one agency has the ability to do this (i.e., they have fittings and adaptors for their four-stand test bench).

Small meters are defined as 5/8- to one-inch meters. The four agencies that have test benches do not have a well-defined testing schedule for small meters. Most agencies test meters based on customer complaints or if an account appears to have issues, but no regular random sampling programs are in place. Some of the other three agencies that do not have benches send samples to an off-site, third-party tester for occasional testing, but this is not a part of a regular program. Shipping costs may be a limiting factor. One agency used a portable handheld meter to test small meters in the field (on-site testing) as part of recent sample testing. This agency did not mention the possible "built-in" meter testing biases for this type of testing for small meters. A discussion on the merits of small meter testing in the field is provided in Section 6 of this technical memorandum.

2.1.3 Meter Testing Standard Operating Procedures

Four agencies have meter testing SOPs. Three agencies have specific SOPs for large meter testing only and do not address intermediate and small meters. The fourth agency has an SOP for small and large meter testing. As part of the SOP survey questions, agencies were asked about meter testing training. All agencies stated that the knowledge of meter testing is acquired through on-the-job training, and no formal training program is currently offered.

2.1.4 Meter Testing Forms

Samples of meter testing forms (with test results) should indicate the type of meter tested; details such as the serial number, address, and account number; tests conducted (flow rates); test results (percent accuracy of the flow rate); and if the meter passed or failed the test. Agencies indicated that their testing includes the AWWA Manual M6 low, intermediate, and high flow tests specified in Chapter 5 by meter size. Field testing flow rates followed the same AWWA guidance, except that high flow test rates appear to be limited by the capacity of the agency-specific portable test meter and hose assembly. Flow rates for accuracy testing will be discussed further in this technical memorandum. One agency denoted the use of specific flow testing for compound meters where the “crossover flowrate” would be tested.

2.1.5 Triggers for Meter Tests

Another question asked in the interview survey included what conditions trigger a meter test. Responses included high customer bill complaints, tests requested by agency accounting staff, and inconsistent meter readings based on customer billing history. When asked about what happens when a meter fails the accuracy testing, most agencies responded that they replace the small meter. Large meters can generally be adjusted or have measuring chambers cost-effectively replaced. When asked about how the meter testing program is funded, most agencies responded via their operations budgets.

2.1.6 Agency Testing Needs

Each agency was asked to identify their specific “needs” list. The interviewer also added a few observed needs to the list as well. All agencies’ lists include similar items. Similar needs include a formalized testing program, meter testing training for staff, and use of other agency’s test benches if possible. Shared test benches will be examined further in Section 6 of this technical memorandum.

2.2 Water Audit Information Review

Each agency is required by California to submit a validated annual water audit by October 1 of each year for the previous calendar year. Specific requirements must be met for the submittal to be certified as “validated.” It was assumed that the information supplied in the agency audits was validated and reviewed prior to submittal to the state.

The consulting team has a few Certified California Water Audit Validators on staff and, as part of the information collection, they reviewed audits for 2018 and 2019 to see what information was available and usable for this evaluation. Some agencies only supplied the 2018 audit, while others supplied both 2018 and 2019 audits. One agency did not have an audit posted to the project Dropbox site.

2.2.1 Relevant Audit Entries

The AWWA Manual M36 water audit software is a free Microsoft Excel spreadsheet authored by volunteers of the Water Loss Control Committee, of which members of the consulting team are long-standing participants. The software has been updated multiple times and currently exists as Version 5.0. The software is called a top-down audit tool to be used to determine total distribution system losses, apparent losses, and real losses. Specific data entries relevant to customer meter testing were evaluated by the consulting team. Billed Metered Water Use under the Authorized Consumption component of the audit included studies, along with the Unbilled Metered Water Use and Billed Unmetered Water Use entries. Additionally, the Apparent Water Loss section, in which the apparent loss is calculated, contains a single entry for overall meter inaccuracy for the entire meter population of the water system. Each agency is required to enter a composite weighted meter inaccuracy percentage for the entire deployed meter population. A third area of review was the Customer Retail Unit Cost (CRUC) section where the average retail price per unit of water is entered. The CRUC is obtained by dividing the annual revenue for the billed metered accounts by the total billed metered water use for the same time period yielding the unit costs. Usually the CRUC is expressed in dollars per 1,000 gallons (gal) or 100 cubic feet (cu ft). The consulting team also evaluated the apparent loss costs as calculated by the audit to determine the potential cost recovery through meter replacement, keeping in mind that part of the apparent loss cost is tied to two lower volumetric default values contained in the audit (unauthorized use [theft] and systematic data handling errors).

2.2.2 Authorized Water Use

Billed Metered Annual Consumption: This is the volume amount each agency reported as water that was metered and billed for. None of the figures appeared to be out of the ordinary.

Billed Unmetered: Two agencies have water that is billed but not metered. During the interview with the City of Sac, they explained that they have several accounts that remain unmetered that are planned to be metered in the near future. SCWA also has billed unmetered use, but they did not explain where the estimated volumes came from in the Comments section of the audit. During the interview, nothing was expressed about the unmetered accounts.

Unbilled Metered: Typically, these are metered accounts such as municipal buildings and other municipal metered uses (e.g., parks, public swimming pools). They are often overlooked for meter evaluations because they are not a high priority and do not produce income.

Meter Inaccuracy Entry: The percentage error of the meter population entry for the Consortium agencies appears to be understated. This will be discussed in Section 6 of this technical memorandum. The meter inaccuracy percentage error has bearing on metered uses and calculated real water losses (leakage). It is typical for water utilities to underestimate the meter error they have (even those that have regular meter testing programs) because mechanical meters have unmeasured volumes. Mechanical meters are designed to be accurate at the AWWA Manual M6 low test flow rate. Significant water use occurs below this flow rate. Meters are inaccurate below the low test flow rate. Unmeasured flow is not counted as percent inaccuracy.

Apparent Loss Cost Calculations: The apparent loss calculation total is a combination of two default values that have no real bearing on meter uses plus the more significant meter inaccuracy entry. The meter inaccuracy percentage error has bearing on metered uses. The two default values do not result in the calculation of a large volume of the total water lost in the water system. However, meter error is a more significant volume with a larger value and impact on California regulatory targets for resource management.

Number of Connections: This entry is important to compare with the deployed number of meters for each system. It is not unusual to have more connections than meters because of unmetered fire lines. For the Consortium, two systems had more meters than connections. The CHWD total meter count was higher than the total connection count. The PCWA meter count from Phase 1 is over four times higher than the audit connection count.

CRUC of Water: This unit cost was applied to the cost of water ($ valuation) for the calculations of potential return on investment on meter testing.

2.3 Key Findings from Interviews on Meter Testing

The Consortium would benefit significantly by each agency adopting a formal water meter testing program with defined parameters that stipulate meter testing frequency of a random sample by size and type of meter. The goal would be to make the meter test program at least break even for cost justification. The next section of this technical memorandum outlines the number of meters that should be tested, along with the frequency of the testing. In addition, estimates of cost would be determined for each agency to implement a standard meter accuracy test program. A calculation would be made to determine the “break even” costs for each agency to test meters based on a set of parameters and costs for testing. The goal would be to make the program self-sustaining year after year. The meter testing results compiled over time could also be used to project potential meter change-out programs by developing relationships between accuracy and age and accuracy and throughput for each meter size. Because four of the seven participating agencies have meter test benches, cost sharing for use of those benches and the benefits of scale are explored as well.

2.3.1 Meter Testing Program

While each agency currently has or had a meter testing program, not all meter testing programs appear to be yielding desired results or providing actionable information for meter testing, replacement, and auditing. As part of the Study, a set of SOPs are outlined for Consortium consideration that can justify a useful, profitable, and practical meter testing activity. During the agency interviews, some agencies perceived themselves to have more meters than the count showed. The consulting team was not able to determine why this discrepancy in reporting exists.

2.3.2 Types of Testing Performed

Four of the seven systems have meter test benches that have additional testing capacity. The City of Sac has a Mars 24-stand, automatic, computerized bench for small meters and a second test bench that can handle 3-inch to 16-inch meters. All benches use gravimetric tanks and scales for calibrated volumes during testing procedures. The Mars test bench has an outdated meter testing software system that is costly to upgrade. The computer that controls the testing operations and results recording will need its operating system upgraded. Currently, the data system in the meter testing software does not allow for queries to be run on batches of meters by size, type, test result, or other parameters. The test data cannot be exported to an external database, such as Microsoft Excel, for further meter studies and evaluations. Cost estimates for upgrades are over $270.000 and require a $110,000 annual subscription service to a cloud-based data storage system managed by Mars.

Additionally, when the test bench is fully loaded with one-inch meters, the high flow tests are difficult to run due to the overall head loss through the bench. The large meter test bench has a 10-inch spool mag-style meter to measure flow but also uses gravimetric tanks for total flow measurements and has the ability to perform endurance test by bypassing scales. The same issues apply to the computerized system for the intermediate and large meter bench regarding meter data from testing. The City of Sac has the test bench tanks and scales certified annually to ensure the tanks are accurate and the scales weigh water correctly. Dated inspection stickers are attached to the scales.

To overcome the software issue with the testing data, the City of Sac is looking into a modified meter testing data collection for the meters tested on the benches. Meter technicians can use data entry for test results on field computer tablets and can upload the data to a database managed by the utility or a third party. The database input can be accomplished using specific apps installed on a tablet. The procedure will require more manual data input by meter technicians, but the overall cost to implement will be less than a complete computer upgrade for the meter test bench. Meters for testing on the test bench will need to be installed following an established SOP for meter bench operations. If an SOP does not exist, the utility will need to create one using in-house staff and documenting the step-by-step procedure into a standard form. If an SOP does exist, it should be reviewed and updated to include procedures that the utility currently performs that are not documented and new manual recordings of meter testing results available for download. The data from the meter testing can be integrated with the utility's management software (e.g., City Works, Arc GIS) where the data can be used for meter testing planning and predictive analysis for meter change-outs.

Other agencies that have meter test benches (i.e., SJWD and Folsom with Mars automatic benches, and PCWA with an older Ford manual bench) can continue to conduct meter testing based on the bench capacity and the meter testing frequency selected by each utility. The three agencies without benches (i.e., CHWD, SCWA, and SSWD) can evaluate the costs of testing by outsourcing but will need to consider shipping costs as part of the program or make arrangements with the other four agencies to have meters tested locally in the region. This is discussed further in Section 6 of this technical memorandum.

2.3.3 Large Meter Testing

Regarding use of the large meter test bench, the City of Sac is advised to look at comparing costs of on-site large meter testing at the meter setting location versus use of the large meter test bench. For testing on the large meter test bench, the large meters need to be removed from the settings and transported to the meter testing facility, set into the bench for testing, tested, and then possibly transported back to a meter setting and re-installed. That procedure takes time (and labor costs) and may cause potential leakage issues and mechanical failures. It also requires having blank spool pieces inserted in the meter setting or having a spare meter to install in place of the meter that was removed for testing.

It is recommended that the City of Sac, along with the other agencies that do not have calibrated portable meter testers (SCWA, CHWD) for in-place large meter testing, purchase portable testers with appropriate hoses and fittings. Service vehicles will also be needed (e.g., van, pickup truck, or pulled trailer) to transport the portable meter to large meter settings for testing, along with a two-person testing team. Meter testing training will also be needed to ensure testing procedures are followed and the integrity of the meter tests are of the highest standards. Other agencies have portable testers and can share their experiences and knowledge regarding on-site meter testing with other members of the Consortium.

Consideration should also be given to third-party testers to test the meters on site, but the agencies need to define the SOPs and decide on program setup to ensure the quality of testing they desire. Testing methodologies can vary from tester to tester. In this technical memorandum, suggestions for testing methodologies that inform meter testing procedures and how to evaluate and use test results are provided.

Based on the number of large meters each agency deploys per the Phase 1 work effort, costs for meter testing implementation have been calculated for each agency and are described in the next section of this technical memorandum. It was assumed that each agency will conduct its own in-house testing based on the hourly costs currently used for agencies' staff and that the testing methods used will encompass field testing on site for meters sized 1.5 inches and greater. This assumption was validated through a comparison with test bench testing costs and related issues. Since the City of Sac is the only agency with a large meter test bench, if all large meters in the region were pulled and tested at their facility, a bottleneck may be created from the number of meters that could be tested daily.

The number of days required to test given meter groups from agencies without benches is provided (see Appendix B, Cost Inventory Table). The City of Sac initially intends to employ a two-person testing team with the goal of growing to several two-person teams over time. The other agencies could likely get by with one two-person testing team each. Those that use third-party testers can compare the estimated costs of using in-house staff with the current contracted prices. Productivity will vary with meter size and meter setting and will be relative to the number of meters tested per day (some days will have more meters tested than others). This will be further explored in Section 5, Standard Operating Procedures for Large Meter Testing, of this technical memorandum.

Regarding a suggested frequency for large meter field testing, it is economically prudent to test meters three inches and larger once per year. Lower consumption meters can be shifted to a two-year cycle but should be considered for resizing if warranted due to inaccuracy at low flow rates.

2.3.4 Intermediate Meter Testing

If each agency moves forward with the use of in-house staff and a portable test meter to be used on site for large meter testing, intermediate-sized meters are recommended to be included as part of a regular on-site meter testing program, subject to availability of an in situ meter test port. The schedule and costs for intermediate meter testing are also given in Appendix B.

Intermediate displacement and turbine meters will likely need to be temporarily removed from service to facilitate testing on site. Compound meters generally have test ports built into the meter body to accommodate on-site testing. Newer displacement meters have test ports as well, and displacement meters can be ordered with test ports built in. The procedure for this testing will be discussed in Section 5 and is based on the consulting team's experiences in testing meters nationwide under several conditions (weather, customers, equipment, and staff utilization). Even if a displacement meter is temporarily removed and a fitting is installed to allow on-site testing, it is expected that a well-experienced meter testing team should be able to test up to seven meters per day, depending on the meter setting, weather, and customer. One agency stated that they test their intermediate meters about every 10 years, but revenue generation should likely be a better way to decide the correct testing interval.

The frequency of intermediate meter testing is also discussed in Section 3, Cost of Testing Meters. The costing spreadsheet (Appendix B) that was developed is based on testing intermediate-sized meters on a four- or five-year cycle.

2.3.5 Small Meter Testing

Small meters are best tested on a meter test bench versus in the field because the meter cannot be isolated for testing to enable measurement of the flow in the field. When valves leak on plumbing fixtures or irrigation systems, even at a small rate, the low flow test is compromised with unmeasured flow. Mechanical meters do not accurately measure flow below the AWWA low test rate specified for a meter size. Additionally, small meters do not have test ports that will allow for testing in the field. The amount of time spent testing in the field versus the time removing the meter and installing a new meter is also a consideration.

Using a meter test bench for small meter testing is efficient in that several meters can be tested at the same time in a series. Flow rate control for each of the selected test flows can be better managed on a meter test bench. The agencies will need a replacement strategy and the appropriate replacement meters where several small meters are replaced in the field and brought to the meter bench for testing. Random sampling should be used for characterizing the existing deployed meter population by size. There is a debate on what constitutes a statistically significant representative sample. Meter accuracy testing results do not follow a normal distribution, but random sampling methods often assume this. A defined number of deployed meters should be selected from the small meter population and flow tested to gather weighted accuracy results that represent the meter population. Sample selection and testing will be discussed further in Section 5 for small meters.

One agency (CHWD) tested small meters on site for a period of time using a handheld, calibrated, digital tester. The meter still needed to be removed from the setting and a pipe fitting installed to allow water to be drawn from the setting for the tests. A short hose was installed connecting the test meter to the subject meter, and the test was conducted.

Agencies that had meter testing SOPs but only for large meter testing should implement procedures for intermediate and small meters. The agencies that do not have meter testing SOPs should consider those already adopted for guidance.

Meter testing training should be considered by the seven agencies even if some agencies use third-party testers. Meter staff should know how to accurately test a meter and what is required to maximize the quality of a meter test. Meter testing training should provide more than how to test a meter, such as proper sizing rules, and to some degree, piping layout for proper flow measurement by the meter.

Each agency was asked to offer a specific “needs” list, and the lists included similar items, such as a formalized testing program, meter testing training for staff, and how to use other agencies’ test benches if possible and economical. Additional needs included how to make use of meter data from the tests so that the agency has a growing database for data analytics.

2.4 Key Findings from Reviews of Agency Water Audits

The purpose of reviewing recent annual water audits from each agency was to assess apparent losses and provide insight into metering practices, perceptions, and reporting of the agencies. While the investigation of these audits was not the focus of the scope of this project, gaining relevant insight into meter testing was. These audits were submitted to the State of California, as required, and should reflect the existing water loss conditions of each agency.

Two agencies still have accounts where water use is estimated instead of being metered. These agencies stated they are working towards metering all connections. The water audits were also consulted to derive the CRUC of water, which was used to calculate the breakeven points on the meter testing return on investment analysis spreadsheets. The average meter inaccuracy reported for each agency in the apparent loss component in each audit appears to be understated. The entries range from one percent to 3.75 percent. The 3.75 percent may be close to the actual loss, but one percent is unlikely based upon average meter age and the predominance of mechanical meters. Understating customer metering inaccuracy causes the real loss calculation to be higher than the actual loss. Therefore, the calculated audit performance indicators will also be incorrect.

It is typical for water utilities, even those that have regular meter testing programs, to underestimate the customer meter error. Utilities do not usually take the time to calculate overall meter error, and most do not know how to perform the calculation. The meter percentage inaccuracies indicated in the audits for the Consortium appear to have been an estimate based on limited accuracy testing data. In addition, most utilities do not realize that the small meter accuracy limits for new positive displacement (PD) meters at the low flow test rate are 95–101 percent. This means it is possible for new small meters to be up to five percent inaccurate and still meet AWWA meter accuracy limits. By underreporting the customer meter error, the agencies that use the audit to implement Water Loss Control Plans may be overestimating real losses and committing resources to Water Loss Control Plans that will yield incorrect results and cost too much to diagnose or mitigate.

If the CRUC is applied to the stated meter inaccuracy volumes in each agency’s audit, then the calculated dollar loss could possibly indicate the lowest value of potential cost recovery of apparent loss due to meter inaccuracies. Increased meter inaccuracy would help justify the cost of a meter testing and replacement program. However, many other factors need to be examined, such as those described in this technical memorandum.

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Section 3 Cost of Testing Meters

3.1 Introduction

Meter maintenance programs have an economic advantage that has been recorded in many water periodicals, but most of these programs focus on large revenue recoveries for meters after a long period of time without any meter maintenance. These programs do not help answer how often meters should be tested and what the possible annual revenue recovery can be. Because the economic analysis depends on various factors, such as rates charged for water; the effects of water chemistry; customer demand patterns; and the cost of purchasing, removing, testing, repairing, and installing meters, no specific answer has been provided, and it is difficult to establish a proper economic balance.

If meter accuracies are not maintained, the utility loses revenue. Some new meters are inaccurate. However, if the cost of a meter maintenance program, including testing, is less than the loss of revenue incurred for the sale of water, and in some cases, including wastewater service charges based on water use, the overall result is revenue loss due to inaccurate metering. The utility's customers will pay for utility costs through increased rates, but increased rates could be avoided through effective meter maintenance and replacement. Inaccurate metering also leads to inequitable cost recovery and subsidy of customers who do not pay their fair share (cost of service). Because current water meters are more advanced than those produced a few years ago, they are likely not disposable (as previously thought), last longer, are more accurate, and have more functions. Meters, electronic registers, and AMR/AMI systems are too valuable to dispose or ignore maintenance of. Meter accuracy data is critical for developing a cost-based MRP.

To calculate the cost of meter accuracy testing for the Consortium, the consulting team established some necessary parameters. The consulting team obtained a count of meters by size and overall hourly salary costs for the staff from each agency. This hourly figure was applied to the amount of time needed to test meters.

From the labor cost data obtained and with the CRUC cost data taken from the annual water audits, the project team calculated the costs of an annual meter testing program and the breakeven points to make the program self-sustaining so that the agency can justify the cost of the test program. Meter testing intervals for different meter sizes were developed based on past experiences of meter testing data compiled from the Midwest U.S. over several years. The test intervals can be adjusted to fit the Consortium agencies, but they represent a starting point needed for the analysis. Equipment assumptions were made based on information supplied by each agency via the survey answers received and data compiled.

3.2 Meter Testing Cost Assumptions

To determine potential meter accuracy testing costs for each agency, the following assumptions were made:

- It was assumed that all large and intermediate meters will be tested in the field using a portable calibrated meter assembly consisting of a three-inch turbine meter to accurately measure higher flows above 15 gallons per minute (gpm) and up to 350–400 gpm, depending on the test port size at the meter setting and the pressure of the water supply at the meter setting. A small 5/8-inch calibrated meter is assumed to act as the bypass meter for low flow testing of large meters with a flow range of 0.25–20 gpm. Appropriate test hoses and fittings will also be required and carried in a suitable service vehicle (e.g., van, pickup truck, small van, trailer). The specific protocol for meter testing using this portable calibrated meter set up is discussed further in Section 5 of this technical memorandum.
- It was assumed that each agency will perform the testing with its own staff (some currently do this). The testing team used in the field will be a two-person team with appropriate training and experience so that the level of productivity will average three to four large meters (≥ three inches) tested at the various meter locations in the course of one business day. For intermediate meters, it was assumed that seven meters (1.5- and two-inch) can be tested each day on site.
- The assumption for small meters is that meters will be removed from the meter setting (in the field) and transported to the meter test facility. It was assumed that each agency will replace the old meter being tested with a new/used meter in the setting or will install temporary jumper pipes (spacer) if a meter cannot be replaced. It is important to note the current "low lead/no lead" rules for brass bodied meters. Costs for small meter replacement were calculated and included as a line item in Appendix B. If temporary jumper pipes are used, the replacement meter cost is not a factor. The cost for the jumper pipe would be considerably less than a meter but the labor to install it would likely be about the same. Agencies will need to account for estimated water uses during the meter testing time until a meter is placed back in the setting.
- Four agencies have meter test benches, and it was assumed that these four agencies will use their own benches for small meter testing. It was assumed that the other three agencies would use one of the existing Consortium agency benches for small meter testing (share the existing bench of one of the other agencies). Costs for testing small meters did not include a possible meter test bench sharing cost in this section but is addressed later.
- For the base costing case, large meters were assumed to be tested in the field annually. Intermediate meters were assumed to be tested every four years, or 25 percent per year. Small meters were assumed to be tested based on a statistically calculated sample size representing a 95 percent confidence that the sample would represent the overall small meter population within a five percent margin of error.

3.3 Optimal Meter Testing Intervals

- A matrix Excel spreadsheet was developed based on each agency's deployed meter inventory so that the consulting team could assess how to divide the meter population into size classes that could be tested periodically.

The meter counts based on size class were used to develop the ideal meter testing intervals based on the following criteria.

Small Meters

Small meter counts for each agency were too large to regularly test all meters in the system; therefore, a random selection method of possible testing was reviewed based on accepted statistically significant random sampling techniques, whereby a 95 percent confidence level could be attained for the selected sample. Every meter will have an equal chance of being selected regardless of age, throughput, meter model, and brand. It was felt that, if any inaccuracy issues were to show up in the sampling, such as a particular brand or age of meter failing the accuracy tests, the results of the test would be unbiased and could be used to determine specific meter problems. This "natural" sorting of meter statistics will allow for adjustments to the testing sample selection that will need to be made later on.

Intermediate Meters

Intermediate meter counts for each agency indicated that the meters can be tested as an entire group, dividing the meter count equally into batches for testing where 25 percent of the intermediate meter population could be tested annually, resulting in a four-year testing cycle. A five-year testing interval was also evaluated and costed. The initial assumption is that each meter will generate $14,000 over four years ($3,500 per year), or in the case of the five-year testing interval, $2,800 per year per meter, in customer-billed revenue on average. If more meters are identified as not meeting minimum accuracy specifications on an annual basis, then replaced or rebuilt, the result will be more 'lost revenue' captured on an annual basis. Once the cost justification numbers are calculated, if the revenue cannot justify a four- or five-year program, the meters can be shifted to a longer testing interval as long as overall meter accuracy can still be met. The four-year interval program will help sort out the initial costs of the testing for each agency.

Large Meters

The large meter counts indicated that three-inch and larger meters should be selected for annual testing per guidance from AWWA. It has been the experience of the consulting team that, generally, three-inch and larger meters generate an annual revenue of $14,000 or more each year (depending on the water rates charged). This is a general guideline based on the consulting team's experience across the country and the calculated average of annual revenues generated by meters that were properly sized for their settings. The annual revenue generation is dependent on the

CRUC (or average retail cost of water). Therefore, if a utility has a lower CRUC, then the annual volume use will need to be higher to meet the annual revenue threshold of $14,000. When a meter does not generate a specific level of annual revenue, the meter may be oversized (too big for the setting). Again, if the cost justification for annual testing shows that the meter can be shifted to a different testing interval, then that shift can be made after securing a baseline test.

3.4 Meter Testing Cost Development

Average hourly costs for each agency were taken from each agency's Cost Inventory Table (Appendix B). The City of Sac did not provide hourly staff costs; therefore, $59 per hour was used as an average rate. This value is similar to the hourly rates provided by other agencies. It was assumed that two-person teams will be used for field tests and that one person would perform the small meter removal work and test bench testing. An exception is that the City of Sac is assumed to have a two-person meter testing team for their meter test facility due to the capability for large-volume small meter testing on their test bench. Table 1 indicates basic cost assumptions for labor for each agency per one- and two-person field testing teams plus a one-time capital cost for purchasing equipment for large- and intermediate-sized meter testing. The one-time cost includes a comparison meter, hoses, and a vehicle for transport and storage. This cost was assumed equal for all agencies.

Table 1. Cost Assumptions by Agency

Agency	Hourly Cost	Daily Cost (2-Person Team)	Daily Cost (1-Person Team)	Large Meter Test Equipment
City of Sac	$59	$944	$472	$36,500
SSWD	$60	$954	$477	Own Equip.
SCWA	$55	$880	$440	$36,500
Folsom	$55	$880	$440	Own Equip.
CHWD	$55	$880	$440	$36,500
PCWA	$54	$861	$430	Own Equip
SJWD	$54	$856	$428	$36,500

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

The hourly costs were converted to daily costs for a two-person team. The meter sample total for each meter size group was divided by an assumed daily testing productivity rate (four large, seven intermediate, and 24 small meters tested per day per agency, except the City of Sac, which is assumed to test 72 small meters per day due to the capability of their test bench). A total annual cost to test each meter group by size was then calculated so that each agency has a cost assigned for each size group. The costs were totaled for an overall annual testing cost for each agency. Unit testing costs per meter test were also calculated. See Tables 2 and 3 for estimated unit and annual large and intermediate meter field testing costs by agency.

Table 2. Large Meter Field Testing Costs by Agency

Agency	Unit Cost	Large Meter Count	Annual Cost	Days to Test
City of Sac	$236.00	2,421	$571,356.00	605.3
SSWD	$238.40	447	$142,086.40	111.8
SCWA	$220.00	334	$73,480.00	83.5
Folsom	$220.00	172	$37,840.00	43
CHWD	$220.00	86	$18,920.00	21.5
PCWA	$215.20	115	$24,748.00	28.8
SJWD	$214.08	28	$5,994.24	7

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Table 3. Intermediate Meter Field Testing Costs by Agency

Agency	Unit Cost	Intermediate Meter Count	Annual Cost	Days to Test
City of Sac	$134.86	7,194	$242,540.57	256.9
SSWD	$136.23	2,437	$116,196.16	87
SCWA	$125.71	3,047	$95,762.86	108.8
Folsom	$125.71	856	$26,902.86	30.6
CHWD	$125.71	1,186	$37,274.29	42.4
PCWA	$122.97	976	$30,005.03	34.9
SJWD	$122.33	333	$10,184.09	11.9

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Testing small meters is more complex than testing for larger sizes because they must be identified and sampled due to the large population, removed and replaced, transported to the meter test facility, and then tested. All of these elements have cost.

Determining the sampling method and size is an important first step in determining cost. Some utilities want a statistically based sample size from a random selection of deployed meters of the same size. In the base cost estimate, the consulting team combined the small meter counts and used a published, statistically based table to determine the sample size for each agency. This table was published by the Research Advisors and is included as Table 4. Utilities that use this sample size method generally use the 95 percent confidence level at a margin of error of five percent. This means one can be 95 percent confident that the sample results fall within the range of the overall meter population with a range of five percent error. Given the small meter populations of the seven agencies, the required number of random samples varies from 371 to 383. Sampling frequency is assumed as annual to maintain a current accuracy estimation of the entire small meter population.

For agencies that perceive this sample size is excessive relative to the value it provides, a collection of at least 100 data points for each small size is recommended to begin building a utility-specific meter test database to determine the relationship between accuracy and age and accuracy and throughput for each testing flow rate (currently low, intermediate, and high). Additionally, recent databases indicate that the distribution of accuracy results versus the number of measurements does not follow a “normal” distribution. This is particularly obvious at low flow. Therefore, the statistical methods and equations on which Table 4 is based may not apply to meter accuracy testing of small meters. One alternate option may be for agencies to apply age-based criteria to their random sampling, whereby they only test meters that exceed a certain age, such as 15 years.

Development of representative best linear fit of the data can be used for assessment of meter accuracy by size for the entire deployed meter population. Using individual meter age and volumetric throughput, developed linear equations can be applied to each deployed meter to estimate existing accuracy. Meter inaccuracy volumes for each meter can be used to calculate the value of the lost water using existing, utility-specific water rates and sewer rates, if applicable. Cost of meter replacement can be compared with annual sums of the value of lost water to determine the economic optimum time for meter replacement or the number of years it will take to repay the meter replacement cost for each meter. Pending further establishment of these relationships for each meter size for each agency, the statistical sampling method is recommended for random testing. Cost estimations for sampling and testing are presented for each agency in Tables 5, 6, and 7.

Individual cost entries were established for the small meter costs for each agency so that replacement costs for meter change-out were included. The level of meter replacement productivity (labor to remove and replace) was assumed for a daily average per testing team. Also, a figure was derived for costs of new meters as replacements based on a 48-meter rotation for each agency, except the City of Sac because their meter rotation was figured using 100 meters. The rotation will assume 48 new meters will replace 48 older meters, the older meters will be tested, and if they pass the accuracy tests, they will be used in a different meter setting to replace the second set of meters to be tested, and so on until the entire meter sample size is tested. The costs of meter rotation are shown in Table 8. The assumed meter swap out can only occur if the low lead/no lead rules for brass meter bodies can be followed.

Table 4. Statistical Sample Size Requirements for Normal Distributions

Required Sample Size†
from: The Research Advisors

Population Size	Confidence = 95.0% Degree of Accuracy/Margin of Error 0.05	0.04	0.025	0.01	Confidence = 99.0% Degree of Accuracy/Margin of Error 0.05	0.04	0.025	0.01
10	10	10	10	10	10	10	10	10
20	19	19	20	20	19	20	20	20
30	28	29	29	30	29	29	30	30
50	44	46	48	50	47	48	49	50
75	63	67	72	74	67	70	73	75
100	80	86	94	99	87	91	96	99
150	108	120	137	148	122	131	142	149
200	132	150	177	196	154	168	186	198
250	152	177	215	244	182	202	229	246
300	169	200	251	291	207	233	270	295
400	196	240	318	384	250	289	348	391
500	217	273	377	475	285	338	421	485
600	234	300	432	565	315	380	490	579
700	248	323	481	653	341	418	554	672
800	260	343	526	739	363	452	615	763
900	269	360	568	823	382	482	672	854
1,000	278	375	606	906	399	509	727	943
1,200	291	400	674	1067	427	556	827	1119
1,500	306	429	759	1297	460	613	959	1376
2,000	322	462	869	1655	498	683	1141	1785
2,500	333	484	952	1984	524	733	1288	2173
3,500	346	512	1068	2565	558	800	1510	2890
5,000	357	536	1176	3288	586	859	1734	3842
7,500	365	556	1275	4211	610	911	1960	5165
10,000	370	566	1332	4899	622	939	2098	6239
25,000	378	586	1448	6939	646	995	2399	9972
50,000	381	593	1491	8056	655	1016	2520	12455
75,000	382	595	1506	8514	658	1023	2563	13583
100,000	383	597	1513	8762	659	1026	2585	14227
250,000	384	599	1527	9248	662	1032	2626	15555
500,000	384	600	1532	9423	663	1035	2640	16055
1,000,000	384	600	1534	9512	663	1036	2647	16317
2,500,000	384	600	1536	9567	663	1036	2651	16478
10,000,000	384	600	1536	9594	663	1037	2653	16560
100,000,000	384	600	1537	9603	663	1037	2654	16584
264,000,000	384	600	1537	9603	663	1037	2654	16586

Table 5. Annual Small Meter Field Removal and Replacement Count by Agency

Agency	Small Meter Count	Sample Size	Sample % of Total Small Meters
City of Sac	121,892	383	0.31
SSWD	39,788	381	0.96
SCWA	50,073	383	0.76
Folsom	20,454	378	1.85
CHWD	18,683	377	2.02
PCWA	36,102	381	1.06
SJWD	10,093	371	3.68

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Table 6. Annual Small Meter Field Removal and Replacement Costs by Agency

Agency	Testing Team Days	Unit Cost	Annual Cost
City of Sac	19.15	$47.20	$18,077.60
SSWD	19.05	$47.68	$18,166.08
SCWA	19.15	$44.00	$16,852.00
Folsom	18.90	$44.00	$16,632.00
CHWD	18.85	$44.00	$16,588.00
PCWA	19.05	$43.04	$16,398.24
SJWD	18.55	$42.82	$15,884.74

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Table 7. Annual Small Meter Bench Testing Costs by Agency

Agency	Tests Per Day	Unit Cost	Annual Cost	Days to Test
City of Sac	72	$13.11	$5,021.56	5.3
SSWD	24	$19.57	$5,046.13	15.9
SCWA	24	$18.33	$7,021.67	16.0
Folsom	24	$18.33	$6,930.00	15.8
CHWD	24	$18.33	$6,911.67	15.7
PCWA	24	$17.93	$6,832.60	15.9
SJWD	24	$17.84	$6,618.64	15.5

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Table 8. Recommended Annual Spare Small Meter Costs by Agency

Agency	No. of Meters	Manufacturer	Unit Cost	Total Cost
City of Sac	100	Badger	$183.40	$18,340.00
SSWD	48	Badger	$183.40	$8,803.20
SCWA	48	Sensus	$307.50	$14,760.00
Folsom	48	Sensus	$307.50	$14,760.00
CHWD	48	Neptune	$343.75	$16,500.00
PCWA	48	Badger	$183.40	$8,803.20
SJWD	48	Sensus	$407.55	$19,562.40

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

3.5 Agency Example of Meter Testing Cost

In this section, to show how the meter testing cost estimation was accomplished, the City of Sac is used as an example of the step-by-step process of the cost assignments that were made for each meter test group.

The average labor rate of $59 per hour was used. The utility is assumed to deploy a two-person testing team to test large meters at an average of four meter tests per day on site. The two-person daily cost (based on eight hours) is $944. All 2,421 meters sized three inches and larger are assumed to be tested in the field over the course of a year. It will take 605.3 testing team days to complete the testing. With 250 working days in a year, the City of Sac will need to allocate three two-person testing teams. Two testing teams will test 1,000 meters each, and the third testing team will test 421 meters. The total cost to test all three-inch and larger meters will be $571,356 (see Table 2). This assumes that the City of Sac has the needed service trucks, portable test meters, fittings, and hoses to conduct the testing.

The intermediate meter count for the City of Sac (1.5- and two-inch meters) is 7,194. The assumption is to test 25 percent per year over four years, or 1,798 meters a year. The City of Sac will deploy a two-person testing team to test meters in the field, and the testing team is estimated to test seven meters per day on average. It will take one two-person testing team to test the 1,798 meters and 256.9 days to complete the testing. Intermediate meters will likely need to be removed from the setting, a jumper spool pipe installed where the meter existed, and a tee with a valve installed. A hose will be connected to the water source, the meter will be fitted with hose fitting to the test meter, and the meter will be tested on site. Sometimes, it is easier to take the meter to a nearby fire hydrant and use the hydrant as a water source. The meter will then be re-installed (unless it failed). Some intermediate meters (two-inch compound meters and some 1.5- and two-inch displacement meters) have built-in test ports; therefore, removal of the meter will not be needed. The cost to test 25 percent of the intermediate meters annually would be $242,540.57 for the City of Sac (see Table 3).

Small meters must be removed from the random settings and taken to the meter test facility to be tested on a calibrated meter test bench. For the City of Sac, the 121,892 small meter population will have 383 meters randomly selected for testing using a random number selection method. The random selection of the 383 meters will provide a 95 percent confidence level that the sample statistically represents the entire small meter population. A two-person meter replacement team is assumed to be deployed to meter locations to remove 20 meters per day for testing and to replace those meters with new meters taken from stock. It will take 19.15 days to collect all 383 meters from the field. The cost for the two-person testing team for that effort will be $18,077.60 (see Table 6). The small meter test bench capacity for the City of Sac is 72 meters; therefore, meters will be collected for testing and properly stored (the insides kept wet) until at least 72 meters are collected for testing. It is assumed that 72 meters can be tested by a two-person testing team at the meter test facility over the course of one day. It will take 5.3 days to test all 383 meters pulled for testing. The cost for bench accuracy testing the meters at the meter test facility is estimated to be $5,021.56 for all 383 meters (see Table 7). The cost does not include the replacement cost of the new meter in the field. The preferred small meter brand for the City of Sac is Badger. The meter cost is $183.40 each (from Technical Memorandum 1). If it is assumed that 100 new meters are used in rotation for meter change-outs, the new meter costs will be $18,340 (see Table 8).

The total cost to test all meters selected for testing (large, intermediate, and small) for the year will be $836,995.73. Each agency's testing costs have been developed in the costing table in the same manner as the City of Sac example described above. Table 9 summarizes the total estimated annual testing costs for the three meter sizes.

Table 9. Total Estimated Annual Meter Testing Costs by Agency

Agency	Large Meter Cost	Intermediate Meter Cost	Small Meter Cost	Total Cost
City of Sac	$571,356.00	$242,540.57	$23,099.16	$836,995.73
SSWD	$142,086.40	$116,196.16	$5,046.13	$293,605.49
SCWA	$73,480.00	$95,762.86	$23,873.67	$193,116.52
Folsom	$37,840.00	$26,902.86	$23,562.00	$88,304.86
CHWD	$18,920.00	$37,274.29	$23,499.67	$79,693.95
PCWA	$24,748.00	$30,005.03	$23,230.84	$77,983.87
SJWD	$5,994.24	$10,184.09	$22,503.38	$38,681.71

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Modified Sample Testing Selection

The consulting team made a similar table of costs (one-year modified random) based on a different set of assumptions. These modified cost estimates assumed a five-year plan for all intermediate meters and a different sampling population for small meters. The small meter sample selection was limited to meters that were older than 10 years (typically five years past the new meter accuracy warranty period), but still uses a random selection of meters. The small meter selection was based on sampling about 0.5 of one percent for each agency's small meter population. The City of Sac was still subject to a full random sample count of 383 meters because of the large number of small meters to select from. SJWD's sample was about 70 meters because of its small number of deployed meters to select from. In the case of the City of Sac, the modification from a four-year intermediate test plan to a five-year plan changed the costs from $836,995.73 to $788,487.61 for a difference of $48,508.12. The other agencies' cost estimates also went down, but their costs included a slight cost reduction for the small meter test costs because the number of small meters being tested was less than a full statistically based random sample test schedule. The summary of total modified testing costs for all agencies is included in Table 10.

Table 10. Estimated Annual Meter Testing Costs by Agency Based on Reduced Sampling

Agency	Large Meter Cost	Intermediate Meter Cost	Small Meter Cost	Total Cost
City of Sac	$571,356.00	$194,032.46	$23,099.16	$788,487.61
SSWD	$142,086,40	$92,656.93	$16,356.89	$251,400.22
SCWA	$73,480.00	$76,610.29	$15,583.33	$165,673.62
Folsom	$37,840.00	$21,522.29	$6,358.00	$65,720.29
CHWD	$18,920.00	$29,819.43	$6,233.33	$54,972.76
PCWA	$24,748.00	$24,004.02	$11,584.93	$60,336.96
SJWD	$5,994.24	$8,147.27	$4,245.92	$18,387.43

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

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Section 4 Economics of Meter Testing

4.1 Introduction

In the previous section, the annual costs of testing meters by meter size group for each Consortium agency were established. In this section, the consulting team compares the annual costs of testing meters for each agency with the potential revenue recovery from meter repair and replacement. The breakeven point is calculated to recover different testing costs. This value is where a meter group will need to fail accuracy testing (by a certain percentage of accuracy) to make the meter testing program break even and start returning revenue back to each utility. The calculations are based on water recovery costs only (no sewer-related inaccuracy value is included) and do not consider costs of spare meter parts or new meter installations to replace old meters.

Meter testing costs typically do not need to be cost justified. Sometimes meter testing is required by regulation, such as those required by a public utilities corporation for private water utilities, to ensure equity among customers and to justify requested rate increases. The greater value of meter testing rests with characterization of temporal and spatial meter accuracy response to constantly changing water pressure, water flow, and water quality conditions currently experienced in distribution systems. An evolving meter testing database contains information necessary for cost-effective meter maintenance and meter replacement planning. Relationships between meter accuracy and age and meter accuracy and volumetric throughput by meter size and type are critical for making decisions applicable to the entire meter population regarding auditing results and often expensive interventions to reduce system losses. The following discussion is for illustration only to assist in justifying a large and intermediate meter testing program. Economic justification is different for small meters because accuracy for the entire deployed small meter population is inferred from sample testing and extrapolation of sample accuracy relationships.

4.2 Economic Analysis Assumptions

Each agency's annual meter testing cost for the large, intermediate, and small meter sizes presented in the previous section is used as the cost basis. These costs are shown in Table 9. For cost recovery from meter repair and replacement, each agency's CRUC derived from each validated water audit submitted annually by regulation of the State of California is used to calculate recovered revenue. Each group of meters (large, intermediate, and small) has its own cost recovery calculations for each agency. The City of Sac is used as the example for the analysis presented below, but other agency results are included in the summary tables. A large Microsoft Excel workbook was developed for the calculations because the methodology is the same for the large and intermediate size meter groups for all agencies. Table 11 includes the primary economic assumptions for all agencies. Included in Table 11 for each agency are the average retail unit revenue per hundred cubic feet (CCF) of water sold, annual water meter counts by size group for accuracy testing, and the assumption that 15 percent of all meters tested for all sizes is an average failure rate for large- and intermediate-sized meters based on extensive testing in the field and on test benches for thousands of water meters over decades of testing in the U.S. Note that small meters have highly variable failure rates because sample constituency and methodology (random versus targeted) are variable.

Table 11. Cost Recovery Economic Assumptions by Agency

Agency	Average Retail Unit Revenue	Large Meter Test Count	Intermediate Meter Test Count	Small Meter Test Count	Percent Failure Through Testing
City of Sac	$1.33	2,421	1,799	383	15; large and intermediate
SSWD	$1.07	447	609	381	15; large and intermediate
SCWA	$1.74/$4.04	334	762	383	15; large and intermediate
Folsom	$1.87	172	214	378	15; large and intermediate
CHWD	$1.02	86	297	377	15; large and intermediate
PCWA	$1.67	115	244	381	15; large and intermediate
SJWD	$0.92	28	83	371	15; large and intermediate

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Application of the proposed cost recovery analysis is demonstrated for the three meter size groups using the City of Sac as an example in the following text.

4.3 Large Meter Testing Cost Recovery

The City of Sac has an average CRUC of $1.33 per CCF of water sold (from Audit data 2019). The annual calculated costs to test all 2,421 large meters is estimated at $571,356 based on the past rate cited in the water audit data from the audit data. By dividing this annual cost by the CRUC, the amount of water that will need to be recovered from repaired and replaced meters will be 429,591 CCF for one year to fund testing cost only. The average cost to test a large meter is $236 per meter based on the City of Sac labor rates applied to a two-person testing team. Table 12 summarizes large meter testing costs for all agencies.

Table 12. Large Meter Field Testing Costs by Agency

Agency	Average Retail Unit Revenue	Large Meter Test Count	Tested Count	Annual Cost	Unit Cost/Test
City of Sac	$1.33	2,421	2,421	$571,356.00	$236.00
SSWD	$1.07	447	447	$142,086.40	$317.87
SCWA	$1.74/$4.04	334	334	$73,480.00	$220.00
Folsom	$1.87	172	172	$37,840.00	$220.00
CHWD	$1.02	86	86	$18,920.00	$220.00
PCWA	$1.67	115	115	$24,748.00	$215.20
SJWD	$0.92	28	28	$5,994.24	$214.08

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

If it is assumed that the meter failure rate for the large meter testing program is 15 percent, then 363.15 meters will fail to meet accuracy limits. This calculates to an annualized field testing cost of $1,573.33 per failed meter. Dividing by the CRUC results in 1,182.96 CCF per failed meter that needs to be recovered to fund field testing costs through repair or replacement of the failed meters.

If it is assumed that each three-inch and larger meter generates an average annual revenue of $14,000 at current water rates, by dividing the annual loss cost recovery required per meter ($1,573.33) by the average annual revenue, a weighted average maximum testing percentage for the failed meters tested is yielded. For the City of Sac, the calculated loss is 11.25 percent. The average group of failed meters will need an average maximum accuracy of 88.75 percent. Accuracy above this maximum will not provide the opportunity for repair and replacement to recover the lost revenue required to offset meter testing costs. The calculations for lost revenue and water volumes are shown in Table 13 for each agency, with the maximum average accuracy required from the failed meter test group. In the consulting team's experience, the average accuracy of failed large meter groups can be much less than the values shown in Table 13, providing opportunity to increase revenue to recover additional costs for meter repair and replacement.

Table 13. Large Meter Failure Assumptions

Agency	Large Meter Count	Failed Large Meters	Cost/ Large Meter	Minimum CCF Recorded/Large Meter	Maximum Accuracy
City of Sac	2,421	363.15	$1,573.33	1,182.95	88.8
SSWD	447	67.05	$2,119.11	1,980.48	84,86
SCWA	334	50.1	$1,466.66	842.91/363.03	89.5
Folsom	172	25.8	$1,466.66	783.96	89.5
CHWD	86	12.9	$1,466.66	1,437.90	89.5
PCWA	115	17.25	$1,434.66	859.08	89.8
SJWD	28	4.2	$1,427.20	1,551.30	89.8

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

4.4 Intermediate Meter Testing Cost Recovery

The previously described assumptions and process for the large meter group can be similarly applied to the intermediate size group for all agencies. Table 14 provides a summary of estimated annual intermediate field meter testing costs for all agencies. Table 14 is based on field testing 25 percent of the intermediate-sized meters annually.

Table 14. Intermediate Meter Field Testing Costs by Agency

Agency	Average Retail Unit Revenue	Intermediate Count	Tested Count	Annual Cost	Unit Cost/Test
City of Sac	$1.33	7,194	1,799	$242,540.57	$134.86
SSWD	$1.07	2,437	487	$116,196,16	$238.40
SCWA	$1.74/$4.04	3,,047	762	$95,762.86	$125.71
Folsom	$1.87	856	214	$26,902.86	$125.71
CHWD	$1.02	1,186	297	$37,274.29	$125.71
PCWA	$1.67	976	244	$30,005.03	$122.97
SJWD	$0.92	333	83	$10,184.09	$122.33

Notes: CCF = hundred cubic feet; CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

The City of Sac has an average CRUC of $1.33 per CCF of water sold. The annual calculated costs to test 1,799 intermediate meters is estimated at $242,540.57. By dividing this annual cost by the CRUC, the amount of water that will need to be recovered from repaired and replaced intermediate meters will be 182,361 CCF for one year to fund testing cost only. The average cost to field test an intermediate meter is $134.86 per meter based on the City of Sac labor rates. Due to the large size and capacity differences between the average large and intermediate meter, the consulting team cannot use the same average water use and revenue assumptions for the intermediate meter group as those for the large meter group. For the intermediate meter group, it was assumed that annual revenue is $3,500 per meter (0.25 of the assumed average annual use and revenue for a large meter). Although less testing information is available for the intermediate meter group, it is still assumed that 15 percent of tested intermediate meters failed. The resulting calculations are shown in Table 15.

Table 15. Intermediate Meter Failure Assumptions

Agency	Intermediate Meter Count	Failed Intermediate Meters	Cost/ Intermediate Meter	Minimum CCF Recorded/ Intermediate Meter	Maximum Accuracy
City of Sac	7,194	270	$898.30	675.41	74.3
SSWD (5 yr.)	2,437	73	$1,589.33	1,485.36	74
SCWA	3,047	114	$840.03	482.78/207.93	76
Folsom	856	32	$840.71	449.58	76
CHWD	1,186	45	$828.32	812.08	76.3
PCWA	976	37	$810.95	485.60	76.8
SJWD	333	13	$783.39	851.51	77.6

Notes: CCF = hundred cubic feet; CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

There is less opportunity to recover lost revenue from the intermediate meter group due to the small amount of assumed failed meters per year and the large testing cost per failed meter compared with the annual revenue assumption. The calculated average maximum accuracy allowed per failed meter is 77.7 percent or lower to recover annual testing costs from repair and replacement to 100 percent accuracy for all agencies. The experiential average AWWA accuracy failed meter in the intermediate meter group is much higher than the calculated average weighted accuracy shown for the assumptions above. Under the existing average water rates and assumed test failure rate, testing of the intermediate meters every four years is not cost justified. Cost recovery for testing requires a longer testing cycle or a higher failure rate than 15 percent.

4.5 Small Meter Testing Cost Recovery

Small meter testing justification through economics is more difficult than for intermediate meter testing if statistical sampling is employed with the low unit commodity rates enjoyed by the agencies. It is uneconomic to test all small meters in the deployed meter population due to the cost of removal, testing, and replacement. The random sampling and testing techniques suggested characterize the deployed population at a reasonable cost. Small meter testing is best used to help track meter accuracy degradation over time and for decision-making on an economical MRP and a realistic estimate of inaccuracy for the AWWA water audit.

A summary of small meter bench testing costs for all agencies is shown in Table 16. Depending on the average age and cumulative throughput of the deployed small meter population, the failure rate of the tested sample can be quite high. We have seen more than 50 percent failure, particularly at low flow, which is the test rate mechanical meters degrade in accuracy due to wear over time. Additionally, mechanical meters do not accurately measure flow below the AWWA low flow rate for the particular meter size, resulting in lost revenue, even with new meters. The total annual and bench testing unit costs for small meters are minimal compared with the field removal and replacement costs. The information gathered from the testing database is easily worth the entire cost of the small meter sampling and testing program due to the potential full small meter water and revenue recovery from the large count of these meters and large percentage of total system customer demand.

One factor for consideration by Consortium agencies in developing small MRPs is the exceptionally low unit rates for water sold. Some utilities in arid, water-short areas requiring water treatment have rates exceeding 10 times those charged by the Consortium agencies, particularly with seasonal surcharges and increasing block rates. Low-cost water and associated water rates make it tough to justify the cost of capital expenditures based on meter inaccuracy of even 10 percent or more. However, reporting more realistic information on apparent losses in the AWWA Manual M36 water audit may reduce the time and effort in chasing potentially overstated real losses.

Table 16. Small Meter Bench Testing Costs Per Agency

Agency	Average Retail Unit Revenue	Small Meter Count	Tested Count	Annual Cost	Unit Cost/Test
City of Sac	$1.33	121,892	383	$5,021.56	$13.11
SSWD	$1.07	39,788	381	$5,046.13	$13,24
SCWA	$1.74/$4.04	50,073	383	$7,021.67	$18.33
Folsom	$1.87	20,454	378	$6,930.00	$18.33
CHWD	$1.02	18,683	377	$6,911.67	$18.33
PCWA	$1.67	36,102	381	$6,832.60	$17.93
SJWD	$0.92	10,093	371	$6,618.64	$17.84

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

4.6 Meter Accuracy Considerations

The above meter accuracy levels that were calculated for failed meters do not take into consideration accepted accuracy limits that a “passing meter” might fall into. For example, if a four-inch turbine meter tests at 98.6 percent weighted accuracy through its flow tests, and the accepted AWWA accuracy limits are 98.5–101.5 percent, the meter is still losing revenue because it is 1.4 percent inaccurate. However, is it worth facilitating a repair to get the meter to 100 percent accuracy if the meter is meeting accuracy limits? Conversely, if the same meter has an overall accuracy of 98.4 percent and fails to meet accuracy limits, is it worth facilitating a repair to gain back the small loss of revenue? Each agency must set its own policy regarding when a meter needs to be repaired based on revenue lost and cost of repair. Is there cost justification for recovering the 1.4 percent inaccuracy at existing rates? What is the future rate environment expected to be?

Once a meter testing program has been enacted, there is a tendency for overall system meter accuracy to rise over a few years as individual problem meters are identified and corrected. Once bad meters are serviced, they usually function well for a few years before needing additional service, but continued testing is needed to monitor degradation of overall meter performance and control revenue loss.

The State of California is evaluating minimum water loss thresholds through annual audit reporting that will need to be met by water systems in coming years. Those thresholds will impact meter testing programs. While existing cost factors are useful in determining how often a specific meter (by size) should be tested and replaced, new state rules will have bearing on the future of overall meter testing and the Consortium.

The costs used to calculate the previously mentioned cost recovery approach do not consider additional expenditures needed to make a meter testing program fully operational. Capital and operational costs for vehicles were assumed to be already defined by each utility because agencies already own service trucks. However, the City of Sac will likely need additional vehicles (and perhaps additional staff) to accommodate a higher level of field testing for itself and any new testing clients. Cost for new equipment should be justified because portable test meters used for the large meter tests are worthy investments and are easy to deploy by a trained staff. Training for meter testing can easily be conducted and, once established, usually needs minor new training from year to year as new meter designs come to the market, and testing teams need to become familiar with how the meters function and any new testing equipment to meet standards.

The three agencies that do not have existing meter test benches should investigate use of nearby test benches owned by another agency that may charge reasonable testing rates. Section 4.7, Economies of Scale of Sharing Small Meter Test Benches, addresses the potential of using other agencies' meter test benches for small meter testing.

4.7 Economies of Scale of Sharing Small Meter Test Benches

Agencies with test benches will not generate a large revenue testing small meters for other Consortium partners. The consulting team assessed the feasibility of the three agencies without test benches using another agency's test bench. A Microsoft Excel workbook was developed to compare required bench testing costs based on sample size with unit testing costs provided by agencies with small meter test benches. Base costs were established as if each agency had their own small meter test bench. Table 16 summarizes small meter bench testing.

Four agencies have existing test benches that should continue to be used by those agencies for small meter accuracy testing. In general, the three agencies that do not currently have benches should negotiate a reasonable per-meter charge for testing by an agency that is geographically close and convenient. Existing unit costs for small meter testing favor the City of Sac with an existing unit cost of $13.11 per meter. This cost is about $5 per meter less than the estimated unit testing costs of the other three agencies with test benches. The primary economy of scale is due to the size of the City of Sac bench and its ability to test 12 meters at a time compared with the other agencies that can only test four meters at a time. The overall cost differences are $1,764 per year compared with $2,065 per year, depending on which agencies with benches perform the testing compared with the City of Sac. Costs do not include "truck roll costs" or employee time to drive sampled meters to a meter test bench location.

SSWD and SCWA will likely use the City of Sac's test bench because it is closer to both agencies, and unit testing costs are lower. The extra level of testing work for the City of Sac, assuming it can maintain its testing of 72 small meters per day, will be up to three to four weeks to test all SSWD and SCWA small meters for each random sampling group.

CHWD is closer to SJWD and Folsom for testing, but SJWD and Folsom can only test four meters at a time. If CHWD has its group of randomly sampled small meters delivered to Folsom or SJWD, the testing work will take between three and four weeks if the 24 meter tests per day is attained at either agency's test bench. Costs of test bench sharing need to be negotiated between agencies, but avoided capital and continuing operational costs should be considered.

The City of Sac's large meter test bench could be used if other agencies wish to remove a large meter from its setting and transport it to the City of Sac's meter testing facility for testing. As stated previously, this approach is generally not cost efficient given the labor time involved compared with on-site testing. Additionally, fire line meters will likely be too big to remove and transport to the meter testing facility and are generally best tested on site. An additional benefit of the large meter bench testing capability of the City of Sac is the ability to test the portable test meter. These portable field meters are recommended to be tested semi-annually, and the tests need to be conducted with extreme care. The test meters will be used as the standard by which the large meters in each agency's metering system will be judged.

Based on existing testing economics, testing capability, and geographical proximity, bench sharing suggestions for further study and negotiation are included in Table 17.

Table 17. Small Meter Bench Testing Recommendations by Agency

Agency	Average Retail Unit Revenue	Small Meter Count	Tested Count	Recommended Small Meter Test Bench
City of Sac	$1.33	121,892	383	City of Sac
SSWD	$1.07	39,788	381	City of Sac
SCWA	$1.74/$4.04	50,073	383	City of Sac
Folsom	$1.87	20,454	378	Folsom
CHWD	$1.02	18,683	377	Folsom or SJWD
PCWA	$1.67	36,102	381	PCWA
SJWD	$0.92	10,093	371	SJWD

Notes: CHWD = Citrus Heights Water District; City of Sac = City of Sacramento; Folsom = City of Folsom; PCWA = Placer County Water Agency; SCWA= Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Section 5 Standardization of Large Meter Testing

5.1 Introduction

The following are reasons for standardizing Consortium-level meter testing:

- Provides consistent levels of confidence in testing procedures and results.
- Testing results can be compared among agencies.
- Testing data is consistent in amount, format, and quality.
- Consortium-level contracting for outside testing service is easier and consistent.

The Consortium agencies have testing programs, and three agencies provided copies of their meter testing SOPs. Those SOPs generally follow AWWA-recommended meter accuracy limits for assessing test results. The consulting team has access to meter testing records of over 100,000 large meters tested. From this database and related field experience, the consulting team evaluated and documented a large meter testing SOP that not only encompasses the AWWA accuracy limits but adds additional testing and field analysis to assist with meter performance evaluation. The valuations are useful in predicting wear for mechanical meters, the meter type historically used to measure and bill large meter use. The newer electronic (static) meters are evaluated in a similar manner, although they do not exhibit the same mechanical wear and tear due to the straight flow-through flow tube.

5.2 Large Meter Testing Approach

Large meter testing programs must go beyond the stated AWWA meter testing specifications. This can be achieved by gaining a thorough understanding of the limitations of meter testing conducted in the field versus testing meters under a controlled environment in a laboratory or established meter testing facility using volumetric tanks. Testing staff should recognize that field conditions are different from a meter testing facility and that these conditions must be considered when testing meters in the field. Also, the AWWA Manuals M6 and M33 have no set standards for field testing. Instead, they emulate as closely as possible the suggested flow rates in the tables on pages 54–55 of the AWWA Manual M6 or follow each meter manufacturer's suggested flow rates (pages 72–77 of the AWWA Manual M6). The AWWA Manual M33 on flowmeters for water systems has no established flow rates or accuracy levels for flowmeters used for wholesale applications. It refers to AWWA Manual M6 and suggests following the manufacturer's recommended calibration procedures. Therefore, it is imperative to adhere to a strict method of field testing developed over years of testing while taking into consideration the AWWA meter performance standards and meter manufacturers' specifications. This methodology is designed to allow for a systematic diagnosis of the meter's performance based on several flow rates across that specific meter's size and type beyond the AWWA's suggested three tests (minimum, intermediate, and maximum).

Meter sites need to be evaluated prior to testing to ensure that the meter can be tested in place without removal or inconvenience to the customer due to a water shutdown. This will involve gathering data in the field about each meter and meter setting, including a meter inventory, site conditions, operable isolation valves (inlet/outlet), backflow device, and any safety hazards needing to be mitigated for testing to occur. Digital photographs should be taken of the meter setting for further evaluation of the meter and for complete meter records.

5.3 Test Meter Calibration

The testing should be done by comparative methods using a certified test meter to test the customer's meter within its normal operating range or by volumetric methods per AWWA Manual M6. Comparative test meters can record total volume and current velocity for each of the four to eight tests conducted. The test meters may have electronic registers that are automatically reset to zero after each test. These comparative test meter units should be tested and certified accurate at least once, if not twice, each year by sending the meter to the manufacturer or to a laboratory or meter testing facility that has the capacity to test and certify large meters.

5.4 Meter Types for On-Site Field Testing

Meter testing should be performed on site at the meter setting. The primary purpose for testing large meters in place is to keep large meters in their setting instead of removing them and possibly causing problems. Additionally, the meter setting can affect the accuracy of the meter if it is improperly configured. An inlet valve and an outlet valve are necessary to isolate the meter from use during testing. A test port is required for the correct size and position to attain enough velocity of flow to test the meter across the range of flow rates for that specific meter. If a bypass line is available, it will be flushed (by a bleed valve if one can be used) before use to ensure that no water service interruption occurs for a critical customer, such as a hospital. During the test, proper meter application and sizing should be done to assure the utility that the meter and setting are correct for the application. Accessibility to the meter is a major concern, especially regarding large commercial accounts and the potential for revenue loss.

5.4.1 Turbine Meter Testing

Turbine meters should be tested using at least four flow rates (testing across a broad range of flows) if local meter setting conditions allow. Some turbine meters only allow for one flow rate to be used for testing, which should be noted in the testing report. The following four flow rates should be tested per meter size in AWWA Manual M6:

- AWWA low flow.
- AWWA intermediate flow.
- AWWA high flow (the high flow capacity of the test meter may limit this flow). Usually, for a three-inch turbine test meter, the high flow tops at 350–400 gpm.

However, if a flowrate of three to 10 percent of the rated capacity of the meter can be attained for field testing, the test can be considered valid since the accuracy flow curve for turbine meters (accuracy curve graph for a six-inch turbine is shown as Figure 2) at the intermediate and high flows is flat (AWWA Manual M6, page 66; see text below).

- “Start” flow. This is a flow rate that indicates the flow rate at which the meter begins to record flow. While the test will show a meter error at this rate, it can help determine the overall condition of wear for the measuring element (turbine and bearings) and is useful in evaluating the meter’s potential for wear or failure in later years.

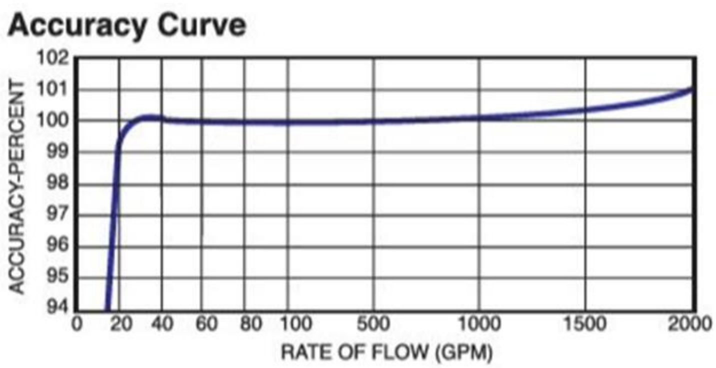

Figure 2. Turbine Meter Accuracy Curve (6-Inch) (AWWA Manual M6, page 66)

“Tests for full-flow accuracy do not need to be made at the “safe maximum capacity” rate shown in the applicable AWWA standard. Registration curves of water meters show that meters in good operating condition follow a general pattern of registration. The specific profile of the accuracy curve can be different for each type of meter. Usually, there will be an intermediate point of maximum registration above the low-flow-metering zone. Depending on the size and type of meter, this point may vary between 3 to 10 percent of the rated meter capacity. At rates above that of maximum registration, the accuracy curve is fairly flat so that there is little difference in accuracy over a wide range of flows. Selection of the maximum rate of flow at which meters are tested is, therefore, not of major importance.”

5.4.2 Compound Meter Testing

Many utilities use compound meters where customer demand patterns warrant a low and high flow meter in one setting. Compound meters are two meters in one. The low flow side is generally a small PD meter. The high flow side is a larger turbine meter. The compound meter has two registers that must be added for billing purposes. Compound meters should be tested at six flows rates, concentrating on the changeover rate (crossover), which is the most critical flow rate in a compound water meter. (AWWA states that three flow tests should be run at minimum—the changeover rate being one of them. Refer to AWWA Manual M6, Chapter 5.) The suggested flow rates for testing and the changeover rate are listed below and may be different from the flow rates in AWWA Manual M6:

- Two-inch compound meters
  - Low flow rates
    - One gpm for five gal or one cu ft (7.48 gal)
    - Five gpm for 10 gal or two cu ft (14.96 gal)
  - Intermediate and high flow rates
    - 20 gpm for 30 gal or four cu ft (29.92 gal)
    - 50 gpm for 100 gal or 10 cu ft (74.8 gal)
    - 100 gpm for 200 gal or 20 cu ft (149.6 gal)
- Three-inch compound meters
  - Low flow rates
    - One gpm for five gal or one cu ft (7.48 gal)
    - Five gpm for 10 gal or two cu ft (14.96 gal)
  - Intermediate and high flow rates
    - 30 gpm for 30 gal or four cu ft (29.92 gal)
    - 75 gpm for 200 gal or 20 cu ft (149.6 gal)
    - 150 gpm for 200 gal or 20 cu ft (149.6 gal)
- Four-inch compound meters
  - Low flow rates
    - One gpm for five gal or one cu ft (7.48 gal)
    - Five gpm for 10 gal or two cu ft (14.96 gal)
  - Intermediate and high flow rates
    - 50 gpm for 50 gal or four cu ft (29.92 gal)
    - 100 gpm for 200 gal or 20 cu ft (149.6 gal)
    - 200 gpm for 300 gal or 40 cu ft (299.2 gal)
- Six-inch compound meters
  - Low flow rates
    - 1.5 gpm for five gal or one cu ft (7.48 gal)
    - Five gpm for 10 gal or two cu ft (14.96 gal)
  - Intermediate and high flow rates
    - 75 gpm for 50 gal or four cu ft (29.92 gal)
    - 150 gpm for 200 gal or 20 cu ft (149.6 gal)
    - 300 gpm for 300 gal or 40 cu ft (299.2 gal)

Note: Low flow test flow rates for compound meters are not set in the AWWA Manual M6 accuracy limits tables, but the percentage accuracy is defined. Low flow tests in the AWWA Manual M6 were designed for meter test benches and not for field testing. It is difficult to test at 0.25 gpm in the field due to the potential of outlet valve leak-through issues. Therefore, by testing at the one gpm test flow rate and comparing it to the five gpm test, if the outlet valve is leaking, then the meter technician can calculate what the leak-by flow rate may be. Adjustments can then be made in the testing procedure.

Test for Crossover Flow Rate: After the low flow and high flow tests are completed for the compound meter, the "crossover" flow rate must be tested. This is the flow rate where the low flow side of the meter starts to reach its maximum flow rate, and the high flow meter's low flow rate has been "crossed over" to the turbine side of the meter. This test will require testing at flow rates below the assumed crossover threshold for the particular sized meter being tested and then increasing the flow rate gradually until the meter reaches its lowest percentage accuracy and begins to show increased accuracy as the flow rate is increased. At a minimum, this process will take three tests for a run of 10 gallons per test (or two cu ft). The accuracy curve for a four-inch Sensus compound meter is provided below (Figure 3).

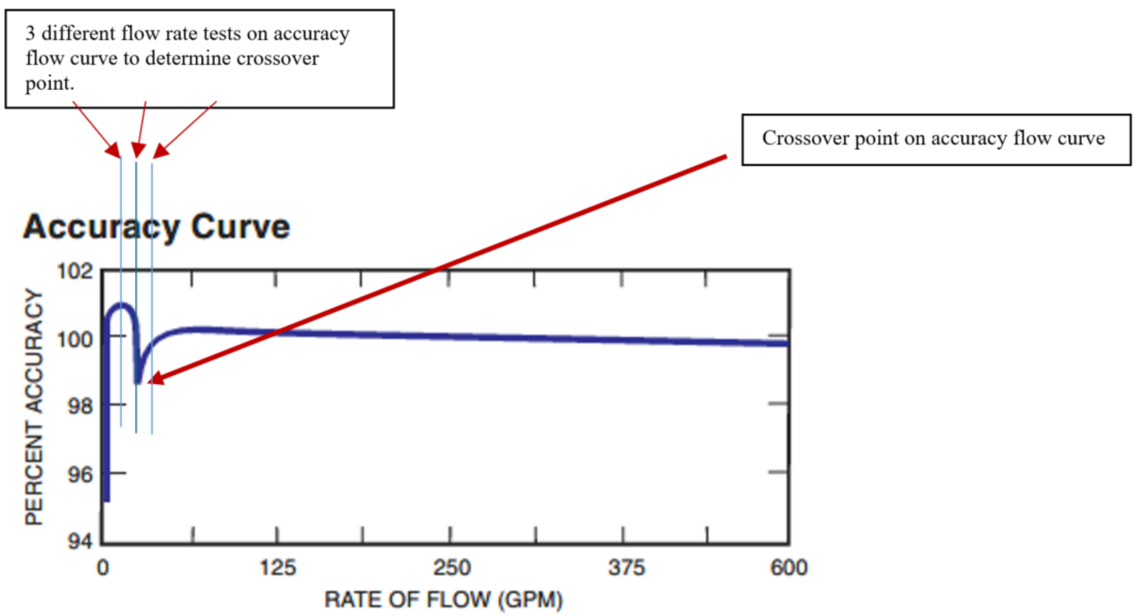

Figure 3. Accuracy Curve for a Four-Inch Compound Meter

Note: Part of the compound meter evaluation is comparing consumptions on the low flow side of the meter with the high flow side. The split of water consumption should be between 20 percent low flow and 80 percent high flow up to 40 percent low flow and 60 percent high flow. If the ratios are different, then the meter may not be properly sized or typed.

5.4.3 Fire Line Meter Testing

Fire line compound meters must be tested in a different manner since their design is for the specific purpose of fire suppression. Each meter side should be tested individually to assess its mechanical issues.

The low flow meter side should be isolated in the setting (usually there are valves that allow for this) and tested as an individual meter specific to its test flow rates.

The high flow meter side should be isolated in the setting (usually there are valves that allow for this) and tested as an individual meter specific to its test flow rates, keeping in mind that the high flow meter may be a turbine meter that is bigger than the test meter being used. The meter test procedure should follow the turbine meter test procedure outlined above.

Meter technicians should test the assembly as a compound. They will start with the low flow tests and work through the high flows and then test for the crossover flow rate to assess the function of the crossover control valve and to determine what flow rate it opens so that high flow can be correctly measured. They should keep in mind the accuracy percentage it should perform at (per AWWA Manual M6 guidance) and that the crossover flow should not go below 90 percent (Figure 4).

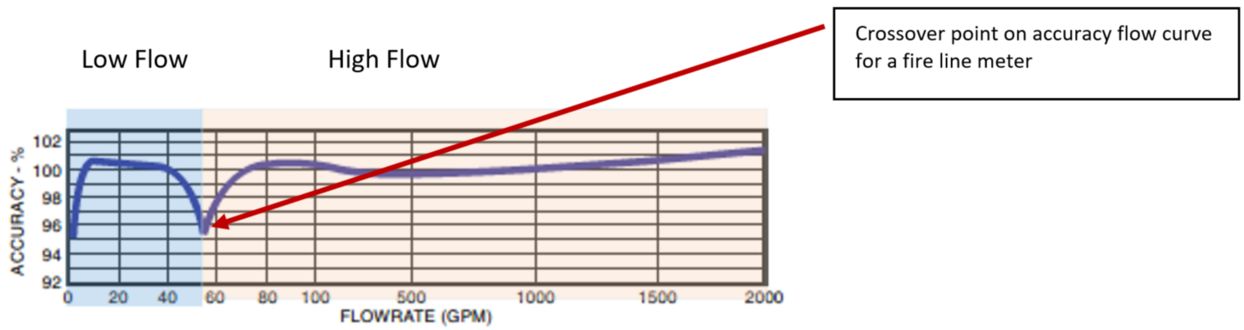

Figure 4. Accuracy Curve for a 10-Inch Fire Line Meter

Compound meters and fire line meters should not be installed in settings where the expected flow rate will function continuously at or near the crossover rate due to the inaccuracy of measurement at this flow.

5.5 General Tasks and Considerations for Field Testing of Meters

The following are specific considerations for conducting large meter field accuracy testing:

- Field staff will work in an orderly and safe manner to ensure protection of the local residents, utility employees, and field staff so no avoidable accidents occur.
- Field staff will wear readily observable photo identification badges while in the field.
- Field staff will obtain a complete meter list from the utility database. The meter list should be organized along meter reading routes to reduce travel time between each meter. Field staff will obtain contact information, such as phone numbers and names of contact persons at each location (if available) from the utility for each customer on the meter list.
- It is expected that the utility will send a letter of notification to each selected customer informing them of a potential inspection and test.

- Initial phone calls may be needed to set appointments for site inspections and meter testing.
- Field staff will visit each meter site to assess the meter setting and meet the customer, building manager, or building maintenance manager.
- Field staff will assemble confined space entry equipment (if the meter is in such a setting). They will follow standard, accepted confined space entry procedures. Note: If the meter vault is full of water, field staff will pump it out and note the reason why water is in vault. They will use a gas detector to test air quality and note any issue with air quality. If the vault fails the air quality testing, field staff will set up a ventilator and vent the meter setting space. If the air quality fails testing limits after 10 minutes of venting, field staff will indicate that the vault has failed and notify the utility of failure. The vault is not to be entered until the problem has been corrected by the utility.
- Field staff will assess all meters listed in the test group. This assessment will include making observations of water use on site and observed meter readings to determine if the meter is the correct type and size for the application.
- Field staff will determine if the meter can be tested in place. If not, they will make recommendations to correct the setting so the meter can be tested in place. This will include sketches and drawings of the site. They will submit this information to the utility management so improvements can be made.
- A meter log will be maintained, indicating the meters to be assessed in the current test group. This log will be reviewed when the testing team is verifying the meter data supplied by the utility, and corrections will be made to provide updated records to the utility. This log will be used as part of the periodic meter reports submitted to the utility managers.
- The following data will be collected during the evaluation process:
  - Contact information for the customer (e.g., name of primary contact person, phone number, address, hours of business operations).
  - Meter ID number, serial number, manufacturer, size, and type.
  - Address and location of meter setting and address of customer. This will include the street and cross street with a description of the location so that the setting can be easily identified.
  - Town/city name with zip code.
  - Meter readings at the time of inspection.
  - Observations made of water use.
  - Any discrepancies in utility records compared with what is found on site.
  - Description of meter condition and meter setting or vault condition (e.g., full of water, vault needs repair). A conditions assessment of piping and fittings should be included.
  - Digital photographs of the meter setting with all valves, fittings, and appurtenances.
  - Sketches of meter settings with fittings.

- Notation if the strainer is upstream of the meter.
- Test port and size.
- Backflow device, if present (note if in a vault downstream of meter), including the type, size, and serial number and if it was testable or not. If the meter is in a vault and the backflow device is in the building, this should be noted.
- Meter bypass line present. If so, include the size. It should be noted if the bypass line is sealed shut or locked.
- Inlet/outlet valves present and operable to attain shutdown.
- Where water from the test can be safely discharged, including sump pits and sanitary sewers. Field staff should discuss safe discharge of water from the test with the customer.
- Area around meter setting/vault and note if it is sufficient to conduct work.
- Fixed ladder in vault.
- Confined space issues, such as levels of oxygen and any other hazardous gas present.
- Specific type of testing needed to test meter.
- Field staff and any utility staff present during inspection or testing. This should be noted in the meter inspection report.
- Inspection reports to be completed for utility management within 10 working days.

• Field staff should schedule the meter test with the customer during normal working hours. Exceptions to testing times will be made on a case-by-case basis, depending on the severity of the loss of water service due to the testing procedure.
• It may be necessary to conduct parts of the meter testing program during off hours, such as at night. The schedule will be agreed on between the customer and the field staff. This may be required in locations that have a high daily use but are closed at night.
• Meters will be tested across a specific range of flows (see above) to determine patterns of mechanical wear at various flow rates. The flow rates used will be a combination of AWWA-recommended flow rates (per AWWA Manual M6), meter manufacturer flow rates, and other flow rates that may be deemed needed to fully evaluate the performance of the meter. Meter flow rates include the following:
  - **Class I Meters:** At least four flow tests. Typically Class I meters are obsolete; therefore, it is likely that, even if these meters are tested, pass or fail, a change-out will be recommended.
  - **Class II Turbine Meters:** At least four flow rates.
  - **Compound Meters:** Six flow rates, including cross over flows.
  - **Pitot Style Testing:** Performed meters where taps have been installed and it is practical to conduct this type of testing.
  - **Fire Service:** Depending on type and style, seven to eight flow tests.

- If a loss of water service for a short period of time cannot be tolerated by the customer, recommendations will be made to the customer and the utility to correct the meter setting to include a bypass around the meter so a service disruption will not occur during future testing.

5.6 Specific Field Accuracy Test Procedures

The following are specific tasks associated with on-site accuracy testing of large meters:

- Customer will be notified during the inspection process when the possible testing date and time will be.
- Field staff will assemble confined space entry equipment (if the meter is in such a setting). They will follow standard, accepted confined space entry procedures. Note: If the meter vault is full of water, field staff will pump it out and note the reason why water is in vault. They will use a gas detector to test air quality and note any issue with air quality. If the vault fails the air quality testing, field staff will set up a ventilator and vent the meter setting space. If the air quality fails testing limits after 10 minutes of venting, field staff will indicate that the vault has failed and notify the utility of failure. The vault is not to be entered until problem has been corrected by the utility.
- Field staff will open the bypass line (if present).
- Field staff will isolate the meter by shutting off the inlet valve first and then the outlet valve. They will gently remove the test plug, observing if shutdown can be attained and if the meter is not under pressure.
- Field staff will connect the test hose to the meter and then to the test meter assembly. They will slowly open the inlet valve to pressurize the hose and test meter and then purge air from the hose and test meter before “zero” testing the meter.
- Field staff will begin the low flow test and then test in progression to next highest flow rate. After all flow rates for the specific size and type of meter have been performed, they will perform one of the following: for compound meters, they will perform crossover tests, and for turbine meters, they will perform “start” tests.
- Crossover tests will involve testing for the crossover flow rate below, at, and above the expected crossover rate for each specific sized compound meter. This is to ensure that the crossover curve has been correctly identified and tested. Field staff will demonstrate that the crossover accuracy requirements are met.
- “Start” testing flow rates for turbine meters will be conducted to show when the specific turbine meter starts to register flow. This test is not specified by AWWA; however, it is an indicator of specific wear patterns inherent to turbine meters that can help with the overall evaluation of the meter’s performance.
- Fire meters and fire line meters will be tested in a specific manner that will help with the overall evaluation of the assembly. Each meter of the assembly will be tested

independent of the other across the range of each meter's size and type. Then the assembly will be tested as a "large compound," specifically concentrating on the "crossover" flow rate between the low flow side and the high flow side.

- Compound meters will be tested at six flow rates (low flow, below crossover, above crossover, intermediate flow, high flow, and crossover flows), and turbine meters will be tested at five flow rates (AWWA low flow, above low flow, intermediate flow, high flow, and "start" flow). The AWWA low flow, above low flow, intermediate flow, and high flow rates used will reflect each meter size and meter type tested, following the test flow rates in the AWWA Manual M6 (pages 54–55) as closely as possible. Field conditions, such as system static pressure, may influence the ability to gather these flow rates and, thus, may be subject to change on site.
- Correction factors will be applied to the test results for each meter based on the accuracy curve of the test meter used. This is extremely important to obtain true accuracy for each flow test for each meter.
- The testing team will document all meter testing results. Meters that were estimated to require extensive repairs (e.g., are not worth the time and materials costs or are obsolete) will be brought to the attention of the meter superintendent so a potential meter change-out can be analyzed by the utility.
- The cost basis for making a recommendation for a meter change-out will be determined by 50 percent of the estimated replacement cost of a new meter or by the meter superintendent.
- Care will be exercised in locating where water will be discharged during testing. Water flowing from the discharge of the test meter will not be allowed to cause interference with private property or pedestrian or roadway traffic and will have a minimum environmental impact. Special attention will be made during freezing temperatures to minimize icing issues at the test site. Typical accepted discharge locations include sanitary and storm sewers or grassy areas capable of absorbing the water. Discharge location will be investigated during the inspection process, with alternative discharge sites selected in case the primary location is found to be unacceptable.

Table 18 provides guidance on large meter testing for various sizes and types of meters. Guidance for small displacement meters is also provided, as well as test flow information and meter capabilities.

Table 18. Flow Rates for Meter Types and Sizes

Meter Testing Cheat Sheet Flow Test Rates						
Compound Meters						
Size	**2**	**3**	**4**	**6**		
Maximum	100	150	200	300		
Intermediate	50	75	100	150		
Above	20	30	50	50		
Changeover	9, 10, 11	14, 15, 16	19, 20, 21	24, 25, 26		
Below	5	5	5	5		
Minimum	1	1	1	1		
Class II Turbine						
Size	**1.5**	**2**	**3**	**4**	**6**	**8**
Maximum	80	120	300	300	300	300
Intermediate	30	50	150	150	150	150
Minimum	2	4	8	16	30	50
Start	1.5	2	3,4	6,7,8	14 - 16	29 - 35
Displacement						
Size	**5/8–3/4**	**3/4**	**1**	**1.5**	**2**	
Maximum	15	25	40	50	100	
Intermediate	2	3	4	8	15	
Minimum	0.25	0.5	0.75	1.5	2	

5.7 Typical Accepted Accuracy Limits

The following are AWWA new meter accuracy limits specified in AWWA Manual M6:

- Displacement meters
  - **Low flow:** 95–101.5 percent
  - **Intermediate and high flows:** 98.5–101.5 percent
- Turbine meters
  - **Low, intermediate, and high flows:** 98.5–101.5 percent
- Compound meters
  - **Low flows:** 96–101 percent
  - **Intermediate and high flows:** 98.5–101.5 percent
  - **Crossover:** No less than 90 percent
- Fire line meters
  - **Low flows:** 98.5–101.5 percent
  - **Intermediate and high flows:** 98.5–101.5 percent
  - **Crossover:** No less than 90 percent

Each agency will need to determine any other accuracy limits that should be applied for field testing. Utilities can refer to the AWWA Manual M6 and the AWWA Standards C700–C715 for further guidance. The repaired meter accuracy limit of 90 percent applies only at the low flow test rate.

5.8 Recommended Standard Operating Procedures for Large Meter Testing

Detailed recommended SOPs for on-site large meter accuracy testing are included in Appendix C, Recommended Large Meter Field Testing Standard Operating Procedures.

Section 6 Recommendations for Meter Testing by Agency

This section is based on the findings and conclusions of the previous sections of this technical memorandum. Two Microsoft Excel workbooks were assembled to summarize existing meter testing methods and costs by agency and recommended changes to existing protocols and estimated future costs. Unlike the previous sections, which combine information in summary tables for all agencies, this section addresses each agency separately. For consistency, all subsection topics are the same and in the same sequence for all agencies. Following the individual agency discussions and recommendations are related meter testing topics applicable to all agencies.

6.1 City of Sacramento

6.1.1 Current Meter Testing Practices

The City of Sac has the newest and largest meter test bench in the area. The facility can test meter sizes from 5/8- to 16 inches. The City of Sac currently uses its bench for all meter accuracy tests. The City of Sac has no existing field testing capability. A sample of 10 percent of all new meters is tested on the bench. All removed meters from customer settings are tested on the bench. The City of Sac does not currently use any outside meter testing firm.

6.1.2 Existing Testing Equipment

The City of Sac has a Mars automatic, purchased meter test bench capable of testing 24 one-inch meters in series in the same line. Small meter testing can generally be conducted in three daily cycles, resulting in the ability to test 72 meters in one day. Due to head loss issues, the rate of testing is 12 meters per cycle, but with a well versed mete testing staff, 72 meters per day is still attainable. The bench comes with a separate line for each test bench. The City of Sac is in the process of procuring field testing equipment.

6.1.3 Recommended Improvements to Meter Testing

It is recommended that the City of Sac implement field testing of large and intermediate meters with its own staff, which will require the purchase of new testing equipment. The City of Sac should implement the recommended small meter sampling and testing program with its own test bench and staff. It is recommended that small meters be randomly selected from the deployed population older than 10 years. The City of Sac should set the criteria for random sampling of small meters to attain a 95 percent statistical confidence interval that the sample results represent the deployed population accuracy results within five percent of the actual value.

The City of Sac should continue sample testing 10 percent of all new meters of all sizes on its test bench. All large and intermediate meters should be tested in place after installation following the suggested SOP. Turbine, compound, and fire line meters have suggested testing methods designed to help meter performance evaluation.

The City of Sac should adopt a written large meter and intermediate meter testing SOP for field staff. The City of Sac should include training for all meter brands and types used by the City of Sac. Meter staff should be trained on field testing various meter sizes, types, and manufacturers and repair in the field. To justify its own large meter field testing program, the City of Sac should write a scope of work and solicit estimates from qualified private testing firms.

Meter testing SOPs should have been included with the City's purchase and installation of its test benches.

6.1.4 Recommended New Testing Equipment

The use of the existing City of Sac large meter test bench is not as economic as field testing in place because on-site testing is less disruptive and less expensive. Use of the large meter bench should include certification testing of the field meter testing units for the City of Sac and other Consortium agencies for which witnesses are required. Pulled large and intermediate meter testing on the test bench may also be appropriate for autopsy and comparison with field results.

For new field testing equipment, the suggested size is three inches with a bypass for both large meter and intermediate meter groups. The estimated cost for this unit is $5,500 per meter. Based on testing volume recommendations and frequencies for the City of Sac, the City of Sac needs four new portable testing units. Associated hoses and fittings for four units are estimated to cost $5,000. If the City of Sac needs to purchase new vehicles for transporting the test units, the unit cost of a new utility truck is $30,000. The City of Sac should buy four computing tablets for field data collection at $500 each. Spare parts for the four testing units are estimated to cost $500. It is recommended that the City of Sac purchase 100 spare small meters for rotating sampled meters that fail the bench test accuracy requirements. The total estimated cost for new field testing equipment and small spare meters is $47,840 without new vehicles.

6.1.5 Staffing Requirements

To handle its own large meter and intermediate meter field testing needs, it is estimated that the City of Sac will need four two-person testing teams working year-round. For annual testing of large meters, the estimated workload is 605 testing team days. For testing intermediate meters every four years, the estimated workload is 257 testing team days. The combined testing team days is 862.

For small meter testing on its own test bench, the City of Sac is estimated to test 72 meters per day using a two-person testing team. Testing the 383 sampled meters will take 5.3 days. The 24-meter test train will have three testing cycles each day. Table 19 provides a summary of recommended meter testing requirements and annual costs.

Table 19. Summary of Recommended Annual Meter Testing Requirements: City of Sacramento

Meter Size Group	No. of Meters	Testing Team Days (Test, R&R)	Annual Labor Cost
Large	2,421	605	$571,356
Intermediate	1,799	257	$242,541
Small	383	6, 20	$5,022, $18,078 (Test, R&R)
Total	**—**	**—**	**$836,996**

Note: R&R = remove and replace

6.2 Sacramento Suburban Water District

6.2.1 Current Meter Testing Practices

SSWD conducts both bench and field testing. SSWD has no bench testing equipment for large or small meters but has a Badger large meter field test unit. Intermediate meters sized 1.5 and two inches are rebuilt every 10 years at a rate of about 250 per year. Large meters sized three and four inches are tested every five years. Meters sized six inches and larger are tested annually. If meters fail the test, they are rebuilt. SSWD uses no contracted testing company.

6.2.2 Existing Testing Equipment

SSWD owns and uses a large meter portable tester manufactured by Badger. They also own a small meter portable tester, which is only used for residential customer bill complaints and quick meter functionality and accuracy checks. They use other utility test benches occasionally but have regular small meter change-out programs, outsourced to a 3rd party for 30% of the small meters that get replaced

6.2.3 Recommended Improvements to Meter Testing

It is recommended that SSWD continue field testing of large and intermediate meters with its own staff. SSWD should implement the recommended small meter sampling and testing program through an agreement with the City of Sac for use of its test bench and staff. It is recommended that small meters be randomly selected from the deployed population older than 10 years. SSWD should set the criteria for random sampling of small meters to attain a 95 percent statistical confidence interval that the sample results represent the deployed population accuracy results within five percent of the actual value.

SSWD should implement sample testing of 10 percent of all new small meters on the City of Sac's test bench. All large and intermediate meters should be tested in place after installation following the suggested SOP. Turbine, compound, and fire line meters have suggested testing methods designed to help meter performance evaluation.

SSWD should continue with its written large meter and intermediate meter testing SOP for field staff. SSWD should include training for all meter brands and types used by SSWD. Meter staff should continue to receive training on field testing of various meter sizes, types, and manufacturers and repair in the field.

Small meter testing SOPs should have been included with the City of Sac's purchase and installation of its test bench, but SSWD staff will need to obtain and review if SSWD chooses to use the Sac City test bench as part of a cost sharing/testing arrangement.

6.2.4 Recommended New Testing Equipment

The use of the existing City of Sac's large meter test bench is not as economical as field testing in place because on-site testing is less disruptive and less expensive. Use of the large meter bench should include certification testing of field meter testing units for SSWD and other Consortium agencies for which witnesses are required. Pulled large and intermediate meter testing on the test bench may also be appropriate for autopsy and comparison with field results.

For new field testing equipment, the suggested size is three inches with a bypass for both large meter and intermediate meter groups. If SSWD needs to upgrade its existing large meter field tester, the estimated cost for this unit is $5,500 per meter. Based on testing volume recommendations and frequencies for SSWD, SSWD needs one portable testing unit plus a spare.

To handle its own large meter and intermediate meter field testing needs, it is estimated that SSWD will need one two-person testing team working about 40 weeks per year. For annual testing of large meters, the estimated workload is 112 testing team days. For testing intermediate meters every four years, the estimated workload is 87 testing team days. The combined testing team days is 199.

For small meter testing on the City of Sac's test bench, SSWD is estimated to test 72 meters per day using a two-person testing team. Testing the 381 sampled meters will take 5.3 days. The 24-meter test train will have three testing cycles each day. Table 20 provides a summary of recommended meter testing requirements and annual costs.

Table 20. Summary of Recommended Annual Meter Testing Requirements: Sacramento Suburban Water District

Meter Size Group	No. of Meters	Testing Team Days (Test, R&R)	Annual Labor Cost
Large	447	112	$142,086
Intermediate	609	87	$116,196
Small	381	16, 19	$5,046, $30,277 (Test, R&R)
Total	—	—	**$293,605**

Note: R&R = remove and replace

6.3 Sacramento County Water Agency

6.3.1 Current Meter Testing Practices

SCWA has conducted limited field testing of large meters in the past (2007–2010) but does not currently. SCWA has no bench testing equipment for large or small meters and no large meter field test unit. SCWA uses no contracted testing company. Small meter accuracy testing was previously done in 2012 on 15 select meters.

6.3.2 Existing Testing Equipment

SCWA has no meter test bench or any large meter field testing equipment.

6.3.3 Recommended Improvements to Meter Testing

It is recommended that SCWA implement field testing of large and intermediate meters with its own staff. This will require the purchase of new testing equipment. SCWA should implement the recommended small meter sampling and testing program through agreement with the City of Sac for use of its test bench and staff. It is recommended that small meters be randomly selected from the deployed population older than 10 years. SCWA should set the criteria for random sampling of small meters to attain a 95 percent statistical confidence interval that the sample results represent the deployed population accuracy results within five percent of the actual value.

SCWA should implement sample testing of 10 percent of all new small meters on the City of Sac's test bench. All large and intermediate meters should be tested in place after installation following the suggested SOP. Turbine, compound, and fire line meters have suggested testing methods designed to help meter performance evaluation.

SCWA should adopt a written large meter and intermediate meter testing SOP for field staff. SCWA should include training for all meter brands and types used by SCWA. Meter staff should be trained on field testing of various meter sizes, types, and manufacturers and repair in the field. To justify its own large meter field testing program, SCWA should write a scope of work and solicit estimates from qualified private testing firms.

Small meter testing SOPs should have been included with the City of Sac's purchase and installation of its test bench, but SCWA staff will need to obtain and review.

6.3.4 Recommended New Testing Equipment

The use of the existing City of Sac's large meter test bench is not as economical as field testing in place because on-site testing is less disruptive and less expensive. Use of the large meter bench should include certification testing of field meter testing units for SCWA and other Consortium agencies for which witnesses are required. Pulled large and intermediate meter testing on the test bench may also be appropriate for autopsy and comparison with field results.

For new field testing equipment, the suggested size is three inches with a bypass for both large meter and intermediate meter groups. The estimated cost for this unit is $5,500 per meter. Based on testing volume recommendations and frequencies for SCWA, SCWA needs two new portable testing units. Associated hoses and fittings for two units are estimated to cost $2,000. If SCWA needs to purchase new vehicles for transporting the test units, the unit cost of a new utility truck is $30,000. SCWA should buy two computing tablets for field data collection at $500 each. Spare parts for the two testing units are estimated to cost $250. It is recommended that SCWA purchase 48 spare small meters for rotating sampled meters that fail bench test accuracy requirements. The total estimated cost for new field testing equipment and small spare meters is $29,000 without new vehicles.

6.3.5 Staffing Requirements

To handle its own large meter and intermediate meter field testing needs, it is estimated that SCWA will need one two-person testing team working 39 weeks per year. For annual testing of large meters, the estimated workload is 84 testing team days. For testing intermediate meters every four years, the estimated workload is 109 testing team days. The combined testing team days is 193.

For small meter testing on the City of Sac's test bench, SCWA is estimated to test 72 meters per day using a two-person testing team. Testing the 383 sampled meters will take 5.3 days. The 24-meter test train will have three testing cycles each day. Table 21 provides a summary of recommended meter testing requirements and annual costs.

Table 21. Summary of Recommended Annual Meter Testing Requirements: Sacramento County Water Agency

Meter Size Group	No. of Meters	Testing Team Days (Test, R&R)	Annual Labor Cost
Large	334	83.5	$73,480
Intermediate	762	109	$95,763
Small	383	16, 20	$7,022, $16,852 (Test, R&R)
Total	—	—	**$193,117**

Note: R&R = remove and replace

6.4 City of Folsom

6.4.1 Current Meter Testing Practices

Folsom has a Mars automatic meter test bench that can test the accuracy of meters sized through two inches. Folsom currently uses its bench for all meter accuracy tests. Folsom also has existing field testing capability and equipment. Folsom reports that all of its commercial meters are tested on a three year program. Their large meters comprise of about 1% of the meter population and intermediate meter population is approximately 4.5% Select small meters are also tested annually, but Folsom does not use statistical random sampling. Folsom does not currently use any outside meter testing firm.

6.4.2 Existing Testing Equipment

Folsom owns and uses large meter portable field test meters for on-site accuracy testing. Folsom also owns and operates a Mars eight-stand, automatic test bench with testing capability up to two-inch meters. Folsom staff were trained and certified to operate this equipment on February 25, 2020.

6.4.3 Recommended Improvements to Meter Testing

It is recommended that Folsom implement field testing recommendations for large and intermediate meters with its own staff. The existing Folsom field testing equipment can achieve this goal. Folsom should implement the recommended small meter sampling and testing program with its own test bench and staff. It is recommended that small meters be randomly selected from the deployed population older than 10 years. Folsom should set the criteria for random sampling of small meters to attain a 95 percent statistical confidence interval that the sample results represent the deployed population accuracy results within five percent of the actual value.

Folsom should sample test 10 percent of all new small meters on its test bench. All large and intermediate meters should be tested in place after installation following the suggested SOP. Turbine, compound, and fire line meters have suggested testing methods designed to help meter performance evaluation.

Folsom should adopt a written large meter and intermediate meter testing SOP for field staff. Folsom should include training for all meter brands and types used by Folsom. Meter staff should be trained on field testing of various meter sizes, types, and manufacturers and repair in the field. To justify its own large meter field testing program, Folsom should write a scope of work and solicit estimates from qualified private testing firms.

Small meter SOPs should have been included with Folsom’s purchase and installation of its test bench.

6.4.4 Recommended New Testing Equipment

The use of the existing Folsom large meter test bench is not as economical as field testing in place because on-site testing is less disruptive and less expensive. Use of the large meter bench should include certification testing of field meter testing units for Folsom and other Consortium agencies for which witnesses are required. Pulled large and intermediate meter testing on the test bench may also be appropriate for autopsy and comparison with field results.

For new field testing equipment, the suggested size is three inches with a bypass for both large meter and intermediate meter groups. The estimated cost for this unit is $5,500 per meter, but Folsom already owns field test meters. Based on testing volume recommendations and frequencies for Folsom, Folsom can use its existing units. If Folsom needs to purchase new vehicles for transporting the test units, the unit cost of a new utility truck is $30,000. If Folsom does not own field data collection tablets, Folsom should buy one or more for field data collection at $500 each. It is recommended that Folsom purchase 48 spare small meters for rotating sampled meters that fail bench test accuracy requirements. The total estimated cost for new spare small meters is $14,760.

6.4.5 Staffing Requirements

To handle its own large meter and intermediate meter field testing needs, it is estimated that Folsom will need one two-person testing team working 15 weeks per year. For annual testing of large meters, the estimated workload is 43 testing team days. For testing intermediate meters every four years, the estimated workload is 31 testing team days. The combined testing team days is 74.

For small meter testing on its own test bench, Folsom is estimated to test 24 meters per day using a one-person testing team. Testing the 378 sampled meters will take 15.8 days. The eight-meter test train will have three testing cycles each day. Table 22 provides a summary of recommended meter testing requirements and annual costs.

Table 22. Summary of Recommended Annual Meter Testing Requirements: City of Folsom

Meter Size Group	No. of Meters	Testing Team Days (Test, R&R)	Annual Labor Cost
Large	172	43	$37,840
Intermediate	214	30.6	$26,903
Small	378	16, 19	$5,022, $18,078
Total	—	—	**$87,842**

Note: R&R = remove and replace

6.5 Citrus Heights Water District

6.5.1 Current Meter Testing Practices

CHWD conducted limited field testing of one-inch meters in 2018 and 2019 using a Mars small meter tester. In 2019, 56 one-inch meters were tested in the field with this tester. Eight of these meters were tested by the City of Sac on its test bench, with the majority exhibiting accuracy within AWWA limits. CHWD has no bench testing equipment for large or small meters and no large meter field test unit. CHWD has used a contracted testing company on demand in the past.

6.5.2 Existing Testing Equipment

CHWD owns and uses a Mars small meter field test unit. CHWD does not own a large meter field test assembly.

6.5.3 Recommended Improvements to Meter Testing

It is recommended that CHWD implement field testing of large and intermediate meters with its own staff. This will require the purchase of new testing equipment. CHWD should implement the recommended small meter sampling and testing program with the existing test bench of the City of Sac or Folsom. It is recommended that small meters older than 10 years be randomly selected from the deployed population. CHWD should set the criteria for random sampling of small meters to attain a 95 percent statistical confidence interval that the sample results represent the deployed population accuracy results within five percent of the actual value.

CHWD should sample test 10 percent of all new small meters on a shared test bench. All large and intermediate meters should be tested in place after installation following the suggested SOP. Turbine, compound, and fire line meters have suggested testing methods designed to help meter performance evaluation.

CHWD should adopt a written large and intermediate meter testing SOP for field staff. CHWD should include training for all meter brands and types used by CHWD. Meter staff should be trained on field testing of various meter sizes, types, and manufacturers and repair in the field. To justify its own large meter field testing program, CHWD should write a scope of work and solicit estimates from qualified private testing firms.

Small meter SOPs should have been included with the City of Sac and Folsom purchases and installation of their test benches, but the CHWD staff will need to obtain and review.

6.5.4 Recommended New Testing Equipment

The use of the existing City of Sac or Folsom large meter test benches is not as economical as field testing in place because on-site testing is less disruptive and less expensive. Use of either large meter bench should include certification testing of field meter testing units for CHWD and other

Consortium agencies for which witnesses are required. Pulled large and intermediate meter testing on the test bench may also be appropriate for autopsy and comparison with field results.

For new field testing equipment, the suggested size is three inches with a bypass for both large meter and intermediate meter groups. The estimated cost for this unit is $5,500 per meter. Based on testing volume recommendations and frequencies, CHWD needs two new portable testing units with one unit as a spare. Associated hoses and fittings for two units are estimated to cost $2,000. If CHWD needs to purchase new vehicles for transporting the test units, the unit cost of a new utility truck is $30,000. CHWD should buy two computing tablets for field data collection at $500 each. Spare parts for the two testing units are estimated to cost $250. It is recommended that CHWD purchase 48 spare small meters for rotating sampled meters that fail bench test accuracy requirements. The total estimated cost for new field testing equipment and small spare meters is $13,750 without new vehicles.

6.5.5 Staffing Requirements

To handle its own large and intermediate meter field testing needs, it is estimated that CHWD will need one two-person testing team working 13 weeks per year. For annual testing of large meters, the estimated workload is 22 testing team days. For testing intermediate meters every four years, the estimated workload is 42 testing team days. The combined testing team days is 64.

For small meter testing on a shared test bench (Folsom), CHWD is estimated to test 24 meters per day using a one-person testing team. Testing the 377 sampled meters will take 15.7 days. The Folsom eight-meter test train will have three testing cycles each day. Table 23 provides a summary of recommended meter testing requirements and annual costs.

Table 23. Summary of Recommended Annual Meter Testing Requirements: Citrus Heights Water District

Meter Size Group	No. of Meters	Testing Team Days (Test, R&R)	Annual Labor Cost
Large	86	21.5	$18,920
Intermediate	297	42.4	$37,274
Small	377	16, 19	$6,912, $16,588 (Test, R&R)
Total			**$79,694**

Note: R&R = remove and replace

6.6 Placer County Water Agency

6.6.1 Current Meter Testing Practices

PCWA has a Ford manual meter test bench that can test the accuracy of small meters sized through two inches. PCWA currently uses its bench for certain small meter accuracy tests. PCWA also has existing field testing capability and equipment. PCWA reports that 1.5- to two-inch meters are tested every seven years unless they are rebuilt before then. Meters sized three and four inches are tested every three years. Meters sized six and eight inches are tested every year. Compound and turbo meters sized two inches are tested every four years. Smaller meters are typically not tested. PCWA does not use statistical random sampling. PCWA periodically uses an outside meter testing firm.

6.6.2 Existing Testing Equipment

PCWA owns and uses large meter portable field test meters for on-site accuracy testing. PCWA also owns and operates a Ford four-stand, manual test bench with rotameters. Bench testing capability includes meters up to two inches. PCWA also owns and operates a Badger large meter portable tester.

6.6.3 Recommended Improvements to Meter Testing

It is recommended that PCWA implement field testing of large and intermediate meters with its own staff. Due to existing equipment, it is assumed that PCWA will not need any new field testing equipment. PCWA should implement the recommended small meter sampling and testing program with its own test bench and staff. It is recommended that small meters be randomly selected from the deployed population older than 10 years. PCWA should set the criteria for random sampling of small meters to attain a 95 percent statistical confidence interval that the sample results represent the deployed population accuracy results within five percent of the actual value.

PCWA should implement sample testing of 10 percent of all new small meters on its test bench. All large and intermediate meters should be tested in place after installation following the suggested SOP. Turbine, compound, and fire line meters have suggested testing methods designed to help meter performance evaluation.

PCWA should adopt a written large meter and intermediate meter testing SOP for field staff. PCWA should include training for all meter brands and types used by PCWA. Meter staff should be trained on field testing of various meter sizes, types, and manufacturers and repair in the field. To justify its own large meter field testing program, PCWA should write a scope of work and solicit estimates from qualified private testing firms.

Small meter SOPs should have been included with PCWA's purchase and installation of its test bench, but other agencies with newer benches may share their SOPs.

6.6.4 Recommended New Testing Equipment

The use of the existing City of Sac large meter test bench is not as economical as field testing in place because on-site testing is less disruptive and less expensive. Use of their large meter bench should include certification testing of field meter testing units for PCWA and other Consortium agencies for which witnesses are required. Pulled large and intermediate meter testing on the test bench may also be appropriate for autopsy and comparison with field results.

For new field testing equipment, the suggested size is three inches with a bypass for both large meter and intermediate meter groups. The estimated cost for this unit is $5,500 per meter. If PCWA needs to purchase new vehicles for transporting the test units, the unit cost of a new utility truck is $30,000. PCWA should buy two computing tablets for field data collection at $500 each. It is recommended that PCWA purchase 48 spare small meters for rotating sampled meters that fail bench test accuracy requirements. The total estimated cost for new field testing equipment and small spare meters is $9,803 without new vehicles.

6.6.5 Staffing Requirements

To handle its own large meter and intermediate meter field testing needs, it is estimated that PCWA will need one two-person testing team working about 13 weeks per year. For annual testing of large meters, the estimated workload is 29 testing team days. For testing intermediate meters every four years, the estimated workload is 35 testing team days. The combined testing team days is 64. For small meter testing on its own test bench, PCWA is estimated to test 24 meters per day using a one-person testing team. Testing the 381 sampled meters will take 15.9 days. The four-meter test train will have six testing cycles each day. Table 24 provides a summary of recommended meter testing requirements and annual costs.

Table 24. Summary of Recommended Annual Meter Testing Requirements: Placer County Water Agency

Meter Size Group	No. of Meters	Testing Team Days (Test, R&R)	Annual Labor Cost
Large	115	29	$24,748
Intermediate	244	35	$30,005
Small	381	16, 20	$6,833, $16,398 (Test, R&R)
Total			**$77,984**

Note: R&R = remove and replace

6.7 San Juan Water District

6.7.1 Current Meter Testing Practices

SJWD has a Mars automatic meter test bench that can test the accuracy of small meters sized through 2-inch, which is the size of the majority of SJWD residential customer meters. SJWD does not have any large meter portable testing units and contracts with an outside meter testing firm on an annual basis. SJWD does not use statistical random sampling.

6.7.2 Existing Testing Equipment

SJWD has a Mars automatic small meter test bench that can test four meters at a time. Because the majority of SJWD customers use one-inch meters, the test bench capability is sufficient. SJWD does not currently own any large meter field test unit.

6.7.3 Recommended Improvements to Meter Testing

It is recommended that SJWD implement field testing of large and intermediate meters with its own staff. This will require the purchase of new testing equipment. SJWD should implement the recommended small meter sampling and testing program with its own test bench and staff (See Table 5). It is recommended that small meters be randomly selected from the deployed population older than 10 years. SJWD should set the criteria for random sampling of small meters to attain a 95 percent statistical confidence interval that the sample results represent the deployed population accuracy results within five percent of the actual value.

SJWD should implement sample testing of 10 percent of all new small meters on its test bench. All large and intermediate meters should be tested in place after installation following the suggested SOP. Turbine, compound, and fire line meters have suggested testing methods designed to help meter performance evaluation.

SJWD should adopt a written large meter and intermediate meter testing SOP for field staff. SJWD should include training for all meter brands and types used by SJWD. Meter staff should be trained on field testing of various meter sizes, types, and manufacturers and repair in the field. To justify its own large meter field testing program, SJWD should write a scope of work and solicit estimates from qualified private testing firms.

Small meter SOPs should have been included with SJWD's purchase and installation of its test bench.

6.7.4 Recommended New Testing Equipment

The use of the existing City of Sac large meter test bench is not as economical as field testing in place because on-site testing is less disruptive and less expensive. Use of the large meter bench should include certification testing of field meter testing units for SJWD and other Consortium agencies for which witnesses are required. Pulled large and intermediate meter testing on the test bench may also be appropriate for autopsy and comparison with field results.

For new field testing equipment, the suggested size is three inches with a bypass for both large meter and intermediate meter groups. The estimated cost for this unit is $5,500 per meter. Based on testing volume recommendations and frequencies for SJWD, the agency needs one new portable testing unit. Associated hoses and fittings for the one unit are estimated to cost $1,000. If SJWD needs to purchase new vehicles for transporting the test unit, the unit cost of a new utility truck is $30,000. SJWD should buy two computing tablets for field data collection at $500 each. One is a spare. Spare parts for the one testing unit are estimated to cost $100. It is recommended that SJWD purchase 48 spare small meters for rotating sampled meters that fail bench test accuracy requirements. The total estimated cost for new field testing equipment and small spare meters is $26,662 without new vehicles.

6.7.5 Staffing Requirements

To handle its own large meter and intermediate meter field testing needs, it is estimated that SJWD will need one two-person testing team working four weeks per year. For annual testing of large meters, the estimated workload is seven testing team days. For testing intermediate meters every four years, the estimated workload is 12 testing team days. The combined testing team days is 19.

For small meter testing on its own test bench, SJWD is estimated to test 24 meters per day using a one-person testing team. Testing the 371 sampled meters will take 15.5 days. The four-meter test train will have six testing cycles each day. Table 25 provides a summary of recommended meter testing requirements and annual costs.

Table 25. Summary of Recommended Annual Meter Testing Requirements: San Juan Water District

Meter Size Group	No. of Meters	Testing Team Days (Test, R&R)	Annual Labor Cost
Large	28	7	$5,994
Intermediate	83	12	$10,184
Small	371	16, 19	$6,619, $15,885 (Test, R&R)
Total			**$38,682**

Note: R&R = remove and replace

6.8 Regional Topics Common to All Consortium Agencies

6.8.1 Common Study Goals

One of the primary reasons the Consortium authorized the Study was to assess what possible costs could be shared for meter testing and maintenance, potential future meter change-outs, and upgrades based on long-term testing results and upgraded meter reading systems. It was perceived that sharing the costs for testing and maintenance, at minimum, may have some great benefits. As data was collected and reviewed for existing equipment, how each staff conducted testing, and how test data was generated, there were reported differences in how each agency viewed meter testing. These differences are not major stumbling blocks to comparing and contrasting meter testing methodologies, costs, or cost-sharing opportunities. One Study goal is to obtain and leverage actionable meter test data for meter system planning and upgrades while demonstrating methods to determine revenue recovery thresholds required to obtain self-sufficiency for meter accuracy test programs.

Basic meter testing costs are similar for all agencies. Consortium agencies share common goals for reducing revenue loss, meeting the challenges of the upcoming state rules on water loss control, and using the meter test data to develop policies for meter change-outs.

6.8.2 Suggested Actions for Testing

A brief description of current testing methods has been taken from the interviews conducted with each agency at the beginning of Phase 3. Included was each agency's use or not of contracted testing services for large meter testing on site (at the meter location).

Recommended improvements for meter testing presented above by agency will result in a more efficient use of equipment and workforce. The first area concerns large and intermediate meter testing. It is the consulting team's recommendation that the agencies that currently practice on-site testing for large meters continue to do so but incorporate the intermediate meter testing on site as part of the testing schedule. The main reason for testing intermediate meters on site is that the cost is less than the cost of removing the meter from the setting, transporting it to the meter testing facility for testing, and then returning it to inventory to be redeployed or reinstalled in the original meter setting. In addition, the consulting team recommends the adoption of the methods in the recommended testing SOP for on-site testing to gain a better understanding of how to use meter testing as a diagnostics tool for overall meter performance. The SOP proposed for the agencies has been in use for almost 40 years by the consulting team for field testing and takes into account the benefits of the consulting team's exposure to several meter types and brands and thousands of settings. Additionally, consulting team staff is actively involved with AWWA Manuals M6, M22, and M36 and has used the knowledge gained from committee discussions on meter testing and accuracies. The proposed SOP for testing includes more diagnostic testing than what is currently in the existing meter testing SOPs. The additional testing and evaluation may require extra effort but will add additional useful data for long-range meter replacement planning.

6.8.3 Equipment Recommendations

It is recommended that agencies without portable field meter testing units purchase portable testing units, along with the assorted fittings and hoses needed, to facilitate the testing process in the field. Existing service vehicles (e.g., pickup truck, small van, trailer) could be used by the field staff. Since agencies may already own available service vehicles needed for field testing of large and intermediate meters, vehicle costs were not included as mandatory costs. The roughly estimated portable tester costs are based on Badger equipment. Agencies without equipment can discuss use and maintenance with those that have it. Agencies may want to collect the test data via a tablet (cost estimated at $500 each) where the data can be downloaded at the end of each day or through an application to upload the testing data directly into the agency's meter database. The collection of test data can be made in Microsoft Excel or another field application. The meter database can be used to create an individual meter report. The time variable history will provide a meter performance record for that account and setting. Digital photographs of meters, settings, and tests can enhance the database. The database allows for meters to be grouped and evaluated by size, type, brand, model, and age. Meter use trending, repairs, consumption patterns, longevity, and accuracy performance can be sorted as desired.

6.8.4 Portable Test Assemblies

Portable test assemblies can be purchased from meter manufacturers and meter test bench manufacturers. A utility can also construct or fabricate its own assembly. The test range of the assembly is critical. It needs to be able to test low flow rates for the 1.5- and two-inch intermediate meters and compound type meters (requiring low flow testing ability at 0.5 gpm) but also handle flow rates to at least 350 gpm. The size of the test port and fire hose used to connect the test meter to the customer meter will limit the flow rate of the test meter. Test port sizes vary but are usually one inch up to two inches. A two-inch test port can produce 350 gpm (or more if the pressure is higher), and sometimes 450 gpm can be achieved. One meter manufacturer has a more expensive four-inch testing assembly that is rated at 1,250 gpm. Even if 1,250 gpm was able to be attained in the field for a flow test, discharge volume will be an issue. A three-inch test assembly will likely provide enough testing flow rate capacity for the sizes of meters in the Consortium.

Meter testing trucks and trailers can also be outfitted with automatic test benches at a higher cost. Typical portable testers consist of a three-inch turbine meter for testing high flows and a smaller 5/8-inch mechanical test meter.

6.8.5 Portable Test Staffing

Existing and proposed new staffing levels for each agency were assessed. Based on the predicted average field testing of four large meters per day per two-person testing team and seven intermediate meters per day per two-person testing team, each agency can accommodate field testing of the three-inch and larger meters each year and 25 percent of the intermediate meters each year.

If the meter testing schedule seems too aggressive or the cost of testing proves to be too high for the year, the threshold revenue amount for the breakeven point of testing can be customized for each agency. The example threshold point of $14,000 annual revenue per large meter used in the cost examples was based on the consulting team’s experience. The average CRUC for agencies is considerably lower than those reported nationwide for other audits.

The sharing of portable testing equipment could also be considered. If an agency completes the large and intermediate meter testing in a three- or four-month period based on expected productivity levels, the portable test meter could be available for use by another agency. Large and intermediate testing services could be also shared. If one agency falls behind on its testing schedule, another agency could assist in the testing process.

The Consortium should consider the assembly of a meter test group made up of individuals from each agency that would conduct large and intermediate meter testing at all 1.5 inch and larger meter locations. It is estimated that seven two-person testing teams would be needed to handle the workload of all agencies combined. The agencies can use a different annual revenue threshold per large meter. This could allow a different test interval. If some three- and even four-inch meters do not produce $14,000 per year annual revenue, the test interval can be increased to two years. That scenario would reduce the workload to allow six field testing teams or less.

6.8.6 Continued Use of the Large Meter Test Benches

Two agencies (Folsom and City of Sac) can test large and intermediate meters on their test benches. Folsom is limited to meters up to four inches in size, while the City of Sac can test meters up to 16 inches in size. The consulting team recommends testing the large meters on site because of the cost and effort to remove the meter, transport it to the meter testing facility, test it, and return it back to the setting. If the agency has a spare meter the same size and type, the meter can be replaced and the old meter tested at the meter testing facility. However, this means that agencies would need to have a stock of spare meters for the exchange in the field. Meter testing facility testing is also inconvenient for the customer. Meter physical and hydraulic settings have bearing on how a meter functions; therefore, removing the meter for testing negates any setting analysis that may influence the meter's performance. The consulting team recommends that agencies use the large meter test benches when needed and convenient because the test benches already exist and are paid for, installed, and operational. The large test benches can be used by other agencies to flow test the field meter testers so that the field testers do not have to be sent to the manufacturer for testing. The field testers should be checked every six months for accuracy since they are the basis for comparative accuracy of all deployed large and intermediate meters.

6.8.7 Outside Contractor Meter Accuracy Testers

The use of outside contractor testers should also be evaluated. A few agencies already employ the use of outside firms to perform on-site field meter accuracy testing. Other agencies that do not have a current large meter and intermediate on-site meter testing program should look at fees currently charged by private testers. When estimating meter testing costs and justifications for testing in this technical memorandum, the cost of testing consisted of the current salary ranges paid by the agencies applied to a daily average of meters that would be tested. Truck roll costs were not included in the per-meter price calculations. Private contractor test fees include all costs plus a markup for profit. Truck roll costs will be included with per diem cost (if the firm is from out of town). Private testing services and fees will vary. An interview process may be needed to ensure the quality of the service and confidence in testing results.

Agencies need to look closely at testing protocols used and quality assurance by an outside contracting firm. Testing methods can be vastly different, but each firm claims that their results meet or fail AWWA accuracy limits. Reporting the test results is critical, and agencies need access to the test results through a database. Will the outside firm provide a paper report, or will the results be available in a database, such as Microsoft Excel? Can the data be exported to other database formats? What data will be collected for each test (e.g., digital photographs, Global Positioning System (GPS) of meter location)? How many tests and flow rates will be recorded? How will data be gathered in the field (tablet or paper)? Will the firm schedule the testing with the customer? Will the agency need to provide field assistance (an added hidden cost)? Will the contractor do more than test the meter at three flow rates (low, medium, and high), or will they employ the use of alternative flow testing rates to fully diagnose the meter? Does the test firm have a testing SOP that will satisfy the agency or match the suggested SOP for testing included in this technical memorandum? Will the test firm provide a conditions assessment and make recommendations for improvement at the meter box or vault? Will all meter test limiting factors be identified and reported?

6.8.8 Small Meter Testing

Small meter testing is being performed by four of the seven agencies on small meter test benches. The other three agencies should look at test bench sharing with at least one of the four agencies. While estimating the costs of small meter testing, the assumption was made that all agencies have access to a meter test bench at similar costs based on labor rates. Costs for removal and re-installation of sampled small meters were calculated based on current labor rates, along with the assumption that 20 meters per day could be changed out by a two-person testing team. The number of change-outs per day is dependent on the sampling location routing of the testing team. Proper routing maximizes efficiency.

The agencies with existing test benches should continue using them. Three of the four agencies use automatic test benches in which meters are installed and flow rates are automatically set for each accuracy test. PCWA has a manual bench in which flow rates are set by the meter technician, and test data is manually recorded instead of logged into a proprietary database. The City of Sac has test data for its 24-stand bench (a single serial meter test line that allows 24 meters to be tested at a time) recorded into a proprietary database (from the meter test bench manufacturer). This does not allow for data to be exported or retrieved for analysis. The upgrade to be able to extract that data for reporting will be costly. The City of Sac could still record the meter test results on a tablet that then exports the data to the City of Sac database as a less expensive method for data collection and extraction until the proprietary database issue is resolved.

The recommended small meter testing strategy is to select meters for testing from a statistically significant random sample of meters 10 years and older based on each agency's small meter population. Approximately 371 to 383 meters would be selected each year for testing. It is suggested that the City of Sac share its bench with SSWD and SCWA because neither agency has a small meter test bench and they are geographically close to the City of Sac. CHWD could have its meters tested by either Folsom or the City of Sac. Details on testing fees would need to be worked out. The other agencies with test benches (PCWA and SJWD) should continue to use their test benches.

Small meter testing procedures and the level of testing productivity needs to be looked at when the electronic meters (static meters) are tested on the meter test benches. Per the AWWA C-715 Meter

Specification, ultra-low flows used for 5/8-inch and 0.75-inch meters will require extra time to test. In addition, any agency with a test bench that has any 5/8-inch and 0.75-inch static meters or will perform testing for another agency that has these meters will need to modify the test bench to perform the required ultra-low flow test procedure. Static meters tested on a test bench will require extra upstream and downstream laying lengths of pipes to provide the correct conditioned flow for the testing. Consequently, testing productivity decreases because it will take more time to test the same number of meters.

6.8.9 Proposed Large and Intermediate Meter Testing Standard Operating Procedure

The SOP outlined in this technical memorandum in Section 5 for large and intermediate meters follows accepted practices for meter accuracy testing per the AWWA Manual M6 but includes additional guidance. The SOP is designed to be used as a diagnostic tool for meter performance. It was originally based on the testing of mechanical meters by providing ways to evaluate test results and diagnose meter issues before the meter is disassembled for repair. This SOP will have value for several more years pending full conversion to newer static meters that have no moving parts. The flow tests used for mechanical meters can also be applied to static meters because the AWWA-accepted accuracy limits apply to both designs.

Small meter SOPs were not proposed for agencies with meter test benches because the benches generally come with testing procedures in the owner’s manual. Test bench manufacturers will often offer training for the meter test benches when the bench is sold and installed at the utility.

6.8.10 Database Development and Management

There are several ways meter testing data can be recorded and tracked. A common method is using Microsoft Access (a relational database) to input Microsoft Excel data from field testing to facilitate accuracy reports, schedule tests, and track overall meter performance.

Several municipal asset management programs can be customized to fit the Consortium agencies’ requirements for collecting field testing data. An application for tablet data collection could be composed by one agency and shared with other agencies. Applications can be customized to fit each agency’s size and data collection needs. This development is another opportunity for cost-sharing and supports the concept for a single meter testing division. If agencies choose to maintain their own meter testing and installation teams, then the Consortium can still consider a shared database system or have independent systems that can communicate with each other without having to translate independent data. Agencies need to decide what meter testing information to collect and how the data should be organized, managed, shared, and reported.

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Appendix A. Interview Summary

Interview Summary

Program Status	City of Sacramento	Sacramento Suburban Water Agency	Sacramento County Water Agency	City of Folsom Water	Citrus Heights Water District	Placer County Water District	San Juan Water District
Meter testing Program	Yes, not formal. Test 10% of all new meters	Large Meter (LG M) testing	No formal program	Yes, not formal, but has structure	No formal program , looking to implement program	Yes, program performed	Yes, not formalized.
Type of Testing (Current)	All bench tests (no field tests currently)	Bench and Field	Limited on selected LG M '07-'09, '10. No testing now.	Bench & Field (All Commercials annually)	Occasional Field tests (2019 1"meter samples) Some tests in 2018	Bench and Field (in house)	Bench and Field (3rd party)
Equipment Field Testing (Inter. & LG M)							
Portable Test Meter							
Portable 3" Test meter w bypass	No Field LG test meter	LG M Portable tester (Badger)	Does not own LG M portable tester	Assume LG portable test meter	Own Mars SM M tester. Does not own LG M Portable tester.	Badger LG M test meter	SJWD does not own LG M portable tester.
Hoses, fittings	No Field LG test meter	LG M Portable tester, with hoses	Does not own LG M portable tester	Assume LG portable test meter, hoses, too.	Own Mars SM M tester. Does not own LG M Portable tester.	Badger test meter, assume hoses, too.	SJWD does not own LG M portable tester. 3rd party performs testing
Utility Truck (Transit Connect, pickup truck)	Fleet Vehicle	Fleet Vehicle	Fleet Vehicle	Fleet Vehicle	Fleet Vehicle	Fleet Vehicle	Fleet Vehicle
LG M (3" <) Test in Place	Current: No LG M Test program in place.	Current: 37 - 6" tested every yr. 3" & 4" are 5 yr. intervals, performed in house	Current: No LG M test program. Last LG M testing done 2007 & 2010.	Current; 100-125 LG M Tested annually.	Current: Combo of in house testing and 3rd party for LG M tests. 2018 tests 52 M with over 1/3rd failure rate. Repairs/replacements done	Current: 10 yr. rotation, 1100 1-1/2" and larger test 100 – 180 LG M in-situ in-house, and 3rd party. 6"-8" tested every yr.	Current: >=3" tested every yr. 3rd party.
LG M (>=3") count	2421	447	334	172 (Count from inventory) interview stated over 500 LG M exist so, discrepancy in count (?)	86	115->=3"	28
Intermediate M	Current: No Inter. M Test program in place. R&R on 10yr. program.	Current: No Inter. M Test program defined.	Current: No Inter. M Test program in place.	Current: Inter. M classified as SM M. Testing only done selectively	Current: No formal Inter. M Test program in place. Appears to have 1-1/2" and 2" lumped with SM M as far as testing goes	Current: Inter. M classified as LG M. These get tested on 10 yr. rotation (see above)	Current: No formal Inter. M Test program in place.
1.5" meter count (per agency)	3415	1026	1687	152	573	606	169
2" meter count	3779	1411	1360	704	613	370	164
SM Meters							
SM Meters count	121,892 (121,494 are 1")	39,788 5/8"-1"	50,073 55k SM M per interview. Approx. 3,000 Billed Unmetered Acc'ts	20,454 (Agency includes Inter M as part of SM M Count so the total is over 22,000)	18,683	36,102	10,093 1" and smaller (majority are 1")
Current Agency Bench Testing status	Yes -24 -1" stand with separate LG Meter Bench	Outsources to 3rd party testers	No Bench testing, no meters sent out to 3rd party for tests. SM M testing done in 2012 (15 selected)	Yes - 4 stand. Staff training & Certs for Bench 2.25.2020	No test bench. Not performed regularly. Had 56 tested in 2019 onsite using Mars portable tested by staff. Dble check 8 tested by SAC City. Determined most w/in AWWA Acc limits	Yes - 4 stand older bench (Ford). Manual bench w/rotometers	Yes, 1" - 4 stand bench
Meter Testing Budget (from Interview)	None stated in interview	Ops budget - $ not defined	None stated in interview	$150k-$200K/yr.	Ops budget - $ not defined	$50k/yr.	None stated in interview
Meter Test SOP?	No	Yes, specific to LG M	No	Yes, specific to LG M	No.	Yes, specific to LG M, and a separate one for SM M.	Yes, specific to LG M
Meter Failure?	If meter fails test, replace	If LG M fails test, rebuilt and retested. SM M replaced.	Meters with reported problems get replaced	If meter fails test, replace	If meter fails test, replace	If meter fails test, replace	If meter fails test, replace
Sample meter test reports?	No, assume reports are PDF from Test bench output	Yes	No	Yes	Yes	Yes	None given at interview, assume Agency has a form

Interview Summary

Program Status	City of Sacramento	Sacramento Suburban Water Agency	Sacramento County Water Agency	City of Folsom Water	Citrus Heights Water District	Placer County Water District	San Juan Water District
Condition triggering test?	High Bills, billing issues	High Bills, billing issues	When Accounting indicates possible issue, high bill	High Bills, billing issues	When Accounting indicates possible issue, high bill	High Bills, billing issues	High Bills, billing issues
Test SOP Training?	OJT but no formal program	OJT for all new testing staff	No Meter test Training SOP in place, OJT	OJT but no formal program (except new bench instructions)	OJT but no formal program	OJT but no formal program. Staff attends workshop, specific staff perform tests on bench	OJT but no formal program, specific staff perform tests on bench.
Agency Needs/wish list	Fix M Test Bench software or come up with alternative solution	Need to create/modify SOP's for SM, INT, LG meter testing.	Create meter testing program for SM, intermediate, LG meters. Create SOP's for each testing procedure. (Bench testing for SM, field testing for INT, LG meters)	Formalize the meter testing program.	Formalize M testing program for all sizes of meters.	Small meters - implement a random selection process for the small meters selected for bench testing.	SOP on SM, Intermediate, and LG meter tests, even though LG meters are tested by 3rd party.
	Set up on site testing for field *Test meter, hoses, training, etc.)	SM need to have random selection process set for sample testing. Need to look at sharing meter test bench with neighboring utility (Sac City) for small meter testing.	SOP for R &R of small meters	Invest in Meter testing classes for staff	SOP for testing (all sizes) needs to be created.	Intermediate Meters – increase testing frequency of the 1.5" and 2 " meters so that these are tested every 4-5 years.	SOP on change outs
	Set Intermediate, Sm M test program	Interval for INT and LG meter testing needs to be set.	Invest in portable test meter along with fittings, vehicle (existing or new) for the INT, LG meters.	Increase the number of meters being tested to reflect sizes/years from suggested testing table	Use of a meter test bench (neighboring Utility for small meters, develop random sampling for SM meter testing selection.		SOP on use of meter test bench
	Possible to share bench with other agencies.	Purchase test bench	Need Meter testing classes for staff.	Small meters - increase sample size to meet confidence levels for annual program. Partner with other neighboring utility (Sac City?) for the small meter testing on the test benches.	Develop intermediate and LG M testing program for onsite testing.	Large Meters – 3"< should be tested every year.	SOP on SM meter testing using random selection
	Testing for the larger meters needs to include right sizing, vault evaluations.		Look at sharing meter test bench with neighboring utility that has bench (Sac City).	Intermediate meters - increase testing interval since these meters generate a significant portion of revenue; test these meters on site.	Testing for the larger meters needs to include right sizing, vault evaluations.	Testing for the larger meters needs to include right sizing, vault evaluations.	Intermediate M make up a significate part of the population and should be given higher level of consideration for testing.
				Large Meters – set testing levels for >= 3" for annual testing.	Training program for staff for LG M testing	Make use of data collection (field tablet) to gather test data.	
					Investment into portable test meter for intermediate and large meters for on-site tests	Create meter testing SOPs based on sizes/types of meters	
					Investment into use of utility vehicle (existing or new) for testing.		

Appendix B. Cost Inventory Table

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Full Random

Program Status	City of Sacramento	Sacramento Suburban Water Agency	Sacramento County Water Agency	City of Folsom Water District	Citrus Heights Water District	Placer County Water District	San Juan Water District
Type of Testing (Current)	All bench tests (no field tests currently)	Bench and Field	Limited on selected LG M '07-'09, '10. No testing now.	Bench & Field (All Commercials annually)	Occasional Field tests (2019 1"meter samples)	Bench and Field (in house)	Bench and Field (3rd party)
Equipment Field Testing (Inter. & LG M)							
Portable Test Meter Costs							
Badger 3" Test meter w bypass	$5,500.00	$5,500.00	$5,500.00	$5,500.00	$5,500.00	$5,500.00	$5,500.00
Hoses, fittings	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00
Utility Truck (Transit Connect, pickup truck)	$30,000.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00
Meter Testing Costs (InSitu)							
Hourly Fee for Tech	$59.00	$59.60	$55.00	$55.00	$55.00	$53.80	$53.52
2 - person crew: Daily fee	$944.00	$953.60	$880.00	$880.00	$880.00	$860.80	$856.32
LG M (3" <) Test in Place each yr.	Current: No LG M Test program in place.	Current: 37 - 6" tested every yr. 3" & 4" are 5 yr. intervals	Current: No LG M test program.	Current; 100-125 LG M Tested annually.	Current: Combo of in house testing and 3rd party for LG M tests.	Current: test 100 – 180 LG M in-situ in-house, and 3rd party.	Current: 3" ≤ tested every yr. 3rd party.
Unit Cost per meter = 4/meter tests/day (LG Size average)	$236.00	$317.87 (3 meters/day)	$220.00	$220.00	$220.00	$215.20	$214.08
LG M (3" <) count	2421	447	334	172	86	115	28
Total cost/yr.	**$571,356.00**	**$142,086.40**	**$73,480.00**	**$37,840.00**	**$18,920.00**	**$24,748.00**	**$5,994.24**
# days for 1 - 2 person test crew to complete tests	605.3	111.8	83.5	43.0	21.5	28.8	7.0
Intermediate M (4 yr. intervals) Test in place	Current: No Inter. M Test program in place.	Current: No Inter. M Test program defined.	Current: No Inter. M Test program in place.	Current: Inter. M classified as SM M. Testing only done selectively	Current: No formal Inter. M Test program in place.	Current: Inter. M classified as LG M.	Current: No formal Inter. M Test program in place.
Unit Cost per meter =7/meter tests/day (Inter Size average)	$134.86	$238.40 (4 meters/day)	$125.71	$125.71	$125.71	$122.97	$122.33
1.5" meter count (per agency)	3415	1026	1687	152	573	606	169
25% per year	853.75	205 (20% /yr)	421.75	38	143.25	151.5	42.25
2" meter count	3779	1411	1360	704	613	370	164
25% per year	944.75	282.2 (20%/yr.)	340	176	153.25	92.5	41
Total cost/yr.	**$242,540.57**	**$116,196.16**	**$95,762.86**	**$26,902.86**	**$37,274.29**	**$30,005.03**	**$10,184.09**
# days for 1 - 2 person test crew to complete tests	256.9	87.0	108.8	30.6	42.4	34.9	11.9
Current Agency Bench Testing status	Yes -24 -1" stand with separate LG Meter Bench	Occasional use of other agencies' benches	No Program	Yes - 4 stand bench	Not performed	Yes - 4 stand bench	Yes, 1" - 4 stand bench
Meter Bench test costs	Sample Size	Sample Size	Sample Size	Sample Size	Sample Size	Sample Size	Sample Size
Sm M Count	121,892	39,788	50,073	20,454	18,683	36,102	10,093
**Sm M Selection count based on 95% table from Small meter Random Selection Strategy for 3 sizes (.625", .75", 1") of SM Meters	383	381	383	378	377	381	371
Percentage of SM M Pop for sample	0.31%	0.96%	0.76%	1.85%	2.02%	1.06%	3.68%
Meters per day: R & R of meters at settings (one day, R & R on site, 2 person crew)	20	12	20	20	20	20	20
# of days needed to pull sample size	19.15	31.95	19.15	18.9	18.85	19.05	18.55
Hour wage for Tech	59	59.6	55	55	55	53.8	53.52
Daily Crew fee (2 person crew)	$944.00	$953.60	$880.00	$880.00	$880.00	$860.80	$856.32

Full Random

Program Status	City of Sacramento	Sacramento Suburban Water Agency	Sacramento County Water Agency	City of Folsom Water District	Citrus Heights Water District	Placer County Water District	San Juan Water District
Cost for R &R for annual sample	$18,077.60	$30,276,80	$16,852.00	$16,632.00	$16,588.00	$16,398.24	$15,884.74
Test Bench Capacity	24	4	4	4	4	4	4
Bench Assumptions	24 stand for 1"	Assume use of a 12 stand	Assume use of a 4 stand	4 stand	Assume use of a 4 stand	4 stand	4 stand
Tests per day per bench (includes set up/take down on bench)	72	72	24	24	24	24	24
Hour Fee per tech	59	59.6	55	55	55	53.8	53.52
Daily Fee 2 person Crew	$944	$ 953.60					
Daily Fee 1 person Crew			$440	$440	$440	$430	$428
Aver Cost/meter test	$13.11	$13.24	$18.33	$18.33	$18.33	$17.93	$17.84
Sample size count (.625", .75", 1")	383	381	383	378	377	381	371
Total Costs /yr. based on SM M sample size	$5,021.56	$5,046.13	$7,021.67	$6,930.00	$6,911.67	$6,832.60	$6,618.64
Number of days to test annual sample	5.3	15.9	16.0	15.8	15.7	15.9	15.5
Spare meters, parts & inventory							
Meter Brand(s) per agency	Badger	Badger	Sensus	Sensus	Neptune	Badger	Sensus
Est. Cost per spare meter for R & R	$183.40	$183.40	$307.50	$307.50	$343.75	$183.40	$407.55
# meters needed for rotation for R & R	100	48	48	48	48	48	48
Costs for Spare Meters for R & R (one time cost)	$18,340.00	$8,803.20	$14,760.00	$14,760.00	$16,500.00	$8,803.20	$19,562.40
Totals							
LG M (3" <) Test in Place each yr.							
Total test cost/yr.	**$571,356.00**	**$142,086.40**	**$73,480.00**	**$37,840.00**	**$18,920.00**	**$24,748.00**	**$5,994.24**
Intermediate M (4 yr. intervals for 1.5", 2") Test in place							
Total test cost/yr.	**$242,540.57**	**$116,196.16**	**$95,762.86**	**$26,902.86**	**$37,274.29**	**$30,005.03**	**$10,184.09**
Total Costs /yr. based on SM M sample size							
Cost for R &R for annual sample	$18,077.60	$30,276.80	$16,852.00	$16,632.00	$16,588.00	$16,398.24	$15,884.74
Total bench test cost/yr.	**$5,021.56**	**$5,046.13**	**$7,021.67**	**$6,930.00**	**$6,911.67**	**$6,832.60**	**$6,618.64**
Total Costs (R & R and tests) Bench Tests SM M	**$23,099.16**	**$35,322.93**	**$23,873.67**	**$23,562.00**	**$23,499.67**	**$23,230.84**	**$22,503.38**
Total Costs Insitu Tests Inter & Large M (1.5" <)	**$813,896.57**	**$258,282.56**	**$169,242.86**	**$64,742.86**	**$56,194.29**	**$54,753.03**	**$16,178.33**
Total Annual Testing Costs	**$836,995.73**	**$295,605.49**	**$193,116.52**	**$88,304.86**	**$79,693.95**	**$77,983.87**	**$38,681.71**
Agency notes	Labor fees assigned because SAC City did not break down hr. fees in Inventory table. .	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for SJ. 3rd party test fees appear to average out to $143/test for large meters by dividing meters tested by total fee charged for the yr.

Modified Random

Program Status	City of Sacramento	Sacramento Suburban Water Agency	Sacramento County Water Agency	City of Folsom Water District	Citrus Heights Water District	Placer County Water District	San Juan Water District
Type of Testing (Current)	All bench tests (no field tests currently)	Bench and Field	Limited on selected LG M '07-'09, '10. No testing now.	Bench & Field (All Commercials annually)	Occasional Field tests (2019 1"meter samples)	Bench and Field (in house)	Bench and Field (3rd party)
Equipment Field Testing (Inter. & LG M)							
Portable Test meter costs							
Badger 3" Test meter w bypass	$5,500.00	$5,500.00	$5,500.00	$5,500.00	$5,500.00	$5,500.00	$5,500.00
Hoses, fittings	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00	$1,000.00
Utility Truck (Transit Connect, pickup truck)	$30,000.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00	$30,000.00
Meter Testing Costs (InSitu)							
Hourly Fee for Tech	59	59.6	55	55	55	53.8	53.52
2 - person crew: Daily fee	$944.00	$953.60	$880.00	$880.00	$880.00	$860.80	$856.32
LG M (3" <) Test in Place each yr.	Current: No LG M Test program in place.	Current: 37 - 6" tested every yr. 3" & 4" are 3-4 yr. intervals	Current: No LG M test program.	Current; 100-125 LG M Tested annually.	Current: Combo of in house testing and 3rd party for LG M tests.	Current: test 100 – 180 LG M in-situ in-house, and 3rd party.	Current: 3" ≤ tested every yr. 3rd party.
Unit Cost per meter = 4/meter tests/day (LG Size average)	$236.00	$238.40	$220.00	$220.00	$220.00	$215.20	$214.08
LG M (3" <) count	2421	447	334	172	86	115	28
Total cost/yr.	**$571,356.00**	**$106,564.80**	**$73,480.00**	**$37,840.00**	**$18,920.00**	**$24,748.00**	**$5,994.24**
# days for 1 - 2 person test crew to complete tests	605.3	111.8	83.5	43.0	21.5	28.8	7.0
Intermediate M (5 yr. intervals) Test in place	Current: No Inter. M Test program in place.	Current: No Inter. M Test program defined.	Current: No Inter. M Test program in place.	Current: Inter. M classified as SM M. Testing only done selectively	Current: No formal Inter. M Test program in place.	Current: Inter. M classified as LG M.	Current: No formal Inter. M Test program in place.
Unit Cost per meter =7/meter tests/day (Inter Size average)	$134.86	$136.23	$125.71	$125.71	$125.71	$122.97	$122.33
1.5" meter count (per agency)	3415	1026	1687	152	573	606	169
20% per year	683	205.2	337.4	30.4	114.6	121.2	33.8
2" meter count	3779	1411	1360	704	613	370	164
20% per year	755.8	282.2	272	140.8	122.6	74	32.8
Total cost/yr.	**$194,032.46**	**$66,397.81**	**$76,610.29**	**$21,522.29**	**$29,819.43**	**$24,004.02**	**$8,147.27**
# days for 1 - 2 person test crew to complete tests	205.5	69.6	87.1	24.5	33.9	27.9	9.5
Current Agency Bench Testing status	Yes -24 -1" stand with separate LG Meter Bench	Outsourced	No Program	Yes - 4 stand	Not performed	Yes - 4 stand	Yes, 1" - 4 stand bench

Modified Random

Program Status	City of Sacramento	Sacramento Suburban Water Agency	Sacramento County Water Agency	City of Folsom Water District	Citrus Heights Water District	Placer County Water District	San Juan Water District
				Meter Bench test costs			
Sm M Count	121,892	39,788	50,073	20,454	18,683	36,102	10,093
	Sample Size	Sample Size	Sample Size	Sample Size	Sample Size	Sample Size	Sample Size
**Sm M Selection count based on approx. 1/2 of 1% for 3 sizes (.625", .75", 1") of SM Meters. SAC City is full random. SJWD is 70 total.	383	190	250	102	100	190	70
Percentage of SM M Pop for sample	0.31%	0.48%	0.50%	0.50%	0.54%	0.53%	0.69%
Aver Age	6.6	8.8	13.3	9	16.8	11.8	14.4
Meters per day: R & R of meters at settings (one day, R & R on site, 2 person crew)	20	20	20	20	20	20	20
# of days needed to pull sample size	19.15	9.5	12.5	5.1	5	9.5	3.5
Hour wage for Tech	59	59.6	55	55	55	53.8	53.52
Daily Crew fee (2 person crew)	$944.00	$953.60	$880.00	$880.00	$880.00	$860.80	$856.32
Cost for R &R for annual sample	$18,077.60	$9,059.20	$11,000.00	$4,488.00	$4,400.00	$8,177.60	$2,997.12
Test Bench Capacity	24	4	4	4	4	4	4
Bench Assumptions	24 stand for 1"	Assume use of a 4 stand	Assume use of a 4 stand	4 stand	Assume use of a 4 stand	4 stand	4 stand
Tests per day per bench (includes set up/take down on bench)	72	24	24	24	24	24	24
Hour Fee per tech	59	59.6	55	55	55	53.8	53.52
Daily Fee 2 person Crew	$944						
Daily Fee 1 person Crew		$477	$440	$440	$440	$430	$428
Aver Cost/meter test	$13.11	$19.87	$18.33	$18.33	$18.33	$17.93	$17.84
Sample size count (.625", .75", 1")	383	190	250	102	100	190	70
Total Costs /yr. based on SM M sample size	**$5,021.56**	**$3,774.67**	**$4,583.33**	**$1,870.00**	**$1,833.33**	**$3,407.33**	**$1,248.80**

Modified Random

Program Status	City of Sacramento	Sacramento Suburban Water Agency	Sacramento County Water Agency	City of Folsom Water District	Citrus Heights Water District	Placer County Water District	San Juan Water District
Number of days to test annual sample	5.3	7.9	10.4	4.3	4.2	7.9	2.9
Spare meters, parts & inventory							
Meter Brand(s) per agency	Badger	Badger	Sensus	Sensus	Neptune	Badger	Sensus
Est. Cost per spare meter for R & R	$183.40	$183.40	$307.50	$307.50	$343.75	$183.40	$407.55
# meters needed for rotation for R & R	100	48	48	48	48	48	48
Costs for Spare Meters for R & R (one time cost)	$18,340.00	$8,803.20	$14,760.00	$14,760.00	$16,500.00	$8,803.20	$19,562.40
Totals							
LG M (3" <) Test in Place each yr.							
Total test cost/yr.	**$571,356.00**	**$106,564.80**	**$73,480.00**	**$37,840.00**	**$18,920.00**	**$24,748.00**	**$5,994.24**
Intermediate M (5 yr. intervals for 1.5", 2") Test in place							
Total test cost/yr.	**$194,032.46**	**$66,397.81**	**$76,610.29**	**$21,522.29**	**$29,819.43**	**$24,004.02**	**$8,147.27**
Total Costs /yr. based on SM M sample size							
Cost for R &R for annual sample	$18,077.60	$9,059.20	$11,000.00	$4,488.00	$4,400.00	$8,177.60	$2,997.12
Total bench test cost/yr.	**$5,021.56**	**$3,774.67**	**$4,583.33**	**$1,870.00**	**$1,833.33**	**$3,407.33**	**$1,248.80**
Total Costs (R & R and tests) Bench Tests SM M	**$23,099.16**	**$12,833.87**	**$15,583.33**	**$6,358.00**	**$6,233.33**	**$11,584.93**	**$4,245.92**
Total Costs Insitu Tests Inter & Large M (1.5" <)	**$765,388.46**	**$172,962.61**	**$150,090.29**	**$59,362.29**	**$48,739.43**	**$48,752.02**	**$14,141.51**
Total Annual Testing Costs	**$788,487.61**	**$185,796.47**	**$165,673.62**	**$65,720.29**	**$54,972.76**	**$60,336.96**	**$18,387.43**
Agency notes	Labor fees assigned because SAC City did not break down hr. fees in Inventory table.	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for Agency.	Labor fees taken from Costs Inventory table for SJ. 3rd party test fees appear to average out to $143/test for large meters by dividing meters tested by total fee charged for the yr.

Assumptions: SM M samples were set to be approx. 1/2 of 1% of SM M pop. so that selection could be made on meters older than 10 years. SAC City would be selected via full Random selection for SM M for every year. Intermediate meter samples would be every 5 YRS. or 20% of Intermediate pop. selected in rotation each year. LG M tested every yr. Some agencies already test LG M every year. Cost of meters used for rotation is a one-time cost for the 10 yr. period.

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Appendix C. Recommended Large Meter Field Testing Standard Operating Procedures

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Recommended Large Meter Field Testing Standard Operating Procedures

Daily Preparation and Clean Up Actions

- Start of Day – review test location list, form a route plan using Google Maps, and be prepared to adjust when necessary.
- End of Day – clean all tools used and put away, restock parts used, check testing equipment for issues, and load up any equipment that you might need for the following day that isn't on the truck (example: meter bodies and pipe fittings). Check fire hose for cuts or damage. Also, proofread your paperwork for errors and turn in paperwork. Report any problems to your manager.

Required Safety and Compliance

- Never walk more than 5 feet away from an open vault lid if you are the assigned Attendant for confined space entry.
- Be equipped with gas detector, ventilator, vault protection, and all other PPE.

Communication with the Customer

1. Begin the project by contacting the project manager to go over all details of the entire testing goals, requirements, and project.
2. Call the water customers you are going to be working for, introduce yourself, and let them know when the testing will be starting. Set up a meeting with meter staff to go over the meters that are going to be tested.

   Questions that should be asked during the client kick-off meeting:

   a. Who will be our contact in the field in case of a broken valve, backflow preventer dumping, or difficult to schedule meters?
   b. What fire hydrants in town are we allowed to use as the water source to test meters with no test ports?
   c. May we obtain letters from the utility to give to their customers explaining who we are and what we are trying to accomplish if you have not received them yet.
   d. Are we repairing any of the meters that are out of calibration or will the utility staff?
   e. Are there any customers that will be difficult to schedule, and will you be able to assist with the scheduling of those meters?

3. Plan out your route using Google Maps to help group the meters together for time management.
4. Go to one of the addresses on your list. Contact the manager\landlord\property manager and explain who you are and that you need to inspect the meter. Inspect the meter.

a. Make sure all information needed for the paperwork/tablet is filled out. It is important that you know who your contact will be for this customer/building and their contact information, including email and cell phone, if applicable (helps create paper trail). It is also important that all the meter's serial numbers, register ID numbers, and AMR/AMI ID numbers are recorded. This is how staff can identify meters within the data system.
b. Is this meter in a confined space? Will you need any permits or special tools for this meter test? Are there any hazards involved?
c. Is the meter accessible?
d. Are there any illegal connections or was the bypass open upon arrival? This should be reported.
e. Are there any booster pumps that need to be shut down during testing?
f. Does the meter setting and isolation valves appear to be in good condition?
g. Is the meter bypassed or will there be a water interruption involved with this test? Estimate how long the water will be off and schedule the appointment for the test. Did you get the name and cell phone number of the person meeting with you for this appointment?
h. Is the bypass undersized?
i. Repeat this process until meter test schedule is full or until all meters are inspected.

Meter Testing

Safety – Check Working Area

1. Look for drains capable of removing water flow.
2. Look for possible problems caused by water on walking\working surfaces.
3. Take time to care for the water customer's private property and ask for things that can be damaged to be moved.
4. Wear proper PPE during meter testing. Must at least wear safety glasses and steel toe boots.
5. May need arrow boards or traffic control during testing.
6. Be aware of electrical components.
7. Be aware of fire protection system sensors. (Hitting one of those sensors will send off a silent alarm, and the fire department may be called without you knowing.)

Shutting Down or Using Bypass

1. Make sure the customer contact is notified in advance if a shutdown is needed.
2. Open the bypass valve first if bypass line exists.

   a. Work all valves slowly (If you operate the valves quickly you may cause water hammer).
   b. Exercise the valves to get a good shut down. If you exercise the valve 3 or more times with no improvement, then the valve must be replaced to make the meter testable.

c. You can easily break a valve by putting too much torque on it when closing it down. Do not use a cheater bar on the valves. You may use a 14” Bergman Safety Spanner Wrench on valves 4” or larger to help shut down the valve. Do not use a pipe wrench. (Pipe wrenches chew up the hand wheels on the valve.)

3. Shut outlet valve in meter setting next.
   a. If there is a ball valve attached to the test port of the meter, then you must shut the inlet valve to the meter setting in order to verify a good shut down in case the meter will need repair work.
4. Shut inlet valve in meter setting.
   a. If there is a backflow preventer at the meter setting, then shut the outlet valve to the backflow preventer first. Then, shut the inlet valve to the backflow preventer before shutting the inlet valve for the meter. This will help prevent the backflow preventer from losing pressure and dumping water from the relief port.
   b. If installing a 1.5” or 2” jumper pipe with a tee and valve for testing, loosen flange bolts on both ends of meter, making sure of complete shutdown before removing meter, Remove bolts while supporting meter and then remove meter. Install jumper assembly with gaskets, and tighten bolts finger tight. Adjust jumper if needed, then tighten bolts. Slowly turn water back on and check for leaks before installing meter on tee for testing.

Removing the Test Port Plug

If you feel pressure on the plug when removing it (if you cannot remove it by hand after loosening it with your ratchet or large wrench), or if there is water spraying from the test port plug, then look for a way to relieve pressure.

1. You can relieve the pressure by loosening the top case bolts but be careful not to take the bolts out of the meter body all the way in case there is still a lot of pressure in the system. Also, do not loosen the top case bolts if the main case gasket is an O-ring. The gasket can blow out and would then need to be replaced.
2. You can also relieve pressure from the #1 test port on the backflow preventer if the BFP is closed.
   a. If you open the #1 test port on the backflow preventer and no water comes out be sure to check the port to see if it is clogged. This is common and, just because no water sprays from the #1 test port on the backflow preventer doesn’t mean the water is completely shut down.
   b. You can exercise the valves to remove debris from the valve seat. This will help achieving a good shut down.

Miscellaneous Steps

1. Install proper test fitting or pipe nipple; be sure to use Teflon Tape (t-tape) on all the threads of the fitting.
2. Connect fire hose. Avoid over-tightening hose to fitting.
3. Install dechlorination assembly on downstream outlet of the test meter. Follow dechlorination procedures for discharge of water during testing.
4. Open inlet valve slowly and allow the hose to fill.
   a. Make sure you "walk the hose" as it is filling to make sure the connections are not leaking or that the hose did not get caught under/near an obstacle.
5. Once the hose is pressurized, open the valve on the test meter slowly to bleed the air out of the line and zero out the test meter.
   a. Be sure not to run higher flow rates than the test meter or the meter at the customer meter setting can handle.
6. Run the appropriate tests for the meter type and size.
   - The order you should run your flow rates are:
     - Minimum (Min.)
     - Below Change Over (B.C.O.)
     - Intermediate (Inter.)
     - Maximum (Max)
     - Change Over (C.O.)
     - Above Change Over + 10 gpm (A.C.O.)
7. If the meter fails any test flow rates, run a second set of tests to confirm the test results. If the results are different, a third set of tests may need to be run. Experienced meter testers will be able to look at the test results and determine what is mechanically wrong with the meter before any repair work is started. If a meter repair is conducted, the water to the test meter will need to be depressurized before the meter can be opened for inspection and repair. Once the repairs/adjustment are made, the meter will need to be retested to verify the repairs brought the meter within accuracy limits.

Un-Pressurizing the Test Meter & Hose

1. Shut the inlet valve to the meter setting.
2. Instruct your technician to de-pressurize the hose by opening the high side valve on the test meter, letting the water drain out of the hose.
3. Remove hose from the meter fittings and drain the hose. Ensure that, when draining and rolling the hose, you do not damage any of the customer's property. Also, clean up after the test if any water was spilled on the floor.

4. Remove all fittings that you have attached to the meter setting.
5. T-Tape the test port plug and reinstall the plug into the meter top case. Avoid over tightening and cross threading.

Re-Pressurizing the Customer Meter

1. Turn on the inlet valve to the meter setting.
2. Slowly, turn on the outlet valve, allowing pressure to build in the building.
   a. If there is a backflow preventer in the meter setting then open the inlet valve to the meter setting first, then open the inlet valve to the backflow preventer keeping the backflow preventer always pressurized. This will help prevent the backflow preventer from losing pressure and dumping water from the relief port.
   b. Slowly, turn on the outlet valve, allowing pressure to build in the building.
3. After the building is pressurized, double check that all valves are fully open to the meter setting and that the bypass is closed and sealed (if applicable).

Cleaning Up

1. Check that you have all fittings and tools before you leave.
2. Check your paperwork to ensure that it is all filled out correctly. Also, take pictures of the meter and upload them to database. Do a meter setting drawing, if necessary.
3. Check the meter to make sure there is water moving through the meter. This will help you determine if there is a problem when opening the valves.
4. Check for any garbage or water that needs to be cleaned up before you leave the customer premise.
5. If the outside temperature is going to fall below 32 degrees, then you must put salt down on wet surfaces.

Testing the Large Meter

1. **Safety**
   a. Keep in mind your surroundings and think of the best place to run water displaced by the test.
   b. Possible consequences of failing to follow this step include but are not limited to:
      i. Water flooding something
      ii. Water freezing a sidewalk or driveway
      iii. Water running into meter vault
      iv. Water destroying landscape
2. **Running the Test Meter Fire Hose**
   a. Avoid over-tightening connections.
   b. Strategically locate the hose

    i. Is the hose in danger of getting cut?
    ii. Will the hose be in the way of personnel at the facility you are working at?
    iii. Don’t run fire hose out a window or under a door jam.
    iv. Use clean hose on carpeted area.

3. **Pressurize the Test Meter & Fire Hose**
    a. Letting air out of the line:
        i. The high side valve on your test meter should be slightly opened to allow the air to bleed out of the line. The low side of your test meter should be shut to keep debris from damaging the smaller meter.
    b. If testing water is from a fire hydrant, both valves on the test meter should be off until the hydrant is completely open.
        i. Do not “overspeed” the test meter or the meter being tested (according to size and type).

4. **Run Appropriate Test**
    a. Avoid slamming the valves shut or opening the valves quickly on your test meter during the testing process.
        i. This can cause a water hammer and break infrastructure.
    b. Run the appropriate test according to the technician testing the customer’s meter.
    c. Tell the technician testing the meter if you have not run the proper amount of water during the test. If the test water amount is off, tell the technician by how much so the appropriate correction can be made in the math calculation for accuracy.
        i. The technician should repeat the amount of water run through the test meter in order to ensure accurate tests.

5. **De-pressurizing the Fire Hose and Clean Up.**
    a. Wait for the meter tester to tell you “pressure” meaning to let pressure out of the test meter\fire hose by opening the 3” valve on your test meter slowly.
    b. Open the low side valve on your test meter, draining the water from the hose and test meter.
    c. Roll up the fire hose tightly. Make sure the water is draining in an appropriate place and not damaging the customer’s property.

6. **Helpful Hints**
    a. In cold weather, keep the test meter in the warm vehicle to keep from freezing when not in use.
    b. Cover the test meter during periods of rain or snow to keep the test meter from becoming damaged.
    c. Keep sandwich bags in your vehicle to cover and protect the electronic register heads on your test meter when it is raining or snowing.

Appendix D. Technical Memorandum No. 4 – Long-Term Planning

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SUBMISSION DRAFT

Meter Replacement Program Planning Study

Technical Memorandum No. 4
Long-Range Planning

December 2020

Prepared for:

Prepared by:

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Agency-Owned	**Agency-Owned** is an advanced metering infrastructure (AMI) network configuration in which the agency procures, operates, and manages the wireless communication hardware and network.
AMI	**Advanced metering infrastructure** is a collection of wireless communication equipment that enables a utility to remotely collect meter data at regular intervals.
AMR	**Automatic meter reading** is a method of collecting meter data through radio-frequencies by walking or driving near the deployed meters.
AWWA	**American Water Works Association**
Backhaul	**Backhaul** is a method of transferring information from data collectors to the AMI headend system; options include Ethernet, fiber optics, landline telephone, broadband over power line, General Packet Radio Service, Cellular Digital Packet Data, Institute of Electrical and Electronics Engineers 802.11 (Wi-Fi), 802.16 (WiMAX), 802.15.4 (ZigBee), 802.15.3 (ultra-wideband), and most recently low-power wide-area networks.
BAU	**Business as Usual** refers to planning scenarios in which future conditions do not change from what decisions an agency has already made regarding those future conditions. For the purposes of this Study, the BAU scenarios are baseline long-term planning scenarios.
CCA	**Cellular Coverage Analysis** includes the evaluation of cellular coverage radius and the coverage probability of an actual network and a network quality assessment.
ccf	**hundred cubic feet**
CHWD	**Citrus Heights Water District**
Consortium	**Water Meter Replacement Program Consortium** includes Carmichael Water District, Citrus Heights Water District, City of Folsom, City of Sacramento, Fair Oaks Water District, Golden State Water Company, Orange Vale Water Company, Placer County Water Agency, the Regional Water Authority, Sacramento County Water Agency, Sacramento Suburban Water District, and San Juan Water District.
CoS	**City of Sacramento**
DCU	A **data collection unit**, also known as a "collector," "gateway," or "base station," is a data collection device installed throughout an AMI network on infrastructure such as poles, buildings, water tanks, or towers to capture meter readings and transmit this data to the a headend system;

	depending on signal propagation and internal data capacity capabilities, one DCU can be used to collect meter data for thousands of meter endpoints.
Encoder	An **encoder** is a meter register specially equipped for automated meter reading (automated register).
Endpoint	An **endpoint** is a device that is connected by wires to an encoder and transmits digitized water use data to a meter reading system.
Folsom	**City of Folsom**
Headend System	**Headend System**, also referred to as the "meter control system," is hardware and software that receives meter data sent to the utility through meter reading technology.
Intermediate Meters	**Intermediate Meters** are meters that have a 1.5-inch or two-inch water flow capacity.
IT	**Information Technology**
Large Meters	**Large Meters** are meters that have a three-inch flow capacity or larger.
LCD	**Liquid Crystal Display**
LTE	**Long-term Evolution** is a standard for 4G wireless broadband technology for cellular device users.
LTE-M	**LTE-M** (also known as "eMTC" and "Cat-M1") is a Low-Power Wide-Area Network technology suitable for low-bandwidth Internet of Things applications. LTE-M uses licensed spectrum just like Narrowband Internet of Things.
MG	**Million Gallons**
MIU	**Meter Interface Unit**
MRP	**Meter Replacement Program**
NaaS	**Network as a Service** is a business model for delivering enterprise-wide area network services virtually on a subscription basis.
NPV	**Net Present Value** analyzed the cash flows of investment decisions over time.
O&M	**Operations and Maintenance** includes activities and costs for operating and maintaining equipment required for metering system functionality.
PCWA	**Placer County Water Agency**

PD	**Positive Displacement** pertains to a mechanical meter type that consists of either a nutating disc, oscillating piston, turbine, or vertical turbine to measure flow.
RF	**Radio Frequency** refers to a wireless electromagnetic signal used as a form of communication in the range 10^4 to 10^{12} Hertz, which is suitable for use in telecommunication.
SCWA	**Sacramento County Water Agency**
SJWD	**San Juan Water District**
Small Meters	**Small Meters** are meters that can have a one-inch water flow capacity or smaller.
Solid-State Meter	**Solid-state Meters** pass electromagnetic or ultrasonic signals through the flow of water to determine the flow rate without any moving parts.
SSWD	**Sacramento Suburban Water District**
Study	**MRP Planning Study**
Total Registered Consumption	**Total Registered Consumption**, also referred to in this Study as "consumption,". It is the total quantity of water that has been recorded by a meter's register.
WAN	**Wide-Area Network** is a telecommunications network that extends over a large geographical area for the primary purpose of computer networking.

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Executive Summary

Long-term planning helps water agencies effectively allocate the resources they need to monitor, assess, replace, operate, and maintain their meters and associated components in an efficient and cost-effective manner. The purpose of this Technical Memorandum No. 4 is to provide recommended meter replacement strategies, meter reading strategies, and financial forecasts for the Water Meter Replacement Program Consortium (Consortium) agencies.

Meter Replacement. A meter replacement strategy informs long-term utility asset and business planning. It provides a basis for anticipating and quantifying the timing and amount of meter investments needed to meet an agency's desired level of service. Meter replacement criteria serve as a tool to identify meters for replacement and when replacement should occur. Meter test data provided primarily by the City of Sacramento (CoS) was analyzed to develop recommendations for Consortium small meter replacement criteria. Intermediate and large meters are recommended to be replaced based on the results of a scheduled test rotation (see Technical Memorandum No. 3).

The results indicate that small (mechanical) meter accuracy decreases primarily at low-flow rates with minimal changes at intermediate- and high-flow rates as meters age and register consumption. The analysis also indicates that total registered consumption is a more significant determinant of changes in accuracy than its deployed age. Consortium agencies are recommended to replace between four and five percent of small meters per year, prioritizing (1) meters that have more than five million gallons (MG) of total registered consumption or (2) meters that are more than 25 years old. Consortium agencies are recommended to replace or rebuild ten percent of intermediate meters per year. Large meters should be rebuilt based on the results of regularly scheduled testing (see Technical Memorandum No. 3).

Table ES-1. Annual Meter Rebuild/Replacement Summary

Meter Type	Replacement Factors	CHWD	CoS	PCWA	SCWA	SJWD	SSWD	Total
Small (1-inch & smaller)	Target Annual Replacement (4%-5%)	798–998	4,876–6,095	1,433–1,791	2,003–2,504	412–515	1,466–1,832	**10,988–13,735**
Intermediate (1.5 & 2-inch)	Estimated Annual Rebuild/Replacement (10%)	119	719	97	304	27	244	**1,510**
Large (3-inch & larger)	Estimated Annual Rebuild/Replacement (7.5%)	7	182	9	26	2	32	**233**

Notes: CHWD = Citrus Heights Water District, CoS = City of Sacramento; PCWA = Placer County Water Agency; SCWA = Sacramento County Water Agency; SJWD = San Juan Water District; SSWD = Sacramento Suburban Water District

Meter Reading. A meter reading strategy provides a basis for anticipating meter reading costs and proactive management of the meter reading platform. Currently, Consortium agencies employ several different meter reading systems. Propagation studies were requested from multiple

Advanced Metering Infrastructure (AMI) vendors based on the information provided in Technical Memorandum No. 2. Badger, Neptune, Sensus, and Zenner submitted studies. The submitted results were evaluated in terms of (1) the system's ability to provide economy-of-scale benefits at the Consortium level and (2) existing experience with the systems among Consortium agencies.

The propagation studies revealed that the Badger ORION cellular and Sensus FlexNet systems are capable of providing benefits at the Consortium level and within a relatively short timeframe (because they are already widely deployed across the Consortium). Both systems offer comparable capabilities for their managed networks (including customer portals and data analytic platforms). It is also important to clarify that final decisions about the least cost alternative will depend on formal bid processes. Thus, the costs discussed herein are not considered final offerings from the participating vendors and are meant to only compare the differences between types of options and potential economies of scale as follows:

- The **Sensus FlexNet platform** can cover the Consortium-wide service area with fewer data collection units (DCUs) than the other evaluated systems. The advantage of a Consortium-level network configuration is that the endpoints have a greater range and, therefore, require less infrastructure to cover multiple agencies, which could provide a less costly and more redundant network compared to alternative systems.
- The **Badger ORION platform** offers flexibility in the speed at which agencies can deploy the system. This is because it employs existing commercial cellular networks for collecting meter data and does not require additional investments in network data collection hardware. This flexibility is an important advantage of this system over the alternatives. For example, it can be deployed for a portion of an agency's meters. However, the provided endpoint pricing and service unit fee were higher than those provided by Sensus. This factor must be considered when evaluating the costs over time for each agency's system needs at full scale.

Most agencies are currently able to deploy endpoints for either the Badger ORION cellular or Sensus FlexNet systems. Though the SJWD does not currently use either AMI system, it could continue to deploy Sensus endpoints for use with its existing Automatic Meter Reading (AMR) drive-by system. This would streamline a future shift to a Sensus FlexNet AMI system if the SJWD chose to do so in the future. The Citrus Heights Water District (CHWD) could take a similar course and use the Sensus AMR system as an interim solution.

Consortium agencies are recommended to place all deployed endpoints on a 15-year preventive replacement schedule in order to reduce the time and effort agencies spend identifying, diagnosing, and replacing failed endpoints. The primary consideration for endpoint replacement is warranted battery life.

Financial Analysis. Agency-specific financial scenarios are presented for a 15-year planning period. The analysis estimates the annual capital and operation and maintenance (O&M) costs for meter hardware replacement and meter reading. Badger ORION cellular, Sensus FlexNet (NaaS), and Sensus (agency-owned) meter reading scenarios were compared with business-as-usual (BAU) scenarios for each agency.

Table ES-2 shows projected annualized hardware costs for each agency over the 15-year planning period assuming best-case unit pricing as a result of joint (Consortium) purchasing arrangements. The key assumption for meters is that, collectively, agencies will be able to secure at least the same pricing as has already been quoted to at least one Consortium member without minimum purchase requirements. However, this should be considered a conservative estimate. Potential Consortium pricing for endpoints was provided by the vendors for the purpose of this Study. The results of a bulk public bidding process may provide better cost savings than what are indicated below.

Table ES-2. Estimated Annualized Meter & Endpoint Replacement Costs

Item	CHWD	CoS	PCWA	SCWA	SJWD	SSWD
Meters	$274,865	$2,011,466	$485,815	$1,127,830	$171,301	$537,785
Endpoints	$275,647	$1,289,429	$326,687	$798,693	$119,438	$223,616
Sales Tax	$24,256	$151,384	$25,716	$69,298	$14,284	$35,549
Material Recycling Fee	$7,918	$75,276	$7,608	$26,392	$3,295	*
Total Hardware Costs	**$582,68**	**$3,527,554**	**$845,826**	**$2,022,213**	**$308,319**	**$796,950**
Potential Cost Savings	**$324,126**	**$0**	**$12,670**	**$596,567**	**$92,410**	**$33,544**

The total annualized labor projections shown in Table ES-3 are based on the most efficient meter and endpoint replacement strategies for each agency. Labor hour projections include meter and endpoint replacements, endpoint troubleshooting and maintenance, pickup reads, and other meter reading needs in the case of some agencies that currently employ manual, touch, or AMR methods.

Table ES-3. Estimated Annual Labor Hours for Meter Replacement and Meter Reading

Item	CHWD	CoS	PCWA	SCWA	SJWD	SSWD
Annualized Labor (hours)	2,826	15,669	5,219	9,026	1,444	3,485

In the next phase, this Study will provide customized implementation plans for each agency. These plans will set a clear course for implementing each agency's desired changes to its meter program based on the findings and recommendations of this Study. The plans will also include recommendations for putting in place key performance indicators that agencies can use to fine-tune their meter testing, meter replacement, and meter reading efforts over time. Finally, the plans will also include recommendations for putting in place the resources and systems to secure Consortium-level benefits that relate to joint purchasing, information sharing, and meter testing.

Section 1 Phase 5 Introduction

1.1 Study Overview

The Meter Replacement Program (MRP) Planning Study (Study) presents a unique opportunity for neighboring water agencies in the greater Sacramento area to explore potential benefits of working together. Water MRP Consortium (Consortium) agencies understand that the utilities of the future will operate in a different paradigm—one that is largely built on public and stakeholder trust, along with cooperation and collaboration with adjoining entities with common interests and economic benefit.

The purposes of the Study are as follows:

- Develop a water meter replacement strategy for participating water agencies.
- Determine the feasibility and a strategy, as appropriate, for long-term, full, or partial integration of MRPs for participating water agencies.

Figure 1 shows the range of potential individual versus cooperative development and implementation of water meter and water meter reading technology replacement for the participating water agencies.

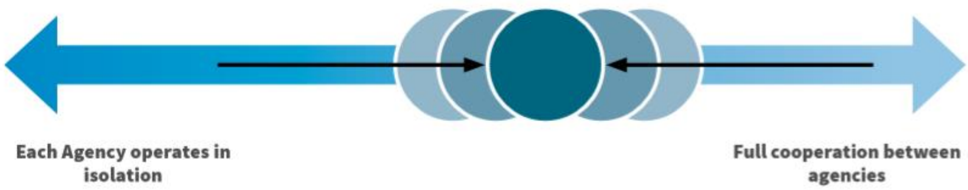

Figure 1. The purpose of the Study is to determine how participating water agencies can sensibly integrate their metering programs over time.

Agencies participating in this phase of the Study include the following:

- Citrus Heights Water District (CHWD)
- City of Sacramento (CoS)
- Placer County Water Agency (PCWA)
- Sacramento County Water Agency (SCWA)
- Sacramento Suburban Water District (SSWD)
- San Juan Water District (SJWD)

Agencies that are members of the Consortium but are not directly participating in this phase of the Study include the following:

- Carmichael Water District
- Fair Oaks Water District
- Golden State Water Company
- City of Folsom (Folsom)

- Orangevale Water Company
- Regional Water Authority

1.2 Introduction to Phase 5

The purpose of Phase 5 is to develop long-term plans for Consortium agency meter programs that balance the priorities and preferences of each individual agency with opportunities to leverage collective efficiencies of scale. Long-term planning recommendations are informed by the results of previous phases, building on the deployed meter inventories and cost information from Phase 1, next generation meter and meter reading options in Phase 2, and meter testing recommendations from Phase 3. Phase 4 is the implementation phase. Phase 5 is being completed before Phase 4 to evaluate the long-term cost implications of the potential meter reading scenarios.

The following three key questions addressed in this Study phase are:

1. **Section 2, Meter Replacement:** When should meters be replaced?
   a. How can data best inform replacement criteria?
   b. Can criteria be flexible enough to function effectively at the Consortium level?
2. **Section 3, Meter Reading Strategies:** Which meter reading systems should be deployed?
   a. Which systems offer benefits at the Consortium level?
   b. Which systems do agencies already have the most experience deploying at the Consortium level?
   c. What are the cost implications of deploying managed (Network as a Service [NaaS]) versus self-managed (agency-owned) systems?
3. **Section 4, Financial Analysis:** What are the financial tradeoffs for meter replacement and meter reading options?
   a. What are the cost savings for joint hardware purchasing (meters and endpoints)?
   b. Can meter and endpoint replacement timing be better synchronized?
   c. What are the cost tradeoffs between AMR (business-as-usual [BAU]), cellular AMI, and fixed AMI networks?
   d. What are the cost saving benefits of AMI compared to AMR?

The recommended approach to long-term planning aims to provide Consortium agencies with greater value over time. The following underlying factors were considered to inform Consortium agencies of robust long-term planning recommendations:

- **Data-Driven Decision-Making –** The ability to modify criteria and schedules as additional data is collected. This will lead to increased cost efficiencies over time.
- **Ability to Adapt –** The ability to adapt to changing conditions (changes in water rates, annual consumption patterns, meter and meter reading technologies, and regulations).

- **Shift Toward Preventive Maintenance –** The ability to replace hardware on a schedule that minimizes failures, rather than expending time and resources to repeatedly address failures. This will lead to operational efficiencies and cost-savings in the form of more predictable costs, resource allocations, and administration.
- **Simplification –** Options that simplify operational responsibilities, such as managed meter reading network options.

1.3 Methodology

The key long-term planning recommendations in Section 5, Conclusions, of this Technical Memorandum No. 4 were derived from the financial analyses in Section 4. The financial analyses are underpinned by the meter replacement strategies in Section 2 and the meter reading scenarios in Section 3. The general methods used for this memorandum are presented in this Section 1.

Meter Replacement – Agency-specific strategies were developed from Consortium-level criteria and informed by meter deployment information collected in Phase 1. Some flexibility was afforded to meter replacement criteria in recognition that there are important distinctions between Consortium agencies. Meter replacement criteria for small meters were based primarily on a CoS meter testing dataset, along with smaller datasets from other agencies, including the SJWD, SSWD, and PCWA. There was insufficient test data to underpin replacement criteria for intermediate meters. Therefore, it is recommended that agencies use the 10-year rebuild schedule employed by SSWD until sufficient test data is collected. Large meter rebuilds should based on the results of regular testing per the recommendations in Technical Memorandum No. 3.

Meter Reading – Meter reading scenarios were developed from the results of propagation studies conducted by several vendors whose systems were presented in Technical Memorandum No. 2. The propagation studies were based on meter and agency-owned asset locations. The meter reading scenarios were selected for further financial analysis based on their potential to provide Consortium-level benefits.

Financial Analysis – Agency-specific financial analyses were developed for meter replacement and meter reading options for a 20-year planning period for BAU scenarios and the scenarios selected from propagation studies prepared by vendors. The analyses estimate potential cost savings from joint meter hardware purchasing and meter reading scenarios that offer Consortium-level benefits. NaaS options were evaluated for meter reading vendors, and an agency-owned alternative arrangement was evaluated for the vendor offering a fixed-network option. Where applicable, benefits in the form of potential savings were incorporated into the financial analyses. Net present values (NPVs) were determined for each cost scenario for agencies to assess the differences in how costs are distributed over time. This is because up-front costs were associated with some meter reading scenarios, while other costs were distributed across the 20-year planning period.

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Section 2 Meter Replacement

A meter replacement strategy serves as a key contribution for long-term utility asset and business planning. It provides a basis for anticipating and quantifying when and how much meter investments are anticipated to occur. The purpose of a meter replacement strategy is to articulate a process for replacing meters efficiently, economically, and in a way that is compatible with future water system operations and potential meter reading systems. An efficient meter replacement strategy is grounded in a robust meter testing regimen. The key tradeoff is between the overall accuracy of deployed meters and the resulting value of lost revenue relative to the cost of replacing, operating, and maintaining meters.

The purpose of this section is to provide customized meter replacement strategies for each agency based on industry best practices and the Consortium's collective evidence base. As agencies continue to collect meter test results, they will be able to continue building this evidence base collectively and further refine and revise their meter replacement strategies.

This section is organized as follows:

- Section 2.1, Key Factors That Influence Meter Performance
- Section 2.2, Analysis of Existing Consortium Small Meter Test Data
- Section 2.3, Meter Replacement Criteria Recommendations
- Section 2.4, Agency Meter Replacement Strategies
- Section 2.5, Areas for Further Research

2.1 Key Factors That Influence Meter Performance

Water meter performance considerations are many and varied. For the purposes of this Study, "performance" is defined as the ability of the meter to accurately measure the amount of water that flows through it over the range of flow rates it experiences in a given setting. Although many factors influence meter performance, this Study identifies the following key factors, which agencies should consider when evaluating meter accuracy test data:

- **Measurement Technology –** Meter performance is influenced by measurement technology. Technical Memorandum No. 2 describes the key differences between mechanical and solid-state (static) meters. The differences in accuracy across various flow rates and deployment times are most relevant to this discussion. Without moving parts, solid-state meters are warrantied to be more accurate at low and ultra-low flows and to maintain accuracy over a longer period of time compared to mechanical meters. Many utility and research meter performance studies validate these technological differences. As presented in Technical Memorandum No. 1, the predominant small and intermediate meter technology for the Consortium is mechanical (positive displacement [PD]).

- **Vendor –** It has been demonstrated that meters that have the same technology but are developed and manufactured by different vendors perform differently. The vendors evaluated in Technical Memorandum No. 2 specify that their meter models will meet or exceed American Water Works Association (AWWA) performance specifications. However, differences in specifications (product data sheets) and warranties occur in most cases. For example, it has been shown that the performance of various models differs over time and that mechanical meters lose accuracy with age and cumulative throughput. As presented in Technical Memorandum No. 1, Badger, Sensus, Neptune, and Zenner are the predominant vendors in the Consortium-deployed meter inventory.
- **Size –** Meter performance varies by size. This is more of a factor for mechanical meters, which are more prone to performance degradation over time than solid-state meters. Criteria should be established for each meter size to account for differences in internal mechanics, flow rates, and uses. As presented in Technical Memorandum No. 1, with the exceptions of the PCWA (5/8 inch) and the SSWD (3/4 inch), the predominant small meter size in the Consortium is one inch. Larger meters have greater flow capacity but are more inaccurate at low and ultra-low flows than typical 5/8- and 3/4-inch meter sizes.
- **Use Patterns –** Meter performance varies based on the range and variability of customer flow rates. This factor encompasses an assortment of conditions. Consortium agencies could consider identifying rates of consumption or performance patterns for meters that are used intermittently (e.g., vacation rentals by owner). These findings could enable Consortium agencies to make meter size adjustments or consider an alternate technology for a given location or use.
- **Meter Composition –** Meter performance also depends on meter materials. Mechanically, models with metal casings (typically copper alloy) are more durable than those in plastic casings. As described in Technical Memorandum No. 2, the Consortium predominantly deploys meters with copper alloy casings.
- **Water Quality –** Delivered water quality is a major factor in meter performance. Meter manufacturers write water quality conditions in their warranties under limitations of liability provisions. Adverse water quality could void the meter accuracy warranty for both mechanical and solid-state meter types. Existing mechanical meter product data sheets also have limits on water temperature (80 degrees Fahrenheit), which if exceeded, may void the accuracy warranty.
- **Meter Installation –** Meter designs have specific manufacturer recommendations for installation. Some designs require specific upstream and downstream pipe diameters, exact horizontal installation, or a screen to be installed upstream to remove particles and to condition the flow. Care must be taken for any manifolding of meters to ensure balanced hydraulics.

2.2 Analysis of Existing Consortium Small Meter Test Data

Meter test data can provide evidence for defensible replacement criteria. The ideal replacement criteria enable agencies to replace meters that no longer perform at the level required. For this Study, AWWA meter accuracy standards were used to set minimum performance levels. These standards are presented in detail in Technical Memorandum No. 2. The purpose of meter testing is to determine the age or cumulative flow points at which a meter is no longer able to meet minimum AWWA accuracy standards. In many cases, AWWA standards do not provide sufficient targets for optimizing economic considerations whereby the meter replacement cost is less than the value of unmeasured water due to meter inaccuracy.

Most Consortium agencies have some accuracy test data for meters that represent those deployed in their service areas. However, the total number of samples is limited and insufficient to draw defensible conclusions about the relationship between the performance of the meter (i.e., its accuracy) and its ability to function properly. Most Consortium agency datasets exist for meters that have been replaced and, therefore, deployed for long periods of time. These meters may not represent the existing deployed meter performance.

One exception is the CoS, which has a larger sample of small meter test results. Meter accuracy test results from the CoS's database were analyzed for two indicators of meter function, age and total registered consumption, to estimate how meter accuracy changes with time of deployment and total consumption. Meter test results were extracted from the CoS's Mars test bench equipment. The data included a registered flow reading at the time of testing. The data was also linked to a deployed meter inventory dataset to associate the accuracy data to age. Once combined, test data was filtered to only include test results that ranged between 50 percent and 110 percent to focus on the performance of functional meters rather than on the entire population of meters tested. Data was organized as follows:

- The largest set of samples included one-inch PD meters. Several models were included in the analysis, but the predominant model was the Badger Recordall 55.
- Test results were controlled by meter technology and size. The sample group included several different mechanical meter models but were predominantly Badger PD meters. There were insufficient samples to analyze meters smaller than one inch or larger than two inches. After cleaning and filtering the data, test values were categorized as shown in Table 1 to develop the estimated change in accuracy by age and consumption for low, intermediate, and high test flows per AWWA Manual M6.

Table 1. City of Sacramento, Number of Low, Intermediate, and High Flow Rate Test Samples by Age and Flow Category

Size	Predominant Model	Age (No. of Samples)				Consumption (No. of Samples)			
		Age (years)	Low	Int.	High	Consumption (MG)	Low	Int.	High
1 inch	Badger Recordall 55	0–5	108	169	168	0–1	914	1,022	1,023
		6–10	117	119	119	1–2	284	297	298
		11–15	40	53	53	2–3	122	127	130
		16–20	52	57	54	3–4	29	30	29
		21–25	615	627	628	—	—	—	—

Notes: MG = million gallons

Consumption – The analysis indicates that accuracy decreases at low flows as consumption increases but does not change substantially at intermediate and high flows. The trend line for average low-flow accuracy crosses the minimum accuracy specification for PD meters, which is 95 percent at approximately 3–4 million gallons (MG). This finding is consistent with the accuracy warranties for many PD meters (see Technical Memorandum No. 2). The distributions of each grouping are also plotted for each consumption grouping (e.g., 0–1 MG, 1–2 MG). The distributions confirm that group sample sizes above 250 MG produce well-distributed results. The results indicate that more samples in the 2–3, 3–4, and higher consumption groupings are needed to produce more robust results (Figure 2).

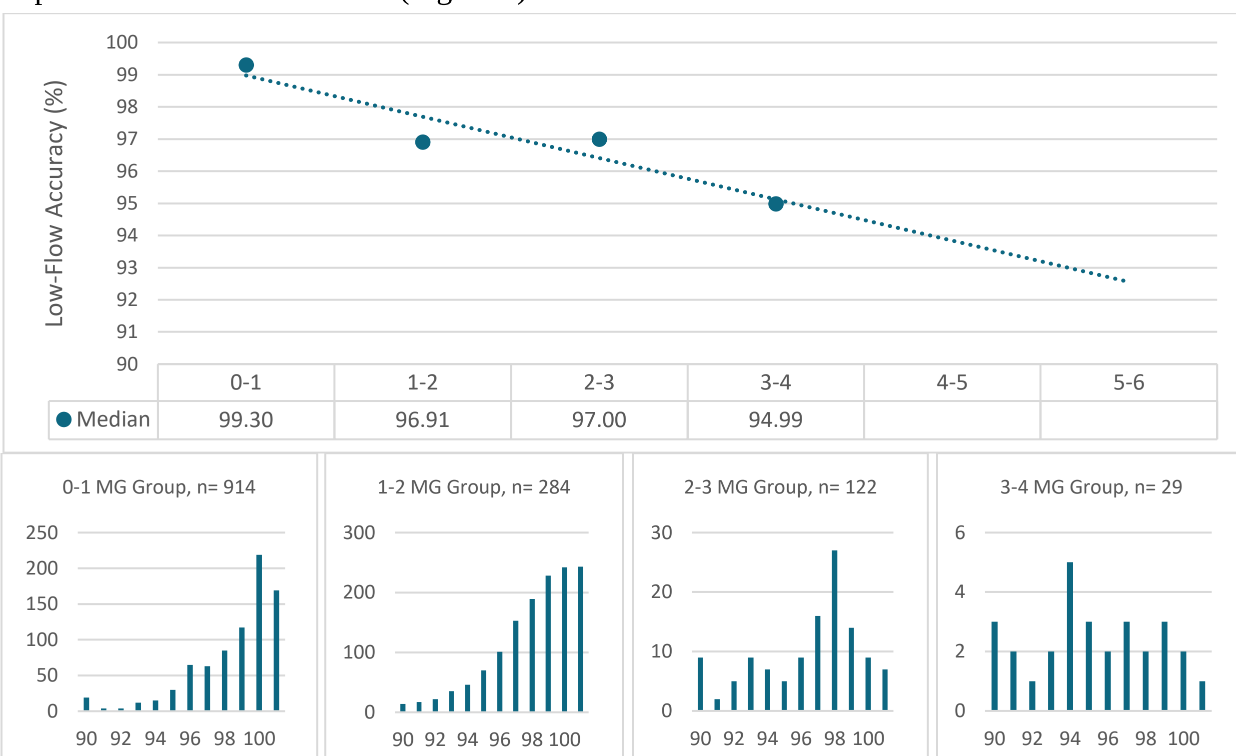


Figure 2. One-Inch PD Meters, Low-Flow Accuracy (%) by Consumption (MG), n = 1,349

Figures 3 and 4 show that little to no change occurs in accuracy versus cumulative flow at intermediate and high flows. As a whole, these findings provide evidence that accuracy changes with total registered consumption primarily only at low flow. This suggests that the overall accuracy of mechanical meters does not degrade significantly because low flow is only estimated to be 15–20 percent of the total flow through a meter. According to the current AWWA M6 Manual (published in 2012 and currently being revised), the percentage of residential flow at low-, intermediate-, and high-flow rates is estimated to be, on average, 15 percent, 70 percent, and 15 percent, respectively. For 1-inch meters, low, intermediate, and high-flow rates are ¾, 4, and 40 gallons per minute (gpm) respectively. It is anticipated that this ratio will change in the upcoming revision to the M6 Manual because of water efficiency improvements. However, even if the ratio of low-intermediate-high flow changes to 20 percent-60 percent-20 percent, overall accuracy will still be marginally affected by changes in the performance of mechanical meters. For example, if a meter's intermediate-flow accuracy is approximately 100 percent, high-flow accuracy is approximately 99 percent, and low-flow accuracy drops to 90 percent; the overall accuracy of the meter only drops to 97.8 percent. The implications of this are discussed further in Section 2.3.

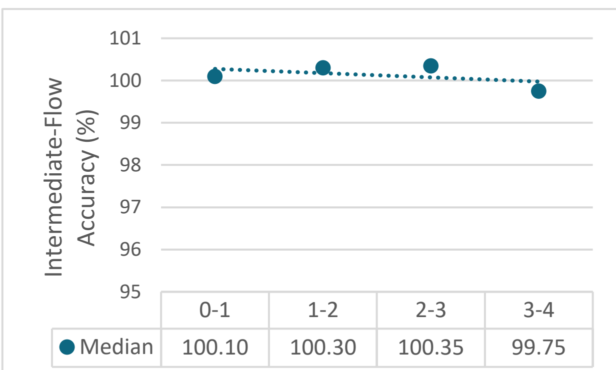


Figure 3. One-Inch PD Meters, Intermediate-Flow Accuracy (%) by Consumption (MG), n = 1,479

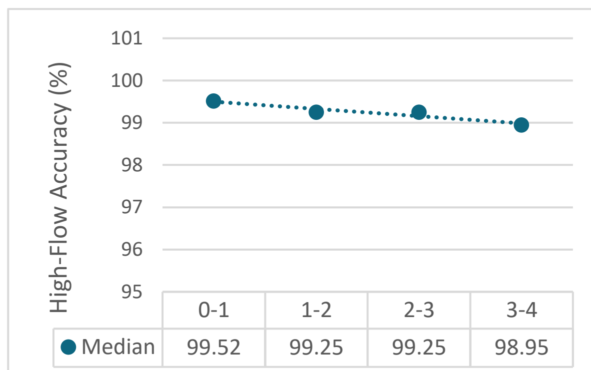


Figure 4. One-Inch PD Meters, High-Flow Accuracy (%) by Consumption (MG), n = 1,451

Age – The analysis indicates that accuracy decreases at low flows with time of service but does not change substantially at intermediate and high flows. However, the decrease in accuracy rate is less than that of accuracy versus consumption. The trend line for average low-flow accuracy does not cross the minimum AWWA accuracy specification for PD meters, which is 95 percent by 25 years of deployment. This result indicates that age alone may not be associated with changes in meter performance in the Consortium agencies' service areas to the same degree as consumption. The distributions of each grouping are also plotted for each consumption grouping (e.g., 1–5, 6–10, 11–15). The 1–5 and 21–25 year groups have the most samples and show well-distributed data (Figure 5).

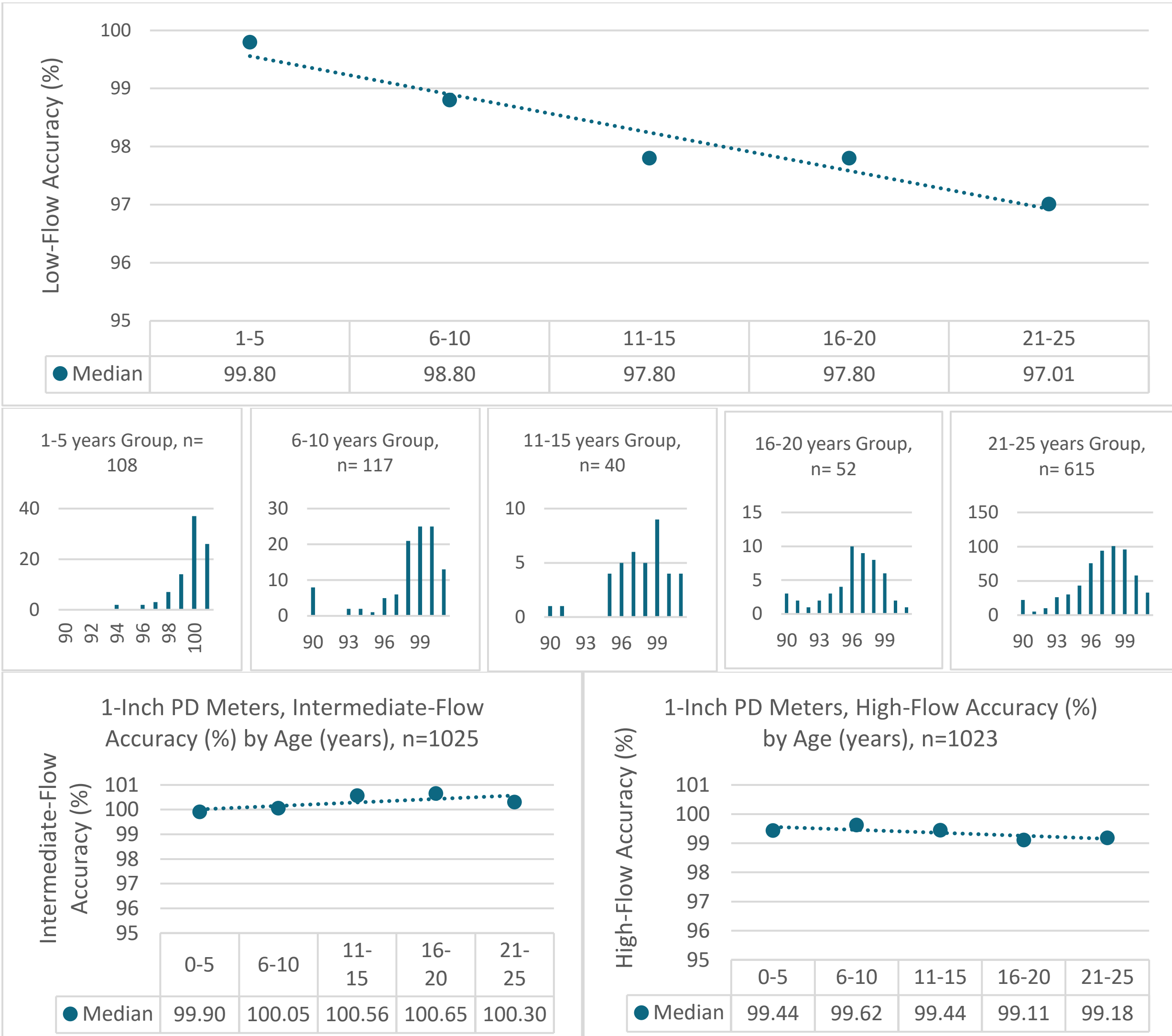


Figure 5. One-Inch PD Meters, Low-Flow Accuracy (%) by Age (years), n = 932

Agency Comparison – Two additional Consortium agency-specific datasets were compared with the CoS analysis (see Figure 6). These datasets were too small to effectively compare results, particularly by consumption groupings. The SJWD results were similar to the CoS results, but accuracy decreased more gradually. However, it should be noted that the number of samples in the the SJWD dataset were smaller than the number of samples in the CoS dataset, which ranged between 30 and 90 samples. The PCWA results were consistently lower than the CoS and SJWD datasets. The number of samples in these groupings was much smaller than that of the CoS dataset (between five and 64 samples). The reasons for the difference between this dataset and the CoS dataset are unclear. One possibility is that meters were out of specification when deployed. Another possibility is that meters may have decreased in accuracy more quickly in the PCWA context where some residences are used more infrequently.

In this “small meter” category, it should be noted that Consortium agencies’ datasets were for different meter sizes, which could have influenced the results. While the CoS and SJWD data were for one-inch meters, the PCWA data was for 5/8-inch meters. In addition, the meter models tested differed. The CoS and PCWA datasets predominantly consisted of Badger Recordall type meters, while the SJWD dataset predominantly consisted of Sensus SR-type meters.

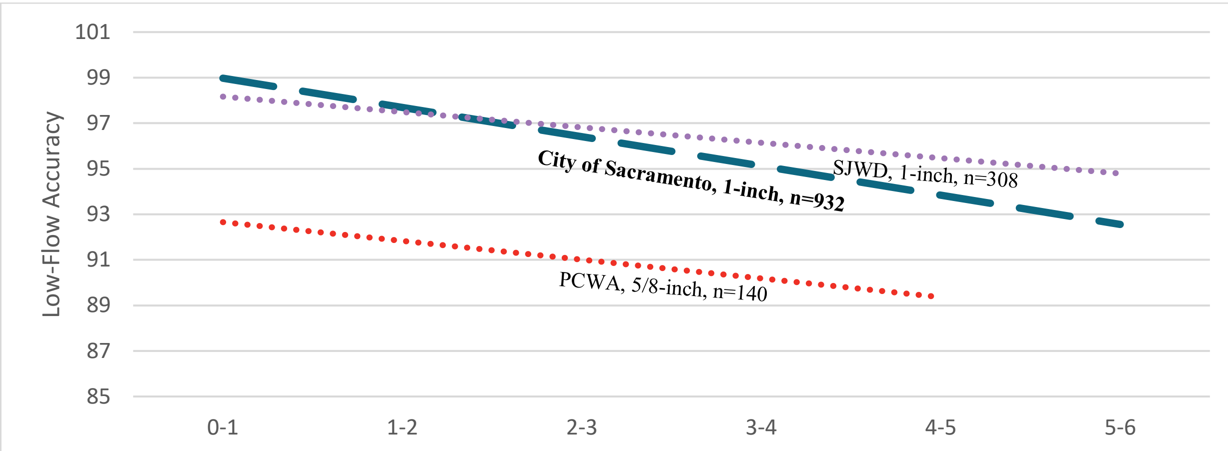


Figure 6. Small PD Meters, Low-Flow Accuracy (%) by Consumption (MG)

The analysis of low-flow accuracy by age is shown on Figure 7. In this comparison, the SJWD dataset is similar to the CoS dataset. Low-flow meter accuracy decreased slightly by age in the SJWD dataset. As with the consumption comparison, the PCWA dataset was an outlier in the age analysis. It should be noted that the sample sizes were much smaller for the PCWA groupings.

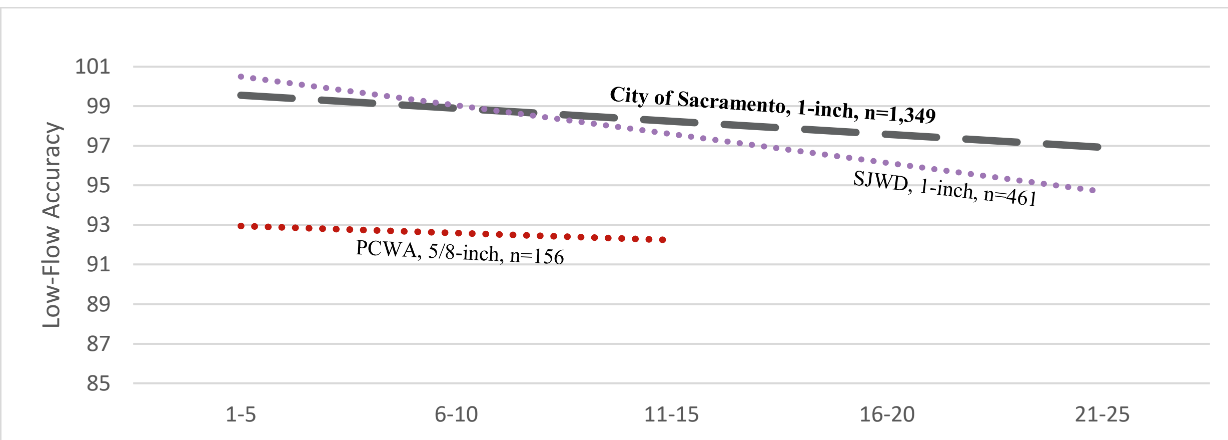


Figure 7. Small PD Meters, Low-Flow Accuracy (%) by Age (years)

2.2.1 Overall Accuracy Implications

Meter testing results indicate that meter accuracy is likely to decrease at flows on the low side but not on the intermediate or high side. The implications of this conclusion depend on the proportion of consumption that happens at low, intermediate, and high flows. For residential meters, the current AWWA M6 Manual recommends using 15 percent, 70 percent, and 15 percent as test result weights for low, intermediate, and high flows, respectively, to indicate overall accuracy. The proportion of low flow is likely to increase relative to intermediate and high flows in the next revision (which is currently in draft form). The expected change reflects the anticipated influence of water efficiency improvements to residential flow rates (Table 2).

Table 2. Overall Meter Accuracy Scenarios Under Different Low-, Intermediate-, and High-Flow Proportions

Accuracy	Proportion of Total Flow	Overall Accuracy
95%	15%	**98.48%**
99%	70%	
100%	15%	
95%	25%	**98.08%**
99%	60%	
100%	15%	
95%	35%	**97.68%**
99%	50%	
100%	15%	
Accuracy	**Proportion of Total Flow**	**Overall Accuracy**
93%	15%	**98.18%**
99%	70%	
100%	15%	
93%	25%	**97.58%**
99%	60%	
100%	15%	
93%	35%	**96.99%**
99%	50%	
100%	15%	

Because low flows only represent a fraction of total flows through a residential meter, changes in overall accuracy are heavily influenced by intermediate and high flows, which the test data indicated do not change with increased consumption and age. This shows that, even in a scenario where low flows compose 35 percent of total flow, overall accuracy would be 97 percent, even when low-flow accuracy drops to 93 percent. Consortium agencies do not currently know what proportion of flow is at the low-flow level, but even if it falls into the 15 to 35 percent range, the overall meter accuracy would range between 97 and 98.5 percent. The test data and analyses did not consider the volume of unmeasured flow for small mechanical meters that could range between five and 10 percent based on recent research. This fact should be considered in meter replacement decisions comparing capabilities and costs of solid-state versus mechanical meters.

2.3 Meter Replacement Criteria Recommendations

The recommended meter replacement criteria for the Consortium reflect the importance of both the financial and technical performance-based implications of replacement scheduling. The analysis of the Consortium’s existing test data in Section 2.2 indicates that consumption-based criteria best reflect changes in meter accuracy. However, Consortium agencies must also account for the financial implications of meter replacement scheduling.

Among Consortium agencies, revenue comes from a combination of fixed and consumption-based rates. This means that revenue is only partially influenced by changes in meter accuracy. Table 3 shows changes in revenue from small meters associated with a one percent change in registered consumption using 2018 consumption rates as a base. The model was based on current fixed and use-based rates (base charges versus commodity charges) and shows that changes in revenue are smaller than changes in registered consumption. For example, a one percent change in registered consumption is associated with a 0.5 percent change in revenue for the PCWA small meters. The changes in revenue indicate the value of overall meter accuracy improvement (and the associated change in registered consumption) or the cost of inaccuracy for each agency.

Table 3. Change in Small Meter Revenue Based On a One Percent Change in Consumption (2018)

Agency	2018 Registered Consumption (ccf)	2018 Calculated Total Revenue	Percent Change in Revenue
CHWD	3,419,278	$13,439,730	0.30%
CoS	15,340,528	$74,644,529	0.30%
PCWA	10,133,124	$35,987,734	0.50%
SCWA	8,084,461	$23,312,884	0.58%
SJWD	4,060,756	$11,273,766	0.33%
SSWD	8,379,064	$29,527,715	0.27%

Notes: ccf = hundred cubic feet

Significant uncertainty remains regarding how deployed Consortium agencies’ meter performance changes with use and time. The CoS dataset provides a suitable basis for setting replacement, but usage patterns will differ between Consortium agencies based on socio-economic factors, family sizes, plumbing fixtures, average lot sizes, and other influences. Regarding the CoS data, register dial turnover, whereby the dials circle back to zero (after 999,999 for a six-digit dial), could influence the analysis for older meters.

While the analysis indicates that registered consumption is the primary determinant of change in meter accuracy performance, a conservative approach to setting replacement criteria is warranted until individual agencies collect more meter testing data. Flexible criteria are proposed to enable individual agencies to tailor their approach to their context.

Small Meters – Based on Consortium meter test results, agencies are recommended to prioritize replacing meters with more than five million gallons in total registered consumption or that are older than 25 years. Agencies should aim to replace between four and five percent of meters per year. Each agency is recommended to perform the following tasks on an annual basis:

- Select meters with the highest total registered consumption that have registered at least five MG. If less than four percent of the total number of deployed meters is reached, then:
  - Add additional meters to replace other meters based on age. Select the oldest meters that are at least 25 years old until the total number of five percent of total deployed meters has been reached or no more meters meet these criteria.
  - If the register fails on a meter that is more than 20 years old, replace the meter and the register and count it as an annual replacement.

Following this process, each Consortium agency will replace between four and five percent of its small meters per year. Agencies with residential customers who use more water on an annual basis will replace closer to five percent per year. Those with residential customers who use less water will replace closer to four percent per year. One advantage of this strategy is that the number and cost (less inflation) of small meter replacements per year will be consistent.

Intermediate Meters – At the time of writing (Q4, 2020), there was insufficient accuracy test results to inform intermediate rebuild or replacement criteria. Thus, it is currently recommended to rebuild or replace intermediate meters on a 10-year fixed schedule. Consortium agencies are also recommended to conduct accuracy testing before and after the rebuilds or replacements in order to establish more informed criteria in the future.

Large Meters – Based on Technical Memorandum No. 3, Consortium agencies are recommended to field test intermediate and large meters on a rotating schedule. Based on test results, agencies can either rebuild or replace the meters accordingly. As stated in the Technical Memorandum No. 3, agencies can anticipate approximately 15 percent of meters to fail testing and require replacement or a rebuild. These assumptions were used as the basis for the agency-specific meter replacement strategies in the following section.

2.4 Agency Meter Replacement Strategies

In this section, the criteria presented in Section 2.3 are used to develop agency-specific replacement strategies. For small meters, the results of CoS’s meter test data analysis provide the Consortium with the most robust basis for its individual meter replacement strategies. Each agency’s strategy is preceded by a brief summary overview of its deployed meter inventory status regarding age of deployment (in years) and total registered consumption (in MG). The two key metrics agencies can use to measure progress over time are average total consumption (MG) and average deployed age (in years).

Agencies can rebuild intermediate and large meters rather than replace them. One exception may be the newer solid-state meters, which cannot be rebuilt due to the integrated electronic components and batteries. The U.S. Environmental Protection Agency Office of Ground Water and Drinking Water has indicated that older meters manufactured and deployed before the 2011 Reduction of Lead in Drinking Water Act can be removed and rebuilt as long as the replacement components meet the lead-free requirements of the act and that the meter is re-deployed in its original location.[1] Rebuilding meters is particularly advantageous for intermediate and large sizes because they register larger volumes of water and are more expensive than small meters.

2.4.1 San Juan Water District

Small Meters – At the time deployed meter data was provided for this Study (Q4, 2019), 3,116 of 10,586 meters exceeded the five MG consumption replacement criterion. Of these meters, 742 have registered more than 10 MG of total usage. Regarding age, 585 of 10,290 small meters have been deployed for 25 years or more (as of 2020).

Per the recommended target to replace four to five percent of small meters per year, the SJWD is recommended to replace between 412 and 515 small meters per year. Given the large number of meters exceeding the five MG consumption replacement criterion, the SJWD should aim to replace 515 meters per year until the number is drawn down. The average annual consumption for small meters from 2016 to 2018 was 271,814 gallons. At this rate, the average meter will cross the five MG threshold in year 19. This indicates that the SJWD may tend toward the large number of replacements (five percent) per year over time (Figure 8).

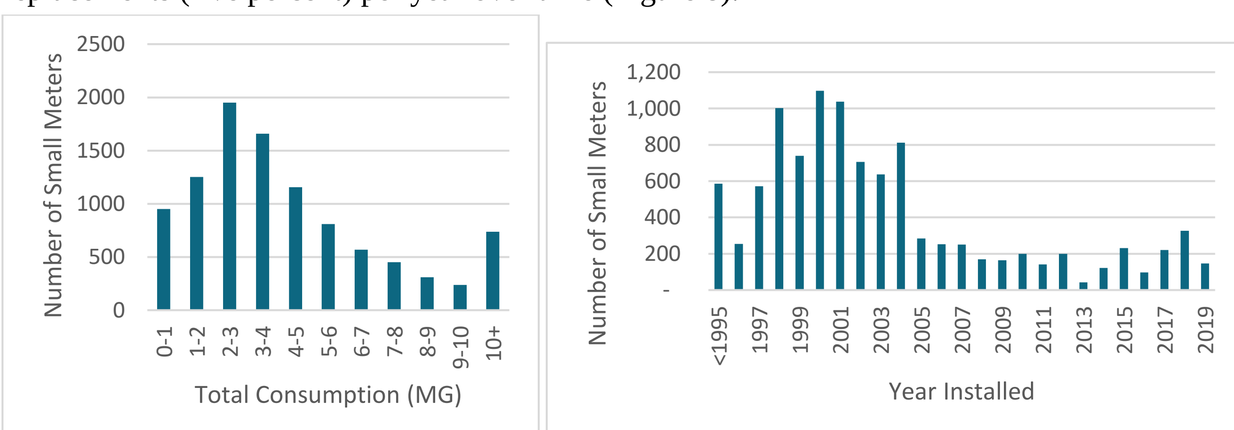


Figure 8. Number of Small Meters by Total Consumption and Age for the SJWD

Intermediate Meters – The SJWD is recommended to rebuild or replace intermediate meters on a 10-year cycle. The SJWD has 130 of 269 intermediate meters with more than 10 MG of consumption (as of Q4, 2019), which is the typical warranty maximum to achieve repaired meter accuracy for two-inch meters. Of these meters, 66 have more than 20 MG of consumption.

[1] See "Summary of the Reduction of Lead in Drinking Water Act and Frequently Asked Questions", EPA-815-13-001 (2013).

Additionally, as of Q4, 2019, 80 of 269 intermediate meters were reported to be older than 25 years. The meters with the greatest consumption should be prioritized for testing and likely either rebuilt or replaced.

Because so many of the SJWD's intermediate meters currently register more than 10 MG of total consumption, the SJWD can anticipate rebuilding or replacing many of the meters tested in the next three to five years.

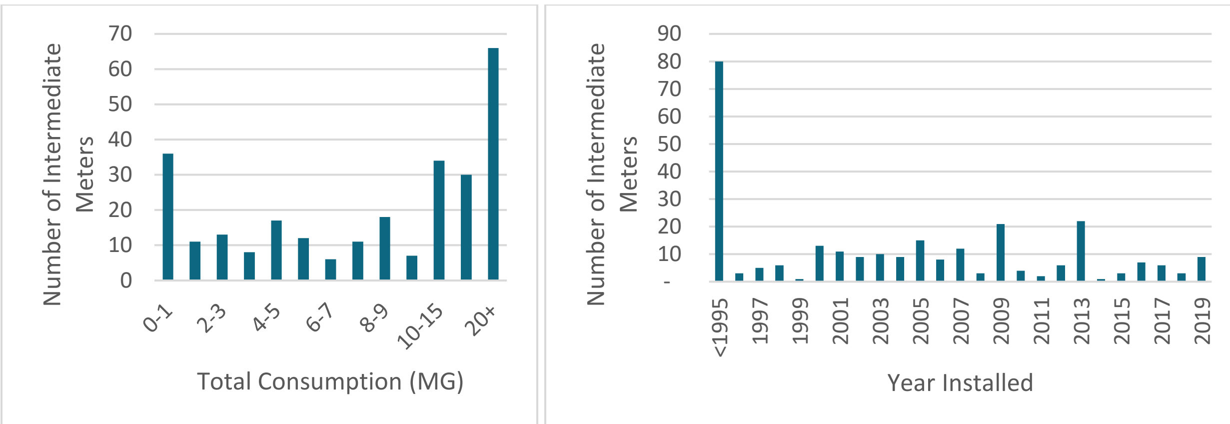


Figure 9. Number of Intermediate Meters by Total Consumption and Age for the SJWD

Large Meters – The SJWD is recommended to rebuild or replace large meters based on the results of scheduled in-place field testing. The SJWD's deployed large meter inventory is relatively young compared to its small and intermediate meters. Seven of 27 large meters have more than 50 MG of consumption. There are only two large meters that were installed more than 20 years ago. For this reason, the consulting team anticipates that the SJWD will likely be able to rebuild its large meters as needed and can anticipate purchasing a small number of new large meters in the near term. Large meters have no consumption-based warranties, and the age-based period is only one to two years. Testing is the best way to determine accuracy longevity by meter manufacturer, size, and type.

On a two-year rotating schedule, the SJWD can anticipate testing approximately 14 large meters per year. The SJWD should prioritize the meters with the greatest consumption. It can anticipate rebuilding or replacing approximately three large meters per year (Figure 10).

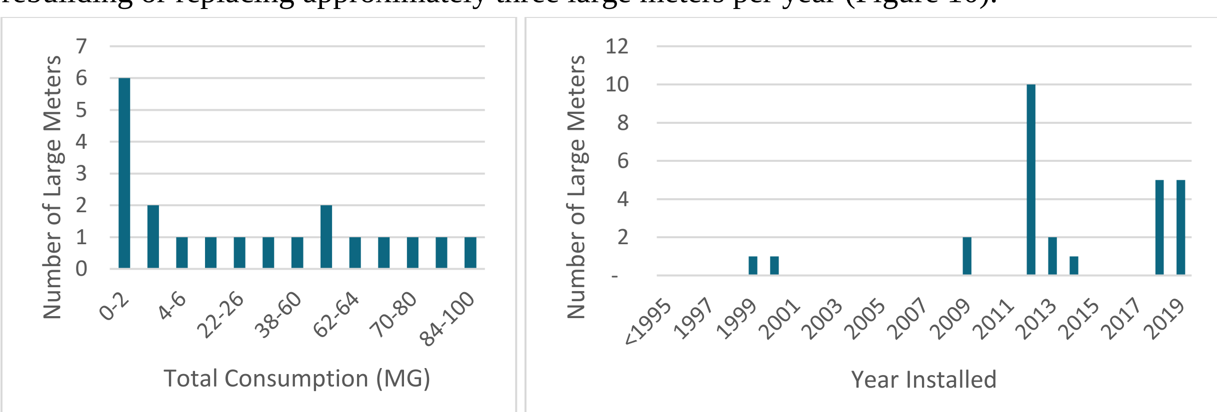


Figure 10. Number of Large Meters by Total Consumption and Age for the SJWD

2.4.2 Citrus Heights Water District

Small Meters – At the time deployed meter data was provided for this Study (Q4, 2019), 1,678 of 18,683 small meters exceeded the five MG consumption replacement criterion. Of these meters, 344 have registered more than 10 MG of total usage. In terms of age, 155 of 19,955 small meters have been deployed for 25 years or more (as of 2020).

Per the recommended target to replace four to five percent of small meters per year, the CHWD is recommended to replace between 798 and 998 small meters per year. It will take two to three years to replace the 1,678 existing meters that exceed five MG of total consumption (plus those that exceed the 25-year age replacement criterion). The average annual consumption for small meters from 2016 to 2018 was 133,910 gallons. At this rate, the average meter will not exceed the five MG threshold within the 25-year period. This indicates that the CHWD may tend toward four percent replacement per year over time. It is likely that many of the CHWD's small meters will not exceed the consumption replacement criterion before they reach the 25-year age replacement criterion (Figure 11).

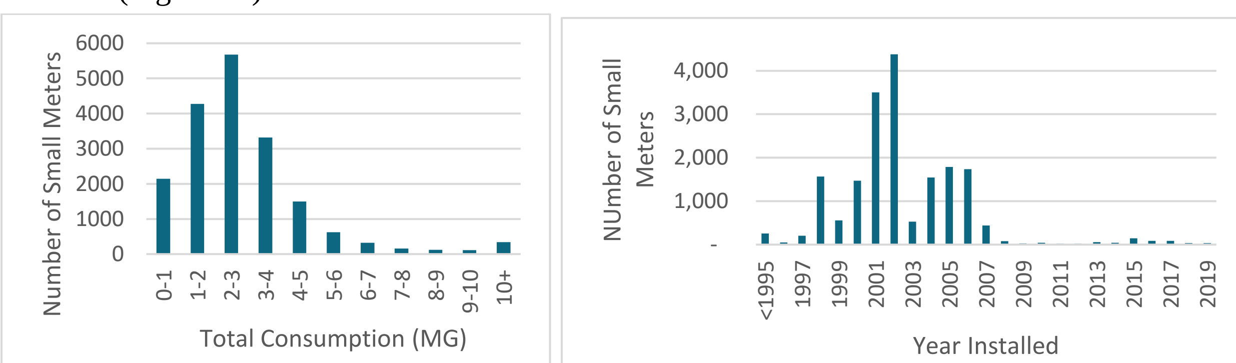


Figure 11. Number of Small Meters by Total Consumption and Age for the CHWD

Intermediate Meters – The CHWD is recommended to rebuild or replace intermediate meters on a 10-year cycle. In total, 514 of 1,186 intermediate meters have registered more than 10 MG of consumption (as of Q4, 2019). Of these meters, 185 have registered more than 20 MG of consumption. Additionally, as of Q4, 2019, 293 intermediate meters were reported to be older than 25 years. The meters with the greatest consumption should be prioritized for testing and likely rebuilt or replaced.

Because many of the CHWD's intermediate meters currently register more than 10 MG of total consumption and were largely deployed before 2000, the CHWD can anticipate rebuilding or replacing many of the meters tested over the next five years.

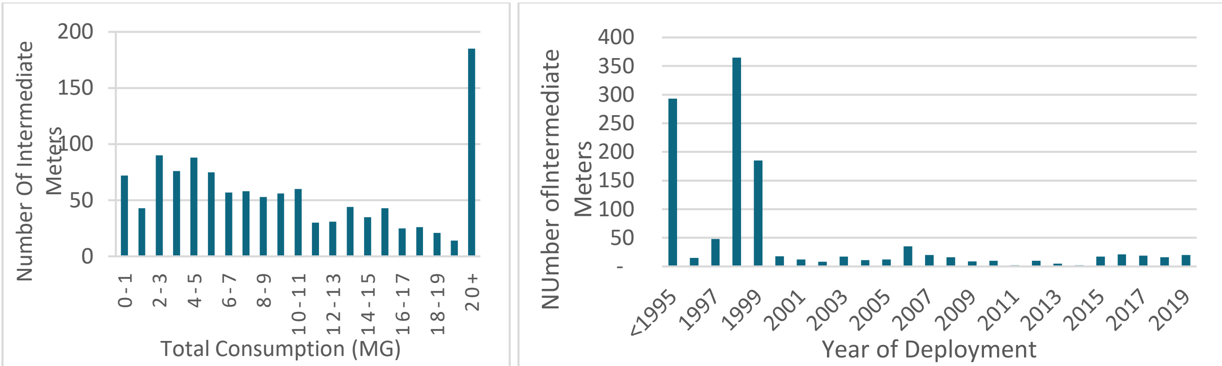


Figure 12. Number of Intermediate Meters by Total Consumption and Age for the CHWD

Large Meters – The CHWD is recommended to rebuild or replace large meters based on the results of scheduled testing. The CHWD's deployed large meter inventory includes 20 of 86 meters that registered more than 50 MG of total consumption. Six large meters registered more than 100 MG of consumption. Only 34 meters were installed more than 20 years ago. As a result, the CHWD can anticipate replacing several of its large meters in the near term pending testing results.

On a two-year rotating schedule, the CHWD can anticipate testing approximately 43 large meters per year. The CHWD should prioritize the meters with the greatest consumption. It can anticipate rebuilding or replacing approximately 15 percent of those tested, or seven large meters, per year (Figure 13).

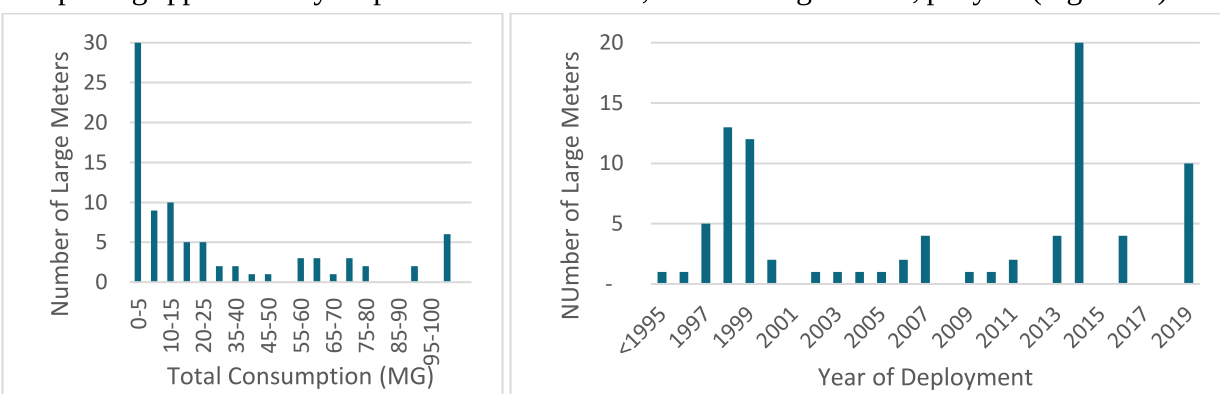


Figure 13. Number of Large Meters by Total Consumption and Age for the CHWD

2.4.3 Placer County Water Agency

Small Meters – At the time deployed meter data was provided for this Study (Q4, 2019), 1,726 of 35,823 small meters exceeded the five MG consumption replacement criterion. Of these meters, 393 have registered more than 10 MG of total consumption. In terms of age, no small meters have been deployed for 25 years or more (as of 2020).

Per the recommended target to replace four to five percent small meters per year, the PCWA is recommended to replace between 1,433 and 1,791 small meters per year. Currently, a few of the PCWA's small meters meet the recommended replacement criteria. This is because the PCWA did not install small meters until 2001. Most of the PCWA's small meters were installed between 2001 and 2011. Therefore, it will not be necessary for the PCWA to replace a significant number of meters until 2026, when many meters will exceed the 25-year age replacement criterion. Until that time, the PCWA will need to replace only the small meters that exceed the five MG consumption replacement criterion.

The average annual consumption for small meters in 2017 and 2018 was 161,620 gallons. At this rate, the average meter will not exceed the five MG threshold within the 25-year period. This indicates that the PCWA may tend toward four percent replacement per year over time. It is likely that many of the PCWA's small meters will not exceed the consumption replacement criterion before they reach the 25-year age replacement criterion. However, it is recommended that the PCWA conduct additional small meter testing to confirm how the performance of its meters corresponds to consumption and age in the context of its service area and customer water use patterns (Figure 14).

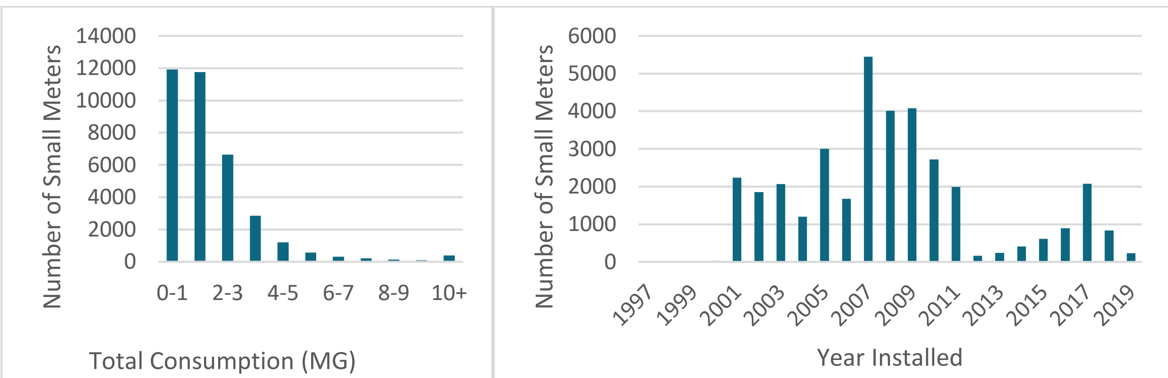


Figure 14. Number of Small Meters by Total Consumption and Age for the PCWA

Intermediate Meters – The PCWA is recommended to rebuild or replace intermediate meters on a 10-year cycle. In total, 496 of the PCWA's 972 intermediate meters have registered more than 10 MG of consumption (as of Q4, 2019). Of these meters, 286 have more than 20 MG of consumption. Additionally, as of 2019, none of the PCWA's intermediate meters were reported to be older than 25 years. Some of the PCWA's intermediate meters were installed between 1999 and 2003, but the majority were installed between 2005 and 2009. The meters with the greatest consumption should be prioritized for testing and likely rebuilt or replaced.

Because many of the PCWA's intermediate meters currently register more than 10 MG of total consumption, the PCWA can anticipate rebuilding or replacing many of the meters tested over the next five years.

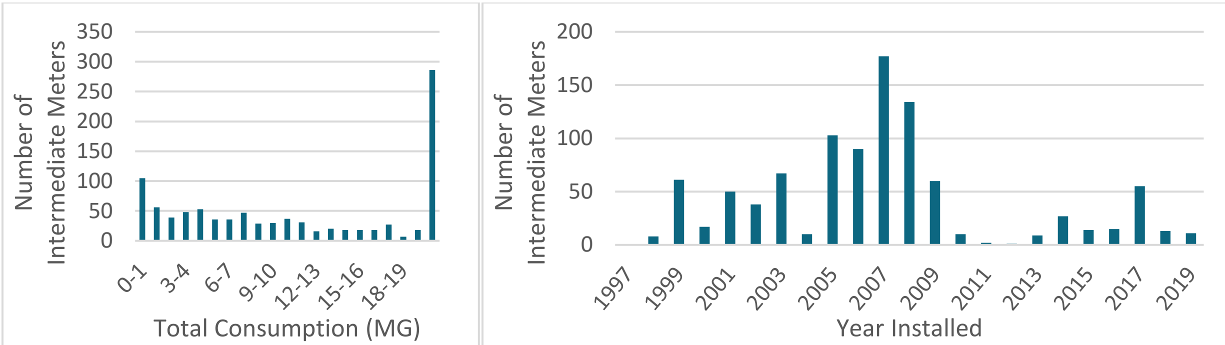


Figure 15. Number of Intermediate Meters by Total Consumption and Age for the PCWA

Large Meters – The PCWA is recommended to rebuild or replace large meters based on the results of scheduled testing. The PCWA's deployed large meter inventory includes 75 of 114 meters that have registered more than 50 MG of total consumption. Thirty-nine large meters with more than 100 MG of consumption are in the inventory, and only one large meter was installed more than 20 years ago. As a result, the PCWA will likely not need to purchase many new large meters in the next several years but should focus on rebuilding meters that fail testing. The PCWA employs a rotating test schedule; therefore, some of the high consumption meters may have already been tested and possibly rebuilt in recent years.

On a two-year rotating schedule, the PCWA can anticipate testing approximately 62 large meters per year. The PCWA should prioritize the meters with the greatest consumption. It can anticipate that approximately 15 percent of those tested, or 10 large meters, will need to be rebuilt or replaced per year. Given the high number of large meters with over 100 MG of consumption, it can anticipate that a greater number will need to be rebuilt in the first two years (Figure 16).

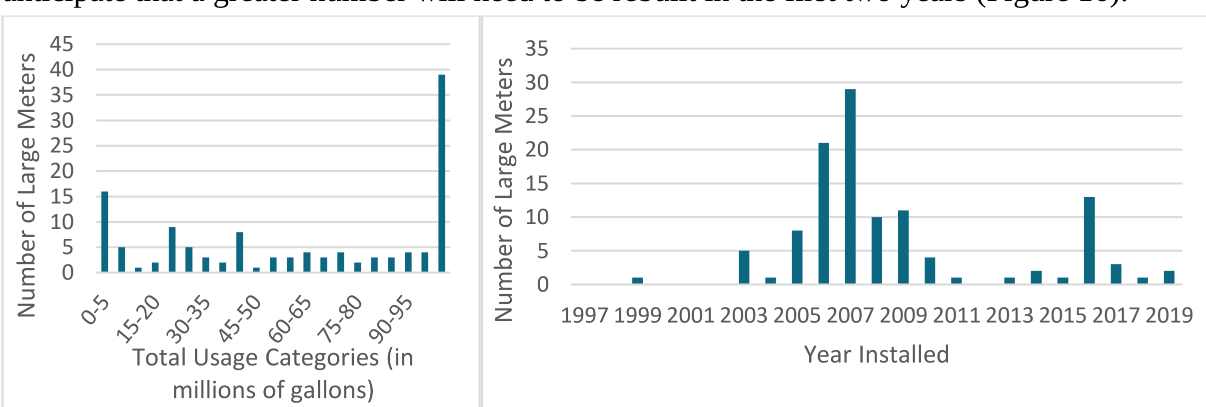


Figure 16. Number of Large Meters by Total Consumption and Age for the PCWA

2.4.4 City of Sacramento

Small Meters – At the time deployed meter data was provided for this Study (Q4, 2019), 1,200 of 121,892 small meters exceeded the five MG consumption replacement criterion. Of these meters, 179 have registered more than 10 MG of total consumption. In terms of age, 593 small meters have been deployed for 25 years or more (as of 2020).

Per the recommended target to replace four to five percent small meters per year, the CoS is recommended to replace between 4,876 and 6,095 small meters per year. Currently, a few of the CoS's small meters meet the recommended replacement criteria. This is because the CoS deployed the majority of its small meters between 2010 and 2012 and 2014 and 2019. Therefore, the CoS may elect to replace fewer meters than four to five percent per year for the next several years.

The average annual consumption for small meters for 2018 was 94,675 gallons. At this rate, the average meter will not exceed the five MG threshold within the 25-year period. This indicates that the CoS may tend toward four percent replacement per year over time. It is likely that many of the CoS's small meters will not exceed the consumption replacement criterion before they reach the 25-year age replacement criterion (Figure 17).

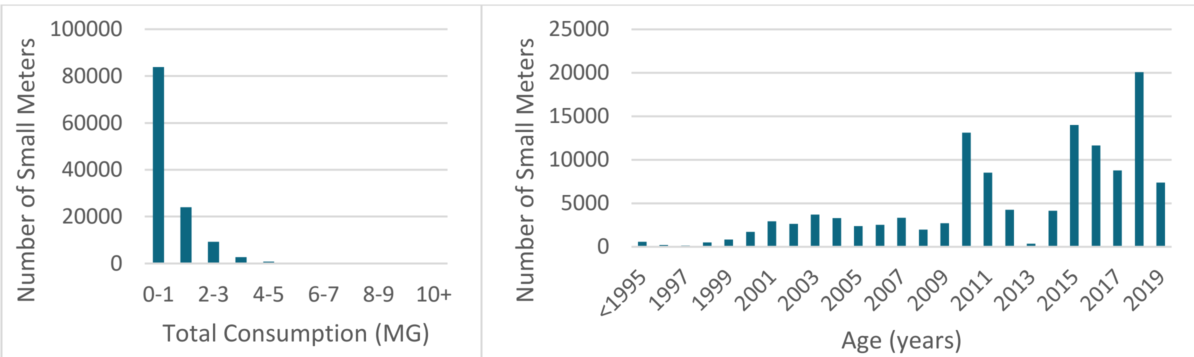


Figure 17. Number of Small Meters by Total Consumption and Age for the CoS

Intermediate Meters – The CoS is recommended to rebuild or replace intermediate meters on a 10-year cycle. In total, 665 of the CoS's 7,194 intermediate meters have registered more than 10 MG of consumption (as of Q4, 2019). Of these meters, 305 have more than 20 MG of consumption. Additionally, as of 2019, 328 of the CoS's intermediate meters were reported to be older than 25 years. The majority were installed between 2007 and 2019. The meters with the greatest consumption should be prioritized for testing and likely rebuilt or replaced.

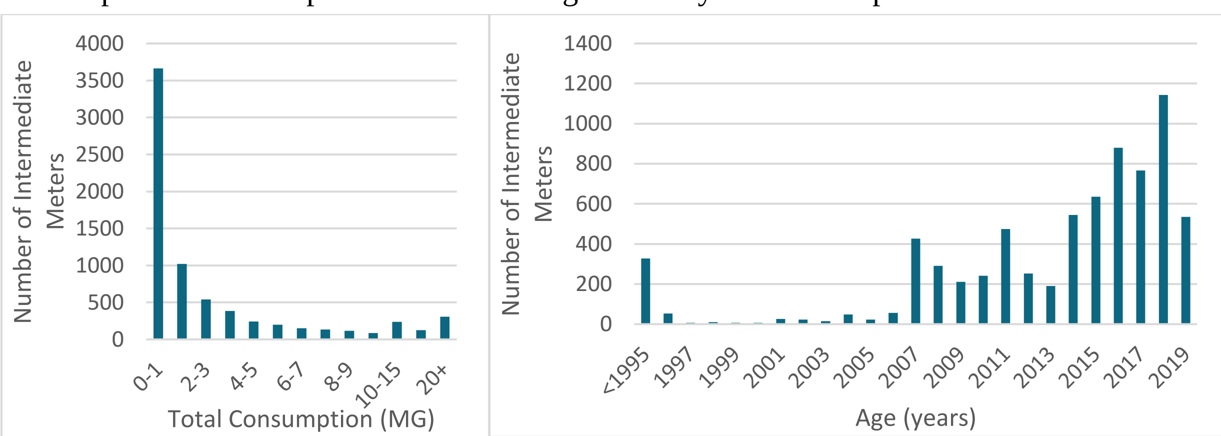


Figure 18. Number of Intermediate Meters by Total Consumption and Age for the CoS

Large Meters – The CoS is recommended to rebuild or replace large meters based on the results of scheduled testing. The CoS's deployed large meter inventory includes 499 of 2,421 meters that have registered more than 50 MG of total consumption. In total, 225 large meters registered more than 100 MG of consumption. Sixty large meters were installed more than 25 years ago, and 153 meters were installed more than 20 years ago. As a result, the CoS will likely need to purchase a number of new large meters in the next several years.

On a two-year rotating schedule, the CoS can anticipate testing approximately 1,211 large meters per year. The CoS should prioritize the meters with the greatest consumption. Given the number of large meters with over 50 MG of consumption, it can anticipate rebuilding a larger percentage of those tested in the first year. After that, the CoS can anticipate that approximately 15 percent of those tested, or 182 large meters, will need to be rebuilt or replaced per year (Figure 19).

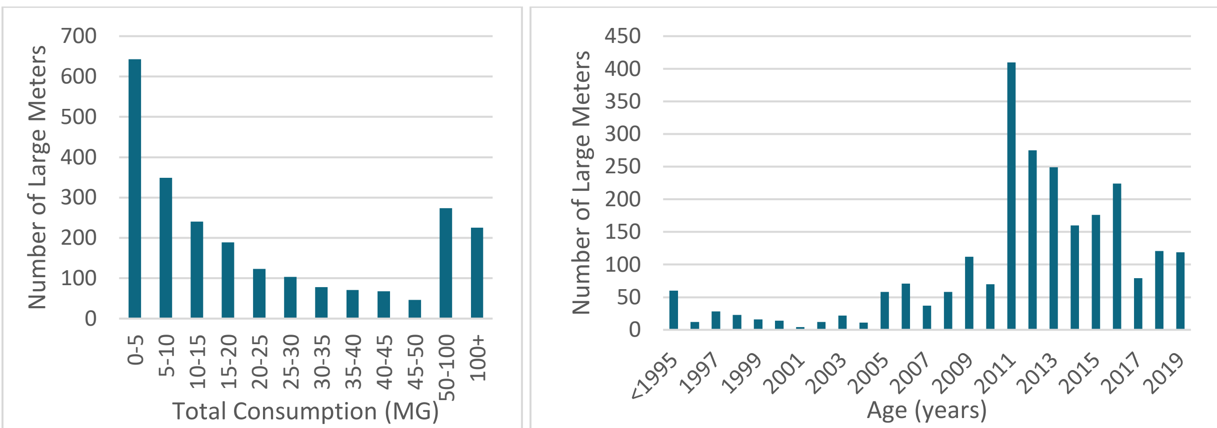


Figure 19. Number of Large Meters by Total Consumption and Age for the CoS

2.4.5 Sacramento Suburban Water District

Small Meters – At the time deployed meter data was provided for this Study (Q4, 2019), 1,226 of the SSWD's 40,172 small meters exceeded the five MG consumption replacement criterion. Of these meters, 362 have registered more than 10 MG of total consumption. In terms of age, only 220 small meters have been deployed for 25 years or more (as of 2020).

Per the recommended target to replace four to five percent small meters per year, the SSWD is recommended to replace between 1,466 and 1,832 small meters per year. Currently, few of its small meters meet the recommended replacement criteria. This is because the SSWD deployed the majority of its small meters from 2004 to 2018. Therefore, the SSWD may elect to replace fewer meters than four to five percent per year for the next several years.

The SSWD's average annual consumption for small meters from 2016 to 2018 was 151,440 gallons. At this rate, the average meter will not exceed the five MG threshold within the 25-year period. This indicates that the SSWD may tend toward four percent replacement per year over time. It is likely that many of the SSWD's small meters will not exceed the consumption replacement criterion before they reach the 25-year age replacement criterion (Figure 20).

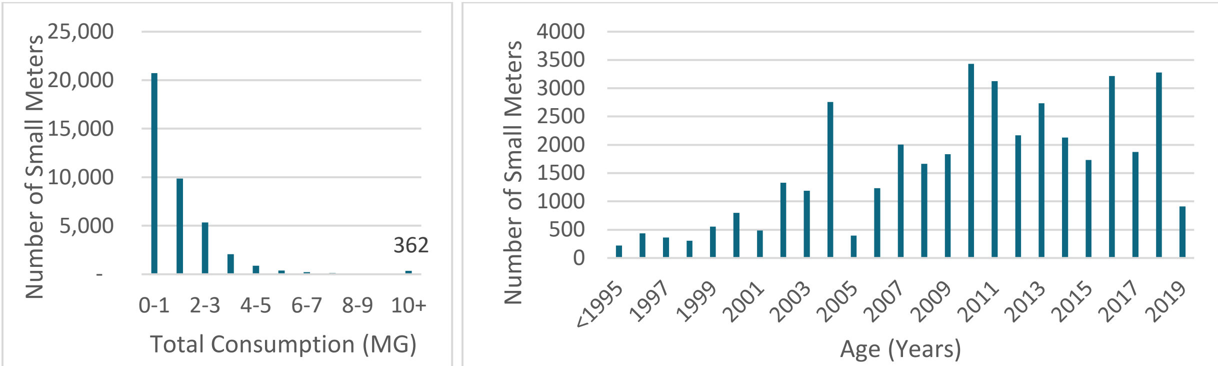


Figure 20. Number of Small Meters by Total Consumption and Age for the SSWD

Intermediate Meters – As of 2019, 313 of the SSWD's 2,437 intermediate meters were reported to be greater than 25 years old. Although more than 600 of the District's intermediate meters were installed before 2000, the majority of the SSWD's intermediate meters were installed at a steady pace after 2000.

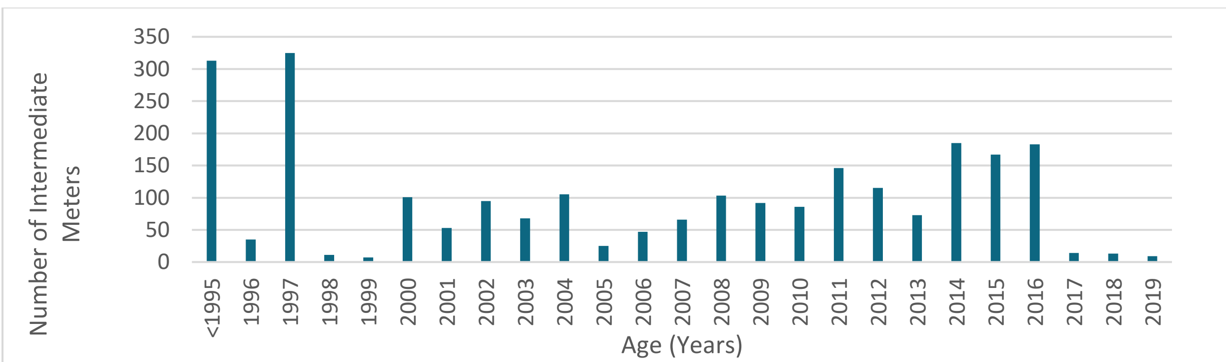


Figure 21. Number of Intermediate Meters by Age for the SSWD

Large Meters – The SSWD is recommended to continue rebuilding large meters based on the results of scheduled testing. The SSWD's large meter inventory is relatively young, with the first meters installed in 2004.

On a two-year rotating schedule, the SSWD can anticipate testing approximately 224 large meters per year. It is recommended to prioritize the meters with the greatest consumption. It can anticipate that approximately 15 percent of those tested, or five large meters, will need to be rebuilt or replaced per year (Figure 22).

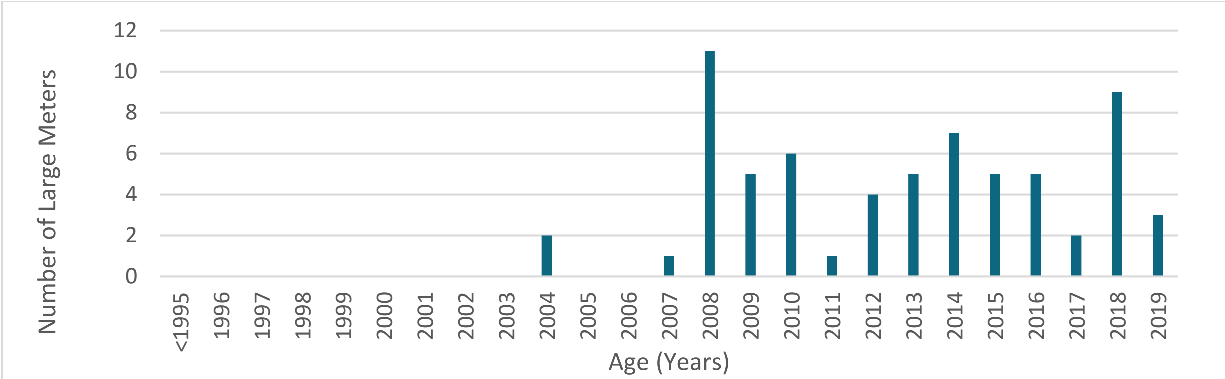


Figure 22. Number of Large Meters by Total Consumption and Age for the SSWD

2.4.6 Sacramento County Water Agency

Small Meters – At the time deployed meter data was provided for this Study (Q4, 2019), 1,055 of 50,063 small meters exceeded the five MG consumption replacement criterion. It should be noted that consumption data was collected starting in 1996, and therefore, any consumption before then is not reflected in this analysis. In terms of age, 156 of 50,063 small meters have been deployed for 25 years or more (as of 2020).

Per the recommended target to replace four to five percent small meters per year, the SCWA is recommended to replace between 2,003 and 2,504 small meters per year. The SCWA has deployed nearly 20,000 meters from 1999 to 2000; however, over 1,000 meters are currently reported to have exceeded their consumption-based criterion. Therefore, the SCWA can take a conservative approach to meter replacement for the next several years. It is recommended that the SCWA immediately replace meters that have exceeded consumption and age-based criteria and increase to at least four percent per year within five years. The average annual consumption for small meters for 2017 and 2018 was 119,152 gallons. At this rate, the average meter will not exceed the five MG threshold within the 25-year period. This indicates that the SCWA may tend toward four percent replacement per year over time. It is likely that many of the SCWA's small meters will not exceed the consumption replacement criterion before they reach the 25-year age replacement criterion (Figure 23).

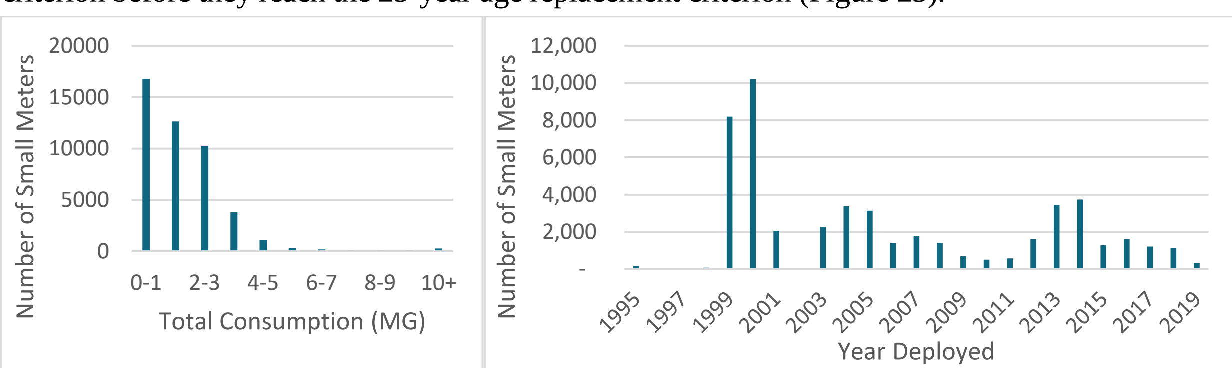


Figure 23. Number of Small Meters by Total Consumption and Age for the SCWA

Intermediate Meters – The SCWA is recommended to rebuild or replace intermediate meters on a 10-year cycle. As of 2019, 640 of 3,044 meters have registered more than 10 MG of total consumption. Of these meters, 328 have more than 20 MG of consumption As of 2019, 25 of the SCWA's intermediate meters were reported to be more than 25 years old. Approximately 40 percent (1,198 intermediate meters) were installed before 2000. The remaining 60 percent have been installed at a steady pace since 2000.

In the first two to three years, the SCWA can anticipate replacing or rebuilding a larger percentage of those tested based on the number of meters that exceed 10 MG of consumption and those installed before 2000 (Figure 24).

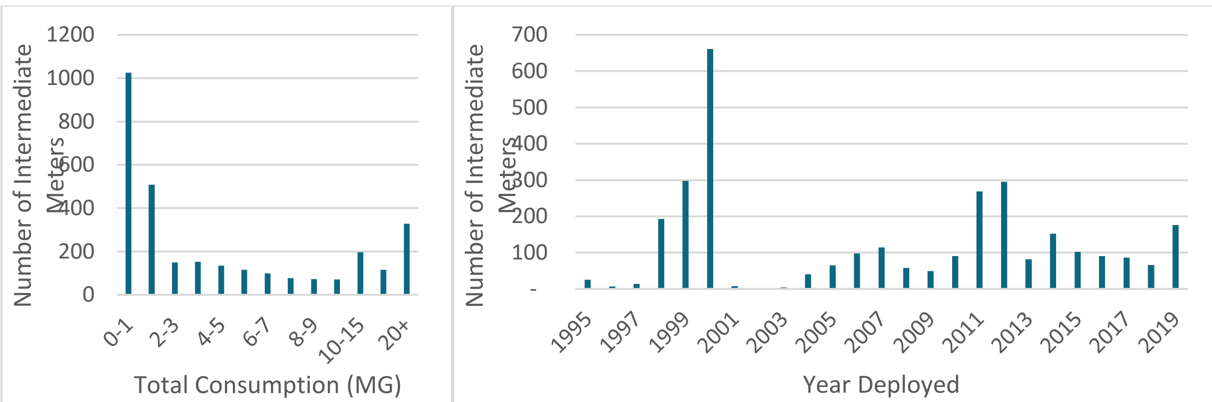


Figure 24. Number of Intermediate Meters by Total Consumption and Age for the SCWA

Large Meters – The SCWA is recommended to rebuild or replace large meters based on the results of scheduled testing. It is recommended that the SCWA prioritize the meters with the greatest consumption. The SCWA has 87 of 336 large meters with more than 50 MG of total consumption. Of these, 38 meters have more than 100 MG of consumption. Approximately half (165 meters) of its large meters were installed in or before 2000. The remaining meters have been deployed at a steady pace since 2000.

On a two-year rotating schedule, the SCWA can anticipate testing approximately 168 large meters per year. Since half of its large meters are older than 20 years and just over 25 percent have more than 50 MG of consumption, the SCWA can anticipate replacing or rebuilding a larger number of the meters tested over the first two years. After that, it can anticipate that approximately 15 percent of the meters tested, or 26 large meters, will need to be rebuilt or replaced on an annual basis (Figure 25).

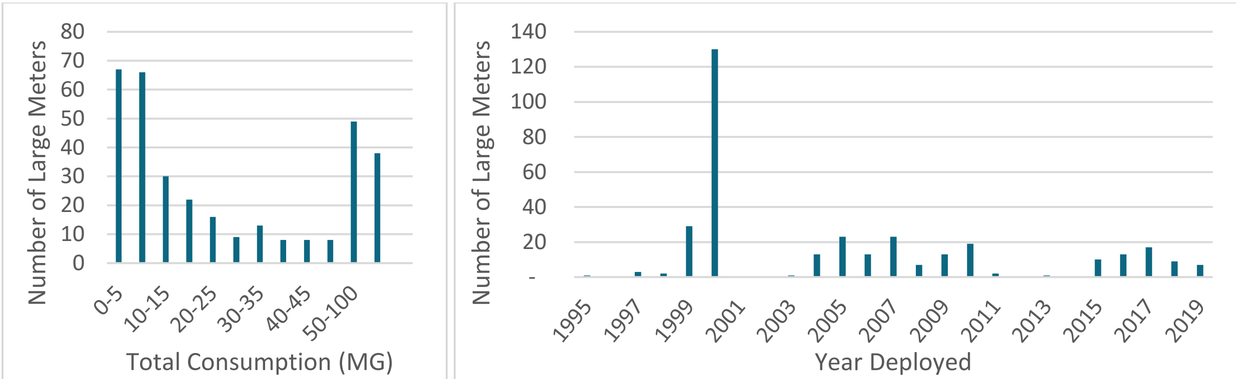


Figure 25. Number of Large Meters by Total Consumption and Age for the SCWA

Over time, Consortium agencies can anticipate replacing between four and five percent of small meters per year depending on average annual consumption. Agencies can anticipate replacing three percent of intermediate and large meters per year based on test results (assuming intermediate meters are tested once every five years and large meters are tested once every two years) (Table 4).

Table 4. Meter Replacement Summary

Meter Type	Replacement Factors	CHWD	CoS	PCWA	SCWA	SJWD	SSWD	Total
Small (1-inch and smaller)	Average Total Consumption (MG)	3.048	0.884	2.022	1.721	4.813	1.594	NA
	Average Deployment Year	2002	2012	2008	2006	2003	2010	NA
	Target Annual Replacement (4%-5% per year)	798–998	4,876–6,095	1,433–1,791	2,003–2,504	412–515	1,466–1,832	10,988–13,735
	Total Deployed	**1,955**	**121,892**	**35,923**	**50,063**	**10,290**	**39,791**	**256,757**
Intermediate (1.5 and 2-inch)	Average Total Consumption (MG)	12.773	6.045	20.761	7.302	16.805	N/A*	NA
	Average Deployment Year	1999	2013	2007	2007	2002	2005	NA
	Estimated Annual Rebuild/Replacement (10% per year)	119	720	98	305	27	244	1513
	Total Deployed	**1,186**	**7,194**	**972**	**3,044**	**269**	**2,437**	**15,102**
Large (3-inch and larger)	Average Total Consumption (MG)	31.863	47.671	101.020	45.531	52.492	N/A*	NA
	Average Deployment Year	2007	2011	1997	2005	2013	2009	NA
	Estimated Annual Rebuild/Replacement (7.5% per year)	7	182	10	26	3	5	233
	Total Deployed	**86**	**2,421**	**114**	**336**	**27**	**447**	**3,050**

Notes: MG = million gallons

2.5 Areas For Further Research

The following are additional areas for further research that agencies should investigate to refine their replacement strategies based on existing data gaps:

- **Test Data Gaps –** There are several consumption and age categories with a small number of test samples. Over time, these can be expanded to provide a more comprehensive understanding of how meters change in accuracy with use and over time.
- **Meter Technology –** Several agencies have deployed solid-state meters. More test data should be collected to help agencies assess what technologies provide the best value over time.
- **Meter Brands and Models –** There are a number of different deployed manufacturers, including Badger, Sensus, Neptune, and Zenner. As more data is collected, it will be beneficial to know how performance differs between manufacturers. A specific manufacturer may sell multiple models (mechanical and solid-state) for comparison.
- **Size –** The CoS's analysis was based on one-inch meters. The smaller meter sizes (5/8 inch and ¾ inch) may perform differently from the one-inch meters. As more data is collected, it may be possible to refine replacement criteria for smaller sizes.
- **Ultra-Low Flow –** Research should be performed to understand how much flow is unregistered at the low end. Because mechanical (PD) meters are predominant in the Consortium, it may be important to understand how much use is unregistered below these meters' ability to accurately measure. Additionally, because every utility has its unique customer base and climate environment, a future study of residential customer use distribution over ultra-low, low-, intermediate-, and high-flow ranges would inform the small meter replacement criteria and the utility-wide weighted meter accuracy required for M36 Annual AWWA Audits.

Section 3 Meter Reading Strategies

A meter reading strategy, separate from a meter replacement strategy, serves as another key element of long-term planning for water meter programs. It provides a basis for anticipating meter reading costs and proactive management of a meter reading system. The purpose of this analysis is to identify opportunities for Consortium-level collaboration based on existing systems and water meter infrastructure of each participating agency. The outcome includes a recommended endpoint management strategy and a set of meter reading strategies that will be subject to the financial analysis in Section 4.

3.1 Business-as-Usual Conditions

Currently (2020), Consortium agencies employ several basic types of meter reading technologies through multiple providers. The CHWD, SJWD, and SCWA have the largest inventories of manual or touch read meters. Several participating agencies employ AMR (drive-by) systems, including the CHWD, PCWA, SCWA, SJWD, and SSWD. Table 5 indicates the primary meter reading systems currently expected to be deployed by each agency in the short-term .

Table 5. Current Meter Reading Systems by Agency

Meter Reading Systems	CHWD	CoS	PCWA	SCWA	SJWD	SSWD
Manual/Touch Read	95%	—	—	63%	93%	—
Neptune AMR	5%	—	—	—	—	—
Itron AMR	—	—	62%	—	—	—
Sensus AMR	—	—	—	<1%	7%	—
Badger AMI (Fixed Network)	—	>99%	—	—	—	—
Sensus AMI (Fixed Network)	—	—	—	36%	—	50%
Badger AMI (Cellular)	—	<1%	38%	—	—	50%

Notes: AMI = advanced metering infrastructure; AMR = automatic meter reading

As shown in Table 5, the agencies trend toward Badger and Sensus systems. Currently, the CHWD has a small number of meters (five percent) on the Neptune AMR system and continues to add more of its meters to it. While the SJWD mostly has manual or touch read systems, it intends to gradually move to the Sensus AMR system. The PCWA currently has the majority of its connections on the Itron AMR system, but over time, it intends to shift to the Badger ORION cellular AMI system. The remaining agencies are on either Sensus or Badger systems. The SCWA, SSWD and the CoS will continue to balance between their current reading systems. Table 6 lists the system that each agency is expected to gravitate toward moving forward (BAU).

Table 6. Forecasted Business-as-Usual Reading Systems by Agency

Consortium Agency	BAU System
CHWD	Neptune AMR and Manual/Touch Read
CoS	Badger AMI (Fixed Network and Cellular)
PCWA	Badger AMI (Cellular)
SCWA	Sensus AMI (Fixed Network)
SJWD	Sensus AMR
SSWD	Sensus AMI (Fixed Network) and Badger AMI (Cellular)

Notes: AMI = advanced metering infrastructure; AMR = automatic meter reading; BAU = business-as-usual

3.2 Propagation Study Overview

To assess the potential benefits of the entire Consortium or several agencies in the Consortium coordinating their water meter reading systems, propagation studies were requested from the following vendors:

- Badger
- Itron
- Neptune
- Sensus
- Zenner

Specifically, the vendors were requested to evaluate each agency individually in its service area and together at a Consortium-wide scale with a collective service area to determine what potential economies of scale and additional benefits are possible if all agencies are on a single meter reading system. In response to this request, the consulting team received propagation studies from all vendors except Itron, which elected not to submit a study. More information on these systems can be found in Technical Memorandum No. 2.

The results of the propagation studies were compared to hardware requirements and coverage for the following systems:

- **Badger ORION Cellular AMI –** Relies on existing commercial cellular networks to transmit data from endpoint to headend system. For this reason, Badger provides NaaS, and agencies only need to purchase and install compatible endpoints. Badger offers two types of endpoints: the LTE-M option, which can transmit meter data on Badger's primary commercial carrier (AT&T), and the LTE-MS option, which can transmit meter data on a secondary commercial network.
- **Sensus FlexNet AMI –** Uses a licensed radio frequency (RF), which enables Sensus to transmit at a higher power level compared to other vendors, such as Neptune and Zenner.

- **Neptune R900 AMI –** Uses unlicensed RFs in the 910–920 megahertz range, which requires Neptune to transmit meter data at a lower power level compared to Sensus.
- **Zenner Stealth AMI –** Uses an unlicensed mesh network in the 902–928 megahertz range, which requires Zenner to transmit meter data at a lower power level compared to Sensus.

The propagation studies modeled the expected level of coverage for the Consortium-wide service area. The results are summarized in Table 7. Zenner did not provide coverage maps or predicted coverage in its propagation study.

Table 7. Predicted Coverage for Meter Reading Systems

Vendor/System	Predicted Coverage (%)
Badger ORION Cellular AMI	99.9
Sensus FlexNet AMI	99.21
Neptune R900 AMI	98.5
Zenner Stealth AMI	Not provided

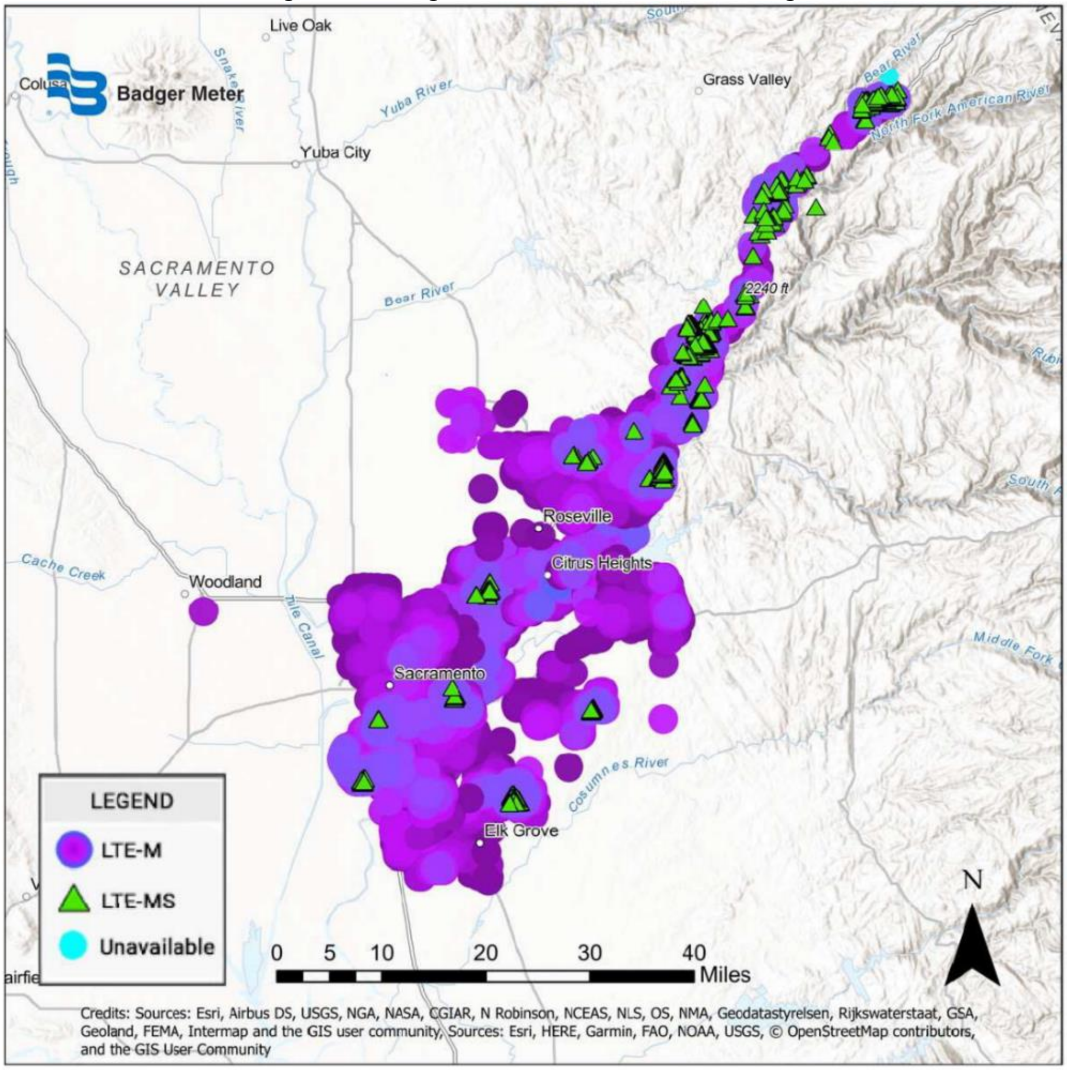
Notes: AMI = advanced metering infrastructure

3.2.1 Badger ORION Cellular Advanced Metering Infrastructure

Badger conducted a cellular coverage analysis (CCA) for its cellular AMI system. Under this system, meter reading data is transmitted from the endpoint using existing cellular technology networks rather than data collection units (DCUs). Data is then forwarded directly to the headend system, which is a database for ongoing analysis, reporting, and billing.

According to the propagation study, the Badger ORION LTE-M and LTE-MS cellular communication network is available in most but not all areas. The study found that approximately 99 percent of locations evaluated could be covered using LTE-M endpoints and 0.9 percent by LTE-MS endpoints. However, it should be noted that some areas shown to be covered by LTE-M may be better covered by LTE-MS. Coverage was determined to be insufficient in approximately 0.1 percent of the Consortium-wide service area (the northwestern area), primarily impacting the PCWA, because some connections in its service territory are in remote areas with limited cellular service. Figure 26 provides an illustration of the LTE-M and LTE-MS coverage for the Consortium-wide service area and shows that the LTE-MS endpoints would be required in the foothill and mountain regions serviced by the PCWA where Badger's primary network provider is less prevalent compared to its secondary carrier.

Figure 26. Badger ORION Cellular AMI Coverage



3.2.2 Sensus FlexNet Advanced Metering Infrastructure

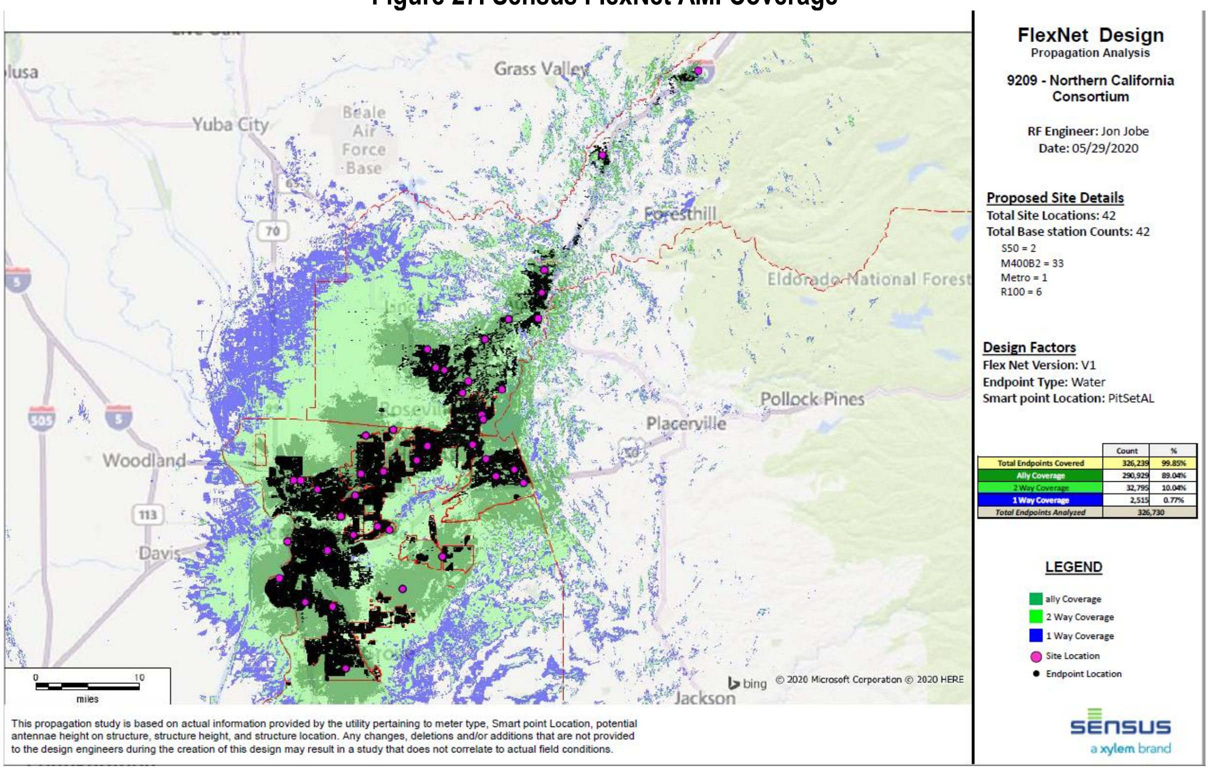
Sensus conducted a propagation study for its RF-based Sensus FlexNet AMI system. Sensus evaluated levels of coverage and redundancy for the FlexNet fixed-network AMI system across the Consortium-wide service area. The analysis was based on the placement of DCUs, the terrain, and other factors that Sensus considers for its software. Because Sensus FlexNet DCUs can cover a relatively wide area compared to unlicensed networks, neighboring agencies could share DCUs. The propagation study assessed the minimum number of DCUs each agency would need to achieve a minimum 98.5 percent coverage and the increased coverage and redundancy when agencies would be able to use additional neighboring DCUs that would be in range of a portion of their service areas. As indicated in Table 8, the lowest projected level of coverage would be 98.5 percent (i.e., PCWA). Figure 27 illustrates the Sensus FlexNet coverage for the Consortium-wide service area.

Table 8. Sensus FlexNet AMI Coverage

Network	DCU Configuration Meeting Minimum 98.5% Coverage		Including Additional DCUs Contributing from Neighboring Agencies	
	Coverage (%)	Redundancy (%)	Coverage (%)	Redundancy (%)
CHWD	99.95	78.35	100	97.55
CoS	99.31	88.35	99.41	93.71
Folsom	99.78	89.19	100	93.47
PCWA	98.51	84.23	98.54	85.01
SCWA	98.30	37.48	98.39	41.19
SJWD	99.46	91.31	99.47	91.94
SSWD	99.16	88.61	99.22	92.94

Notes: DCU = data collection unit

Figure 27. Sensus FlexNet AMI Coverage



3.2.3 Neptune R900 Advanced Metering Infrastructure

Neptune conducted a propagation study for its R900 AMI system. The analysis estimated 98.71 percent coverage for the Consortium-wide service area as represented in Figure 28. Because the Neptune R900 AMI system requires more DCUs compared to Sensus's AMI system, several locations across the Consortium-wide service area would not be covered unless DCUs are placed in locations that agencies did not identify. Without establishing DCU placements at these locations, which would probably include private property, this system would not meet the minimum 98.5 percent coverage for Consortium agencies (Table 9).

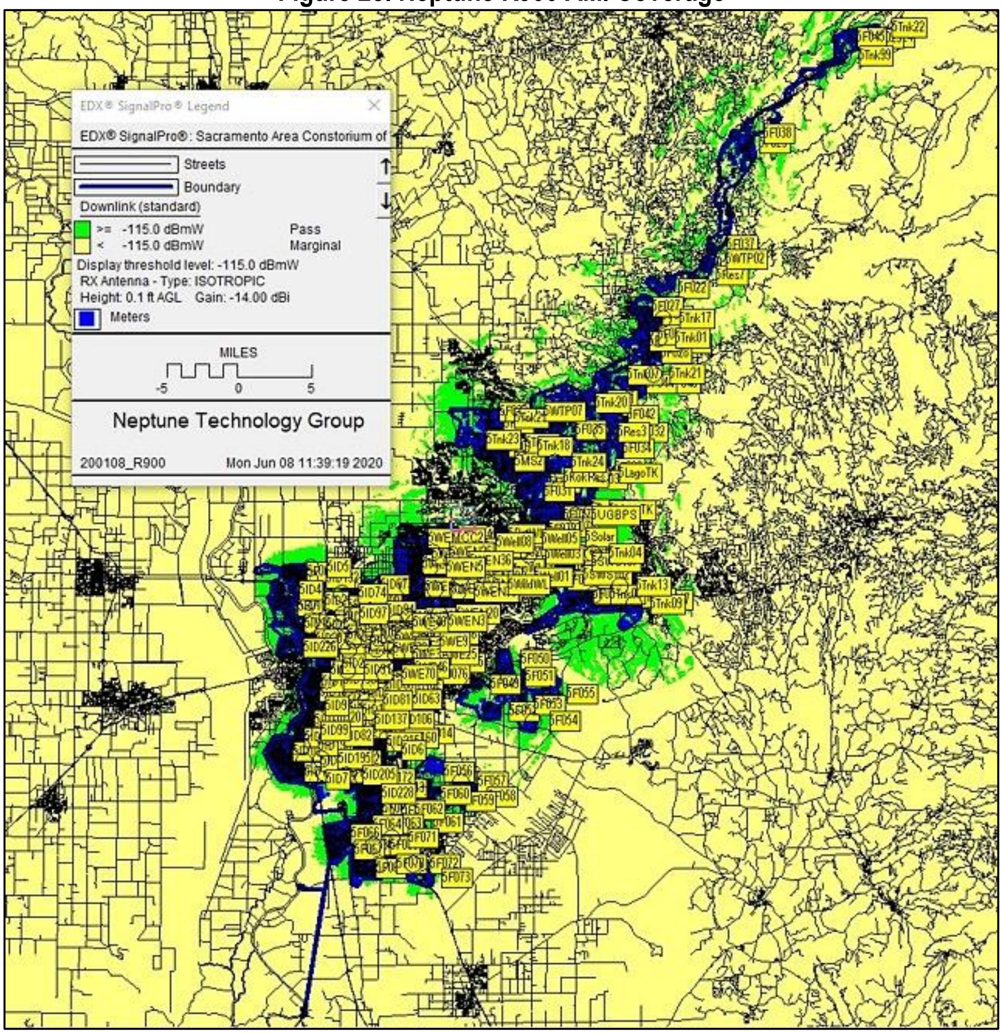
Table 9. Predicted Coverage

Agency	Predicted Coverage[1] (%)
CHWD	98.64
CoS	98.53
Folsom	98.72
PCWA	98.49
SCWA	98.57
SJWD	98.31
SSWD	99.21

Notes:

[1] Assuming additional DCU placements were not identified by Consortium agencies.

Figure 28. Neptune R900 AMI Coverage



3.2.4 Zenner Stealth Advanced Metering Infrastructure

Zenner conducted a propagation study for its Stealth AMI network. The analysis included maps of the individual agency service areas, and Zenner provided estimates for the number of DCUs and repeaters for each agency. Zenner did not provide an estimated level of coverage for its configuration.

3.2.5 Hardware

The propagation studies estimated the number of DCUs or collectors and/or repeaters that would be required to provide the calculated coverage of the Consortium-wide service area. The hardware requirements predicted by the propagation studies varied substantially between vendors as shown in Table 10. The Sensus FlexNet AMI system would require the fewest DCUs among the three fixed-network systems. Badger's ORION cellular AMI system relies on existing cellular network infrastructure provided by telecommunication companies. Therefore, it would not require additional communication network investments. The Zenner Stealth AMI system would have the greatest network hardware requirement, particularly for repeaters, which were not identified by the other vendors.

Table 10. AMI Hardware Requirements (Not Including Endpoints)

	AMI Solution	Badger ORION Cellular	Sensus FlexNet		Neptune R900	Zenner Stealth
Hardware	Agency	Total Needed	Total Needed	Needed by Individual Agency	Total Needed	Total Needed
DCUs	CHWD	0	4	2	18	10
	CoS	0	7	7	84	91
	Folsom	0	4	4	10	20
	PCWA	0	13	12	73	25
	SCWA	0	7	0	56	36
	SJWD	0	7	4	18	7
	SSWD	0	9	0	35	30
	Total	**0**	**44**	**33**	**294**	**219**
	Consortium Total	**0**	**42**	**33**	**216**	**199**
Repeaters	CHWD	0	0	0	0	21 (AC), 200 (MIU)
	CoS	0	0	0	0	182 (AC), 45 (MIU), 91(BE)
	PCWA	0	0	0	0	50 (AC), 10 (MIU), 25 (BE)
	SCWA	0	0	0	0	72 (AC), 20 (MIU), 17 (BE)
	SJWD	0	0	0	0	14 (AC), 14 (MIU)

Table 10. AMI Hardware Requirements (Not Including Endpoints)

Hardware	AMI Solution	Badger ORION Cellular	Sensus FlexNet		Neptune R900	Zenner Stealth
	Agency	Total Needed	Total Needed	Needed by Individual Agency	Total Needed	Total Needed
	SSWD	0	0	0	0	60 (AC), 40 (MIU)
	Total	**0**	**0**	**0**	**0**	**399 (AC), 329 (MIU), 133 (BE)**

Notes: AC = alternating current powered repeater; AMI = advanced metering infrastructure; BE = battery enhanced; DCU = data collection unit; MIU = meter interface unit

Badger ORION Cellular AMI – The Badger ORION cellular AMI system would eliminate the need for standard utility-owned infrastructure by using existing cellular network infrastructure. As indicated in Table 11, no additional collectors (gateways) or repeaters would need to be installed. Because this system uses commercial hardware, it is completely scalable and lends itself to a Consortium-wide integration.

Sensus FlexNet AMI – Deployment of the Sensus FlexNet AMI system would require the smallest investment in additional AMI infrastructure compared to the other fixed-network options. In total, deployment of the Sensus FlexNet AMI system over the entire Consortium-wide service area would require 26 additional collectors to achieve an estimated 99.08 percent two-way coverage across the service area because seven collectors have been deployed by the SCWA, and nine have been deployed by the SSWD. An additional 0.77 percent of the total service area is estimated to have one-way coverage. This is because, as shown in Table 11, collectors can be shared among agencies to ensure specific levels of coverage (two-way) and redundancy. For example, the CHWD would only need two DCUs in its service area if it also has access to one in the SJWD's service area and one in the SSWD's network to achieve 99.95 percent two-way coverage of its connections. The greatest investment would be required from the PCWA, with 12 additional collectors required. This is because PCWA's service area is elongated in shape and is away from the other agencies. Table 11 represents the minimum number of collectors required to meet Sensus' standard network performance guarantees.

Table 11. Collectors Required to Meet Sensus Coverage Requirements

Network	Agency-Specific Sites	Two-Way Coverage (%)	Redundancy (%)	CHWD	CoS	Folsom	PCWA	SCWA	SJWD	SSWD	Total Sites Required to Meet Coverage Requirements
CHWD	2	99.95	78.35	2	0	0	0	0	1	1	4
CoS	7	99.31	88.35	0	7	0	0	0	0	0	7
Folsom	4	99.78	89.19	0	0	4	0	0	0	0	4
PCWA	12	98.51	84.23	0	0	0	12	0	1	0	13
SCWA	4	98.30	37.48	0	2	0	0	4	0	1	7
SJWD	4	99.46	91.31	1	0	1	0	0	5	0	7
SSWD	9	99.16	88.61	0	0	0	0	0	0	9	9

Another advantage of the Sensus FlexNet AMI system at the Consortium level is increased coverage and redundancy through a shared DCU network. Because many of the individual service areas are close to one another, many endpoints would be within reach of two or more DCUs. As shown in Table 12, the proposed DCU locations could provide additional redundancy in coverage to most Consortium agencies.

Table 12. Possible Collector Deployment and Configuration for Increased Redundancy

Network	Agency-Specific Sites	2-Way Coverage (%)	Redundancy (%)	CHWD	CoS	Folsom	PCWA	SCWA	SJWD	SSWD	Total Sites Regionally Available to Meet Coverage Requirements
CHWD	2	100	97.55	2	0	3	3	0	4	4	16
CoS	7	99.41	93.71	0	7	1	6	4	1	6	25
Folsom	4	100	93.47	2	2	4	1	3	3	4	19
PCWA	12	98.54	85.01	2	3	4	12	1	4	5	31
SCWA	4	98.39	41.19	0	7	4	0	4	1	6	22
SJWD	4	99.47	91.94	2	0	4	7	1	5	4	23
SSWD	9	99.22	92.94	2	4	0	0	2	2	9	19

Neptune R900 AMI – Compared to Badger ORION cellular and Sensus FlexNet AMI systems, deployment of the Neptune R900 AMI system would require significant investment in DCUs. Meeting Neptune's 98.5 percent coverage guarantee would require deployment of 216 collectors across the Consortium-wide service area. Sensus has a head start, having already installed 16 of the 42 required DCUs for the SSWD and SCWA. Moreover, the propogation study determined that Neptune would have to place DCUs in locations without existing agency-owned infrastructure to meet a minimum 98.5 percent coverage. This would add significant complexity to implementation of the Neptune R900 AMI system for Consortium agencies.

From a collaboration standpoint, and unlike the Sensus FlexNet AMI system, there is no clear opportunity to share existing infrastructure that would allow for efficient buildout of the Neptune R900 AMI system. Therefore, no benefit to taking a Consortium-based approach to coordinating the purchase of meter reading software would occur beyond the benefit of achieving economy of scale for endpoint purchasing, which exists regardless of vendor. As a result, the Neptune R900 AMI system was not selected as a scenario for consideration in the following cost benefit analysis.

Zenner Stealth AMI – Similar to the Neptune R900 AMI system, the Zenner Stealth AMI system would require significant hardware investments compared to the Sensus FlexNet AMI system, as shown in Table 13. Currently (2020), only Folsom has deployed the Zenner Stealth AMI system in the Sacramento area. Because of this, as with the Neptune R900 AMI system, little benefit to deploying a Consortium-wide Zenner Stealth AMI system exists. This is because so many DCUs and repeaters are needed to put the system in place, and therefore, there is little opportunity for neighboring agencies to share infrastructure. Thus, the Zenner Stealth AMI system was not selected as a scenario for more detailed consideration moving forward.

Table 13. Zenner Stealth AMI Hardware Requirements per Agency

Network	Collectors	Battery-Enhanced Repeaters	AC Repeaters	MIU Repeaters
CHWD	10	0	21	200
CoS	91	91	182	45
Folsom	20	10	12	403
PCWA	25	25	50	10
SCWA	36	17	72	20
SJWD	7	4	14	14
SSWD	30	15	60	40
Total	**219**	**162**	**411**	**732**

Notes: AC = alternating current; MIU = meter interface unit

3.3 Scenario Selection

Meter reading scenarios were selected based on the potential to provide efficiencies and benefits at the Consortium level (Figure 29). Another factor considered was Consortium-level experience with the meter reading systems, which would reduce the overall need for investments. Based on the analysis of the results of the propagation studies, the Badger ORION cellular and Sensus FlexNet scenarios were selected for the financial analysis in Section 4.

3.3.1 1. Business as Usual

In this scenario, each Consortium agency would continue independently with its selected meter reading strategy (see Table 4). The projected system deployments listed in Table 6 represent the BAU, or baseline, scenario for each agency.

3.3.2 2. Badger ORION Cellular Advanced Metering Infrastructure (Network as a Service)

In this scenario, each Consortium agency would employ a full deployment of the Badger ORION cellular AMI system, which is only offered as a NaaS. The system is priced as a monthly service fee. Similar to the Sensus FlexNet AMI system, the Badger ORION cellular system also requires some up-front setup costs that can include a connection fee, data integration fees, training costs, and project management fees. These costs can be negotiable and will vary by agency.

3.3.3 3A. Sensus FlexNet Advanced Metering Infrastructure (Network as a Service)

Sensus also offers a NaaS option for its AMI system. In this scenario, each Consortium agency would fully deploy of a fully managed Sensus FlexNet AMI system. With a NaaS, Sensus would own, manage, monitor, and maintain the system and infrastructure, ensuring each agency has full coverage in its service area and that the network operates at peak performance. Sensus would be responsible for warranty, maintenance, and support of the base stations and Federal Communications Commission-licensed radio spectrum and all interference and mitigation of spectrum, should any arise. Network base stations, firmware, RF spectrum, and system health would be managed and maintained by Sensus Network Operation Center engineers. This option is priced as an annual service fee with some additional one-time setup fees. The annual per-connection service fee includes software and data hosting, DCU costs, installation, and maintenance. Agencies would be responsible for purchasing, installing, and maintaining endpoints.

3.3.4 3B. Sensus FlexNet Advanced Metering Infrastructure (Agency Owned)

In this scenario, each Consortium agency would employ a full deployment of the Sensus FlexNet AMI system, with each agency maintaining full control of its system. Agencies would be responsible for purchasing, operating, and maintaining the wireless communication network, including all hardware. They would also be responsible for paying annual fees for access and use of Sensus cloud-based analytic software based on the number of deployed endpoints.

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Section 4 Financial Analysis

A financial analysis for Consortium agency meter programs is presented in this section. The analysis is based on the results of the proceeding sections related to meter replacement and meter reading recommendations (Sections 2 and 3). Agency-specific financial scenarios and top-level summary findings are included in this section. The financial analysis compares the potential cost efficiencies gained through collaborative investments to the Business As Usual (BAU) scenario for each agency over a 15-year planning period. It corresponds with the recommended endpoint replacement period. The scenarios in this financial analysis are described below.

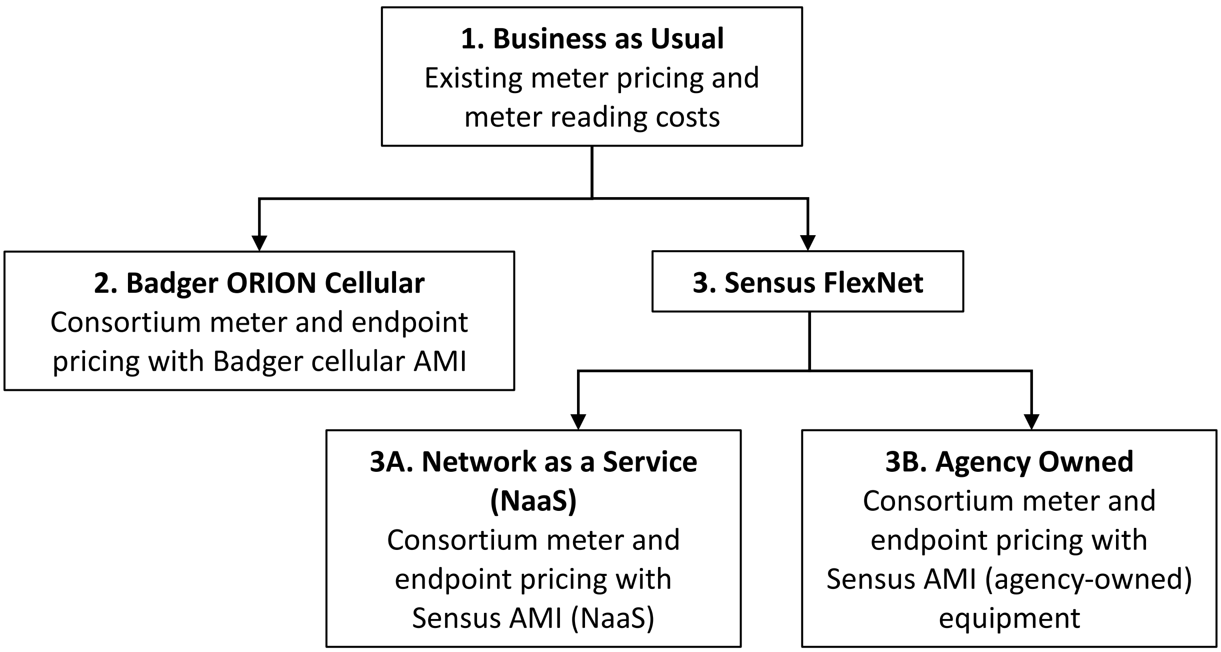


Figure 29. Meter Reading Scenarios

General assumptions that apply across the analysis include the following:

1. **Sales Tax:** The analysis includes sales tax for the hardware costs (meters, meter accessories, endpoints, data collectors, and backhaul infrastructure). The sales tax is not applied to the service cost because California law restricts the application of sales or use tax to the transfer or consumption of tangible personal property or physical property other than real estate. California does not tax services unless they are an integral part of a taxable transfer of property. The 2020 sales tax rate for Placer County and the City of Auburn, where the PCWA is located, is 7.25 percent. The rate for Sacramento, where the remaining agencies are located, is 7.75 percent.
2. **Escalation Factors:** Include the following:
    a. **Hardware and Installation Costs:** Include the following:
        i. An escalation factor is not provided for hardware and installation costs by the service providers. Based on previous cost increases in the Public Works

Costbook, the financial analysis includes a three percent escalation factor every five years for hardware and installation costs.

b. **Maintenance and Service Costs:** Include the following:

   i. **Badger ORION Cellular AMI (NaaS):** Badger did not indicate an escalation factor, and the consulting team does not assume one because agencies could negotiate for at least a 10-year fixed rate. Furthermore, the consulting team anticipates cellular to continue to drop in price as it has done for the last 10 years. Therefore, the consulting team conservatively assumes that the annual prices will not escalate.

   ii. **Sensus FlexNet AMI (NaaS):** The Sensus FlexNet NaaS AMI service fee escalates by three percent every five years as indicated by Sensus.

   iii. **Sensus FlexNet AMI (Agency Owned):** Annual maintenance, service, and software costs increase by three percent annually. This annual adjustment is consistent with other annual escalation factors. The U.S. Bureau of Labor Statistics' Consumer Price Index for All Urban Consumers in the West Region for December had an annual increase ranging approximately from 2.8 to 3.1 percent over the past three years. The Engineering New Record 20-City Construction Cost Index and Building Cost Index for January ranged from 2.6 to 3.3 percent and 1.7 to 3.3 percent, respectively.

3. **Meter and Endpoint Installation:** Meter and endpoint installations are based on truck roll and labor costs and are applied equally to all scenarios.

4.1 Meter Replacement

Consortium-level meter pricing is a significant potential source of cost savings identified in this Study. The financial scenarios presented in this section have been developed based on the meter replacement schedules recommended in Section 2. Each BAU cost scenario is based on the current pricing each agency reported (2020). The BAU scenario is compared to a scenario in which Consortium-level meter pricing could potentially be achieved through a joint purchasing agreement. The potential Consortium meter pricing scenario is not based on a formal bid process and is considered to be conservative as it is based upon pricing that a Consortium member is already receiving and the pricing is not connected to a minimum purchase quantity or total value. As a result, we anticipate that a formal bulk bidding process for Consortium-level quantities has reasonable potential to yield better unit pricing. Key costs and assumptions are presented as follows:

1. **Meters –** BAU meter costs are based on existing pricing for each agency and include a register (vendors report dial and liquid crystal display [LCD] registers to be similar in price). Consortium meter pricing is based on the most competitive meter pricing

currently secured by a Consortium agency. A BAU meter installation cost assumption is used across all scenarios. The analysis assumes a meter recycling fee of $5 per meter for all scenarios.

2. **Endpoints –** The vendors indicated Consortium-level pricing for the endpoints used in the analysis compared to BAU unit costs, which were provided by each agency. Meter box lid retrofits are conservatively assumed to be replaced over the first complete endpoint replacement cycle for all scenarios. Badger (cellular) endpoints will be installed when the meters are replaced. Since endpoints are replaced on a 15-year schedule, many will need to be replaced independently (assuming meters are replaced on a 20- to 25-year schedule).
3. **Installation/Rebuilds (Intermediate or Large Meters Only) –** Agencies are recommended to field test or rebuild intermediate and large meters on a rotating schedule based on meter testing.

Transitioning to an AMI system includes cost efficiencies and other benefits that are challenging to quantify in monetary terms. For example, Sensus FlexNet and Badger ORION Cellular platforms both come with the capability to deploy customer portals that enable customers to track and manage their water use. There are initial costs for transitioning to a new system, which are described in more detail below. The Badger ORION cellular and Sensus FlexNet NaaS scenarios include a significant portion of the initial costs in the service unit fees, while the Sensus FlexNet agency-owed scenario includes setup costs. Cost savings can be quantified for switching from an AMR drive-by system to an AMI system. Key meter reading costs and assumptions are presented as follows:

1. **Service Unit Fees (Badger ORION cellular and Sensus FlexNet NaaS scenarios only) –** For the Badger ORION cellular and Sensus FlexNet NaaS scenarios, the AMI system includes a service fee that covers all hardware, installation, and operation and maintenance (O&M) fees for the AMI system (but not the endpoints). Badger has indicated an annual fee of $8.16 per connection ($0.68 per month per connection), and Sensus is based on an annual fee of $4.20 per meter. The service fee includes all setup and annual costs outside of the costs of the meter, endpoints, and data collectors. First, these pricing estimates are not the product of a formal bidding process and, thus, should not be considered formal quotations. Second, this pricing assumes full participation by all Consortium agencies.
2. **Annual Data Hosting Fee (Sensus FlexNet agency-owned scenario only) –** The regional network interface (RNI) communicates with endpoints and provides the utility with status updates to the utility system. It continuously gathers and processes network data, storing or sending it to customer information and billing systems. The Sensus agency-owned scenario includes an annual fee to host the data.

3. **Data Collectors –** The Sensus FlexNet scenarios include hand-held data collectors to collect and store data in the field. The cost is consistent for the BAU and AMI scenarios for each agency.
4. **Backhaul Infrastructure (Sensus FlexNet agency-owned scenario only) –** The Sensus FlexNet agency-owned scenario includes the cost for backhaul infrastructure to provide the communication link between the base station and RNI. For the Badger ORION cellular and Sensus FlexNet NaaS scenarios, the AMI system includes a service fee that covers all fees for the AMI system, including the backhaul infrastructure and service.
5. **Pickup Reads –** Agencies using an AMI system must collect data from the endpoints that are not read by a wireless network. Data from these endpoints can be collected by data collectors with the Sensus system but must be collected manually with the Badger Cellular system. Agencies must account for the associated costs in labor and truck rolls.
6. **AMR Radio Reads –** Agencies currently using an AMR system collect data on a monthly or bi-monthly basis and incur the associated labor and truck roll costs. As an agency converts from an AMR system to an AMI system, these costs decrease proportionally as meters are converted.
7. **Touch or Manual Reads –** The CHWD, SJWD, and SCWA currently use manual or touch reads for a portion of their deployed meters. As an agency converts from touch or manual reading to an AMI system, these costs decrease proportionally as meters are converted.
8. **Endpoint Maintenance –** The analysis includes an assumption for endpoint maintenance for 0.5 percent of the endpoints annually to replace non-functioning endpoints.
9. **Data Analytics (Sensus FlexNet agency-owned scenario only) –** The Sensus FlexNet agency-owned scenario includes a cost for the annual analytics enhanced hosting fee based on the cost information provided by Sensus. These costs are built into the unit service fees for the Badger ORION cellular and Sensus FlexNet NaaS scenarios.
10. **Customer Portal (Sensus FlexNet agency-owned scenario only) –** The Sensus FlexNet agency-owned scenario includes a cost for the customer portal, a web-based reporting system that allows customers to track their daily water use. The customer portal cost includes the setup fee, portal integration, training, and annual fee. These costs are built into the unit service fees for the Badger ORION cellular and Sensus FlexNet NaaS scenarios.
11. **Setup Costs:** This includes the following:
    a. **Badger ORION Cellular AMI (NaaS) –** This scenario includes the following fees:
        - **System Connections Interfaces –** This includes developing the direct communication links between the Badger data system and the agency's billing, work order, and customer service systems.
        - **Engagement Fee –** A one-time fee with a maximum of $15,000.
        - **Training –** The cost to train staff on the communications system.

- **Project Management –** The cost for project management for the initial system rollout and endpoint installations is not included and is negotiable in the Badger ORION cellular and Sensus FlexNet agency-owned scenarios. Project management is included in the Sensus FlexNet NaaS scenario service unit fee.

b. **Sensus FlexNet AMI (NaaS) –** This scenario includes the following fees:

- **System Connections Interfaces –** This includes developing the direct communication links between the Sensus data system and the agency's billing, work orders, and customer service systems.
- **Training –** The cost to train staff on the new data management system.

c. **Sensus FlexNet AMI (Agency Owned) –** This scenario includes the following fees:

- **RNI Setup Fee –** As described previously, the RNI communicates with endpoints and provides the customer with status updates to the utility system. The RNI setup fee is the cost to set up this system.
- **Sensus Analytics Setup Fee –** As described previously, this scenario includes a cost for annual analytics enhanced hosting. This includes the associated setup fee.
- **Training –** This includes the cost to train staff on the new data management system.
- **Sensus Integration Fee –** This includes developing the direct communication links between the Sensus data system and the agency's billing, work order, and customer service systems.
- **Three Months of Project Management –** Sensus provided an initial BAU assumption of three months of project management for the transition to the AMI system, including endpoint installations.

The Badger ORION and Sensus FlexNet NaaS scenarios include any remaining setup costs covered in the service unit fee.

12. **Revenue/Cost Saving Benefits –** There are cost savings associated with remote access to meter data through AMI systems. Specifically, these cost savings are associated with move-in and move-out meter reads and high-use investigations. In both cases, labor and truck roll savings exist because this information can be collected in the office rather than at the meter location. Savings calculations were provided for the SJWD and PCWA, which are comparing the AMI options relative to BAU scenarios.

A summary comparison of different costs per system is included in Table 14.

Table 14. Types of Costs by Meter Reading Scenario

Type of Cost	Badger ORION Cellular (NaaS)	Sensus FlexNet (NaaS)	Sensus FlexNet (Agency Owned)
Hardware			
Meters (and Registers)	X	X	X
Meter Accessories	X	X	X
Endpoints	X	X	X
Setting Retrofits	X	X	X
Communication			
DCUs	—	—	X
Backhaul (WAN) Infrastructure	—	—	X
Base Station Maintenance	—	—	X
Service Unit Fee (NaaS)	X	X	—
Endpoint Maintenance	X	X	X
Pickup Reads	X	X	X
Manual Reading Equipment	X	X	X
Data Analytics			
Data Hosting Fees	*Included in Service Unit Fee*	*Included in Service Unit Fee*	X
Customer Portal	*Included in Service Unit Fee*	*Included in Service Unit Fee*	X
Setup			
Engagement Fee	X	—	—
Project Management	X	—	X
Systems Integration	X	X	X
Training	X	X	X
Data Hosting Setup	—	—	X
Analytics Setup	—	—	X

Notes: DCU = data collection unit; NaaS = network as a service; WAN = wide-area network

4.2 Financial Analysis by Agency

A financial analysis was developed for each agency to compare the current BAU system to the alternative AMI systems that the agency may be interested in. The financial analysis estimates the annual capital and O&M costs for the system replacements over a 15-year period as described in the previous section. Where the data was available, the financial analysis includes the estimated offset of annual operational savings for move-in/out read investigations and high-usage investigations on meters. Additional operational efficiencies were not included in the financial analysis because it is difficult to quantify all of the true cost savings of switching to an AMI system. A summary of the results for each agency, including the net present value (NPV) for each scenario, is provided in this section.

The NPV accounts for the time value of money and provides an additional method for evaluating and comparing the annual cash flow. Time value of money dictates that time affects the value of cash flows. The NPV is determined by calculating the costs and benefits for each period. After the cash flow for each period is calculated, the present value of each period is achieved by discounting its future value at a periodic rate of return. The NPV is the sum of all discounted future cash flows. The financial analysis for each agency assumes a five percent discount rate based on the market and discount rates used in similar recent analyses. As described in more detail below, the time value of money is an important tool for evaluating the benefits and tradeoffs between the different scenarios. The overall cost may be lower for one scenario, but a heavy up-front investment or other factors may lower the NPV for the scenario. The overall cost, annual cash flow, and NPV should be considered when evaluating the feasibility of a scenario.

One principal objective for considering a new AMI system includes improving the effectiveness of meter reading. As shown in the preceding analyses, effective implementation of an AMI system can reduce the costs associated with drive-by (radio) reads, meter re-reads, and billing. The true value of hourly compared to monthly or bi-monthly reads is difficult to quantify, but operational efficiencies should be achieved. The financial analysis for each agency compares the potential cost efficiencies gained through collaborative investments to the BAU scenario over a 15-year planning period.

4.2.1 Citrus Heights Water District

The analysis indicates that the Badger ORION cellular and Sensus FlexNet scenarios can potentially provide the CHWD with significant cost savings over the 15-year planning period compared to the BAU scenario. As shown in Table 15, the Sensus FlexNet – Agency Owned scenario has the lowest projected cost. Joint hardware purchasing is the most significant potential source of savings, which is estimated at approximately $2.3 million over 15 years.

Meter reading costs are also lower in all scenarios compared to the BAU scenario but are projected to be lowest in the Sensus scenarios. In the Badger ORION cellular scenario, the conversion to AMI can be done at any pace, including the meter replacement schedule. This would result in efficiencies related to installation costs since meters and endpoints could be changed at the same time rather than separately. This also means the potential benefits of AMI (hourly data reads), will be secured more slowly and the District will have multiple meter reading systems, including touch in place for longer. The District could choose to accelerate its AMI conversion by installing endpoints in addition to those that are synced with its meter replacement schedule. Doing so would simplify the system onto one meter reading platform more quickly and secure more AMI benefits over the planning period.

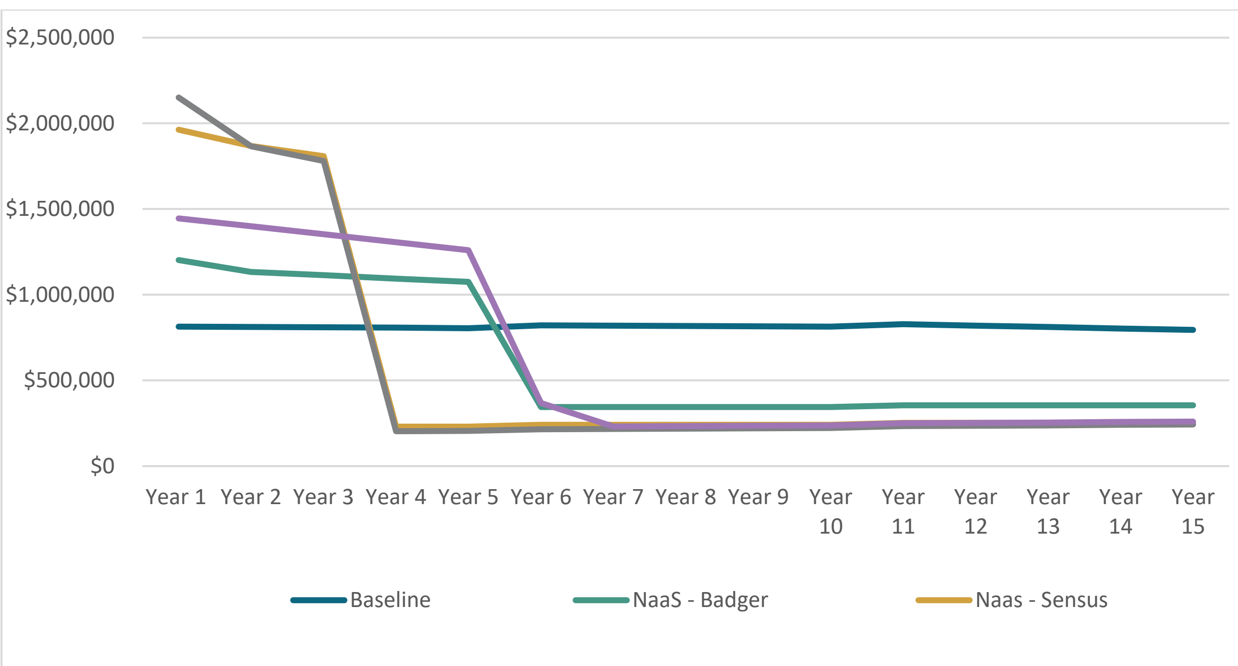
Overall, the Badger ORION cellular and Sensus FlexNet scenarios are lower cost alternatives compared to the BAU. The key tradeoff between the Sensus FlexNet NaaS and Badger ORION cellular scenarios is that the shift to an AMI system takes place over a longer time frame in the Badger ORION cellular scenario. This implies that, if the CHWD selects the Badger ORION cellular scenario, it will need to manage multiple meter reading systems over a longer period and may secure potential benefits of the AMI system (such as fewer truck rolls for high-use investigations and start and stop service meter reads) at a slower pace. The advantage of the Badger ORION cellular scenario is that costs are spread over a longer period of time. One of the reasons a slower rollout is more cost efficient is because a greater percentage of endpoint replacements can be done at the same time as meter replacements which saves on truck roll and labor costs.

Scenario 5 provides an alternative whereby Sensus Endpoints are deployed over a five year period. Over this timeframe, the District reads these meters using AMR and then would be able to switch to Sensus FlexNet AMI at some point after the five year period. In this scenario, the District secures less cost savings from the AMI system over the 15-year planning period, but is also able to spend less on endpoint in the first several years. It is also able to shift entirely to AMR, which is more cost effective than BAU and decide at a later date if and when to shift to AMI.

Table 15. 15-Year Financial Analysis Summary Information for the CHWD

Item	Scenario 1: BAU	Scenario 2: Badger ORION Cellular (NaaS)	Scenario 3: Sensus FlexNet (NaaS)	Scenario 4: Sensus FlexNet (Agency Owned)	Scenario 5: Sensus AMR to AMI
Meter Hardware					
Small Meters	$5,549,503	$3,290,144	$3,290,144	$3,290,144	$3,290,144
Intermediate Meters	$702,593	$660,583	$660,583	$660,583	$660,583
Large Meters	$185,600	$172,245	$172,245	$172,245	$172,245
Endpoints	$2,495,121	$3,409,679	$4,281,477	$4,281,477	$4,633,586
Sales Tax (7.75%)	$472,438	$307,655	$363,845	$363,845	$402,508
Material Recycling Fee	$161,528	$367,125	$111,176	$111,176	$118,776
Subtotal Hardware	**$9,566,784**	**$8,207,430**	**$8,879,469**	**$8,879,469**	**$9,277,841**
Meter Reading					
Communications	$2,630,532	$2,655,566	$1,594,516	$1,007,122	$1,280,569
Data Analytics	$0	$0	$0	$489,786	$529,689
Setup Cost	$0	$49,400	$34,400	$52,965	$52,965
Cost Savings	$0	($1,796,340)	($1,934,520)	($1,934,520)	($1,796,340)
Subtotal Meter Reading	**$2,630,532**	**$908,626**	**($305,604)**	**($384,648)**	**$66,882**
Total Cost	**$12,197,315**	**$9,116,056**	**$8,573,864**	**$8,494,821**	**$9,344,723**
Net Present Value	**($8,864,114)**	**($7,339,745)**	**($7,338,175)**	**($7,332,929)**	**($7,820,187)**

Notes: BAU = business as usual; NaaS = network as a service



4.2.2 San Juan Water District

The SJWD is in the process of converting its meters from touch read to Sensus AMR. As a result, approximately seven percent of its meters currently have Sensus AMR/AMI endpoints. The financial analysis indicates significant potential cost savings from both joint hardware purchasing and conversion to an AMI system.

Joint hardware purchasing is a significant potential source of savings, which is estimated at approximately $350,000 over 15 years for meters. Significant cost savings also exist for endpoint purchases in the Badger ORION cellular and Sensus FlexNet scenarios, which is estimated to be approximatel $1,000,000 over 15-years in the Sensus AMR-AMI scenario. This is because of the increased endpoint purchasing power of the consortium relative to the District individually.

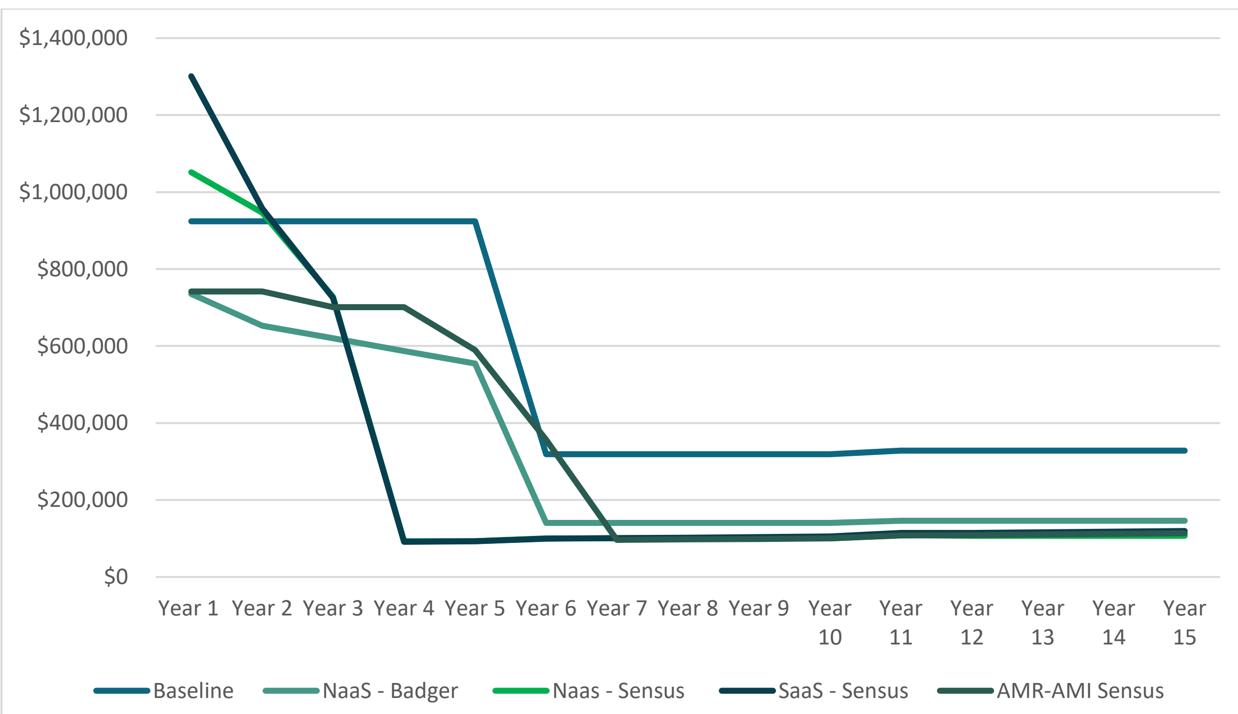
The financial analysis indicates that meter reading costs are lower in the Badger ORION cellular and Sensus FlexNet scenarios compared to the BAU scenario but are projected to be lowest in the Sensus FlexNet scenarios. Potential cost savings through AMI are a significant factor in this outcome. The analysis indicates close to $2 million in savings from fewer truck rolls related to customer start and stop reads and high-use investigations. Both require mid-cycle meter reads, and with an AMI system, the reads could be performed remotely rather than on site. It is important to note that, despite these savings, the financial analysis indicates an overall increase in labor demand. This increase is relevant to all scenarios because it is largely related to projected meter and endpoint replacements and maintenance. In Year 1, the projected number of labor hours is 2,508 for the Sensus FlexNet scenarios.

The SJWD also has another alternate scenario alternative (Scenario 5) because it is currently in the process of deploying the Sensus AMR system. The SJWD could move forward with the Sensus AMR system but defer the AMI system adoption for several years. This would enable the SJWD to deploy endpoints more slowly and defer the decision on when to switch to AMI. In a future year, when a larger number of meters are equipped with Sensus AMR/AMI endpoints, it could transition from AMR to Sensus FlexNet AMI. This option would secure much of the potential benefits identified as hardware cost savings while reducing the total number of endpoint purchases over the planning period. The downside is that the SJWD would not secure cost savings associated with the AMI system for several additional years, which is the case in the Badger ORION cellular scenario (Table 16).

Table 16. 15-Year Financial Analysis Information Table for the SJWD

Item	Scenario 1: BAU	Scenario 2: Badger ORION Cellular (NaaS)	Scenario 3: Sensus FlexNet (NaaS)	Scenario 4: Sensus FlexNet (Agency Owned)	Scenario 5: Sensus AMR to AMI
Meter Hardware					
Small Meters	$2,656,112	$2,317,796	$2,317,796	$2,317,796	$2,317,796
Intermediate Meters	$226,719	$218,703	$218,703	$218,703	$218,703
Large Meters	$36,021	$33,010	$33,010	$33,010	$33,010
Endpoints	$2,828,375	$1,819,424	$1,919,932	$1,919,932	$1,791,572
Sales Tax (8.75%)	$319,144	$213,876	$220,235	$220,235	$214,267
Material Recycling Fee	$52,930	$52,930	$52,930	$52,930	$49,430
Subtotal Hardware	**$6,119,302**	**$4,655,738**	**$4,762,605**	**$4,762,605**	**$4,624,778**
Meter Reading					
Communications	$1,740,022	$1,677,087	$1,087,912	$814,901	$961,138
Data Analytics	$0	$0	$0	$380,182	$335,588
Setup Cost	$0	$49,400	$34,400	$238,371	$238,371
Cost Savings	$0	($1,796,340)	($1,934,520)	($1,934,520)	($1,381,800)
Subtotal Meter Reading	**$1,740,022**	**($69,853)**	**($812,208)**	**($501,066)**	**$153,296**
Total Cost	**$7,859,324**	**$4,585,885**	**$3,950,397**	**$4,261,539**	**$4,778,074**
Net Present Value	**($6,254,822)**	**($3,793,135)**	**($3,427,044)**	**($3,714,441)**	**($4,035,275)**

Notes: BAU = business as usual; NaaS = network as a service



4.2.3 Sacramento Suburban Water District

The SSWD has established a meter reading strategy that places half of its meters on a Sensus FlexNet network and the other half on a Badger ORION cellular network. The District is currently securing good pricing for its meter hardware but there may be an opportunity to secure better pricing through through joint hardware purchasing and meter reading contracting. The analysis also indicates that the District should consider deploying Sensus FlexNet across its entire system as its Badger endpoints require replacement in order to fully leverage its investment in Sensus Communications system (hardware and software).

The SSWD's current meter reading strategy is to connect half of its meters to a Sensus FlexNet network that it is currently rolling out (as of Q4, 2020). The other half of its meters are already on the Badger ORION cellular network. The SSWD's Sensus FlexNet network will be owned and operated by the SSWD; therefore, the costs of putting the network in place have not been included in the financial analysis. In addition, the SSWD currently has a 10-year agreement in place for half of its meters to be read through the Badger ORION cellular network at a service unit fee equal to $0.81 per month.

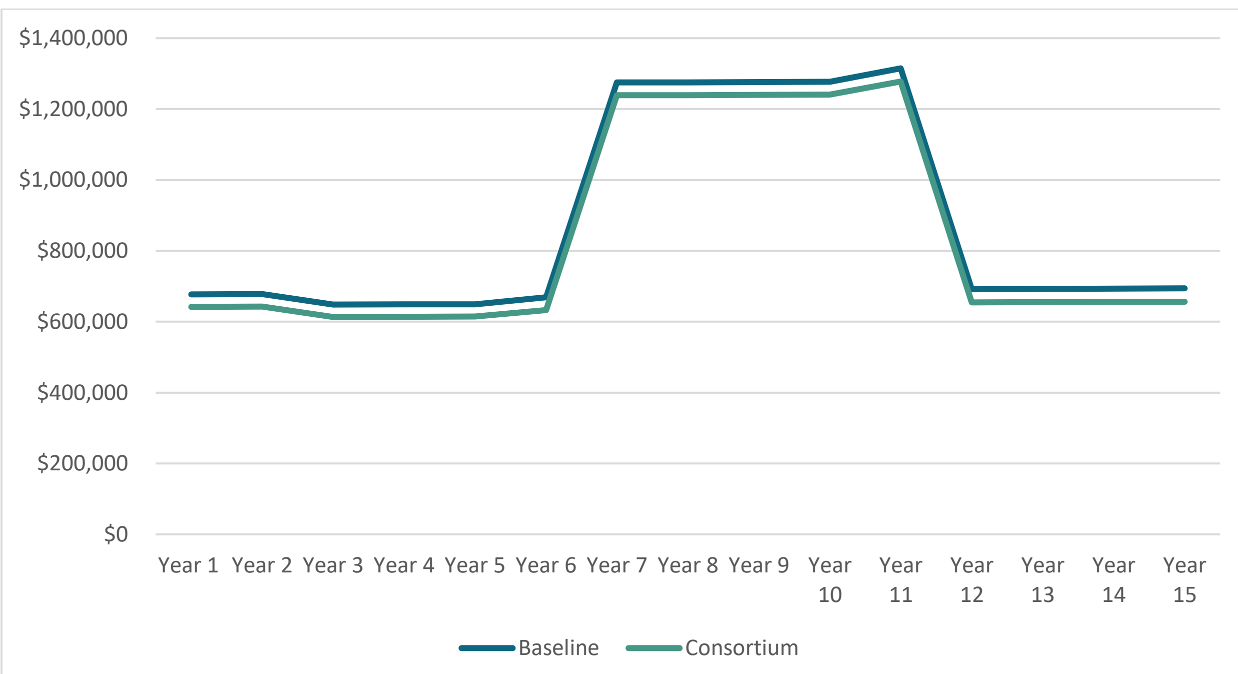
Currently, the SSWD has competitive pricing agreements in place for meter hardware and endpoints. However, other Consortium agencies have secured more competitive pricing by leveraging their larger operational scale/area. As a result, the analysis indicates that potential cost savings are possible over the 15-year planning period exist through joint procurement of meters and endpoints provided that agencies are willing to commit to minimum purchase quantities and can agree on specific hardware configurations.

After the SSWD's 10-year agreement with Badger ORION cellular system is finished, the financial analysis indicates that the SSWD could revisit its fifty-fifty split between Badger ORION cellular and Sensus FlexNet networks. There would be incremental cost increases associated with Sensus software and analytics. However, the District will already have a fully deployed Sensus FlexNet system. The District anticipates needing to purchase these endpoints in years 7-11 of this financial analysis.

Table 17. 15-Year Financial Analysis Summary Information for the SSWD

Item	Scenario 1: BAU	Scenario 2: Consortium Pricing	Difference from BAU
Meter Hardware			
Small Meters	$6,613,363	$6,184,964	($428,398)
Intermediate Meters	$1,397,325	$1,360,177	($37,148)
Large Meters	$559,258	$521,640	($37,619)
Endpoints	$3,354,233	$3,354,233	$0
Sales Tax (7.75%)	$572,224	$533,229	($38,995)
Subtotal Hardware	**$12,496,402**	**$11,954,243**	**($542,160)**
Meter Reading			
Communications	$535,242	$535,242	$0
Data Analytics	$128,147	$128,147	$0
Subtotal Meter Reading	**$663,388**	**$663,388**	**$0**
Total Cost	**$13,159,791**	**$12,617,631**	**($542,160)**
Net Present Value	**($17,639,130)**	**($15,477,487)**	**$2,161,643**

Notes: BAU = business as usual; NaaS = network as a service



4.2.4 City of Sacramento

Currently, the CoS has a fully deployed AMI system in place—the Badger ORION SE (fixed-network) system. Since the system was deployed, Badger has shifted its focus to its cellular network platform. However, the Badger ORION SE system is still supported. The analysis indicates that the CoS's existing meter reading configuration currently provides the best NPV compared to the Badger ORION cellular and Sensus FlexNet NaaS scenarios. However, this finding should be qualified as not including the cost of maintaining the fixed AMI network hardware.

The CoS is in the position to have already secured the best meter pricing in the Consortium due to the scale of its operation. This means that, unlike for the other Consortium agencies, the financial analysis does not indicate economy-of-scale benefits for hardware purchasing. However, the CoS may be able to secure additional savings through a joint bidding process with other agencies, increasing the total bid quantity beyond the pricing they currently secure through joint purchasing. The financial analysis shows how costs can be distributed when endpoints are placed on a 15-year replacement cycle.

One primary benefit of the Badger ORION cellular and Sensus FlexNet NaaS scenarios for the CoS is no O&M costs of the AMI system. The O&M is provided as a service and these costs are incorporated into the per-connection unit fees ($9 per connection per year for Badger ORION LTE and $4.2 per connection per year for Sensus FlexNet). The City should consider this when it revisits its AMI options.

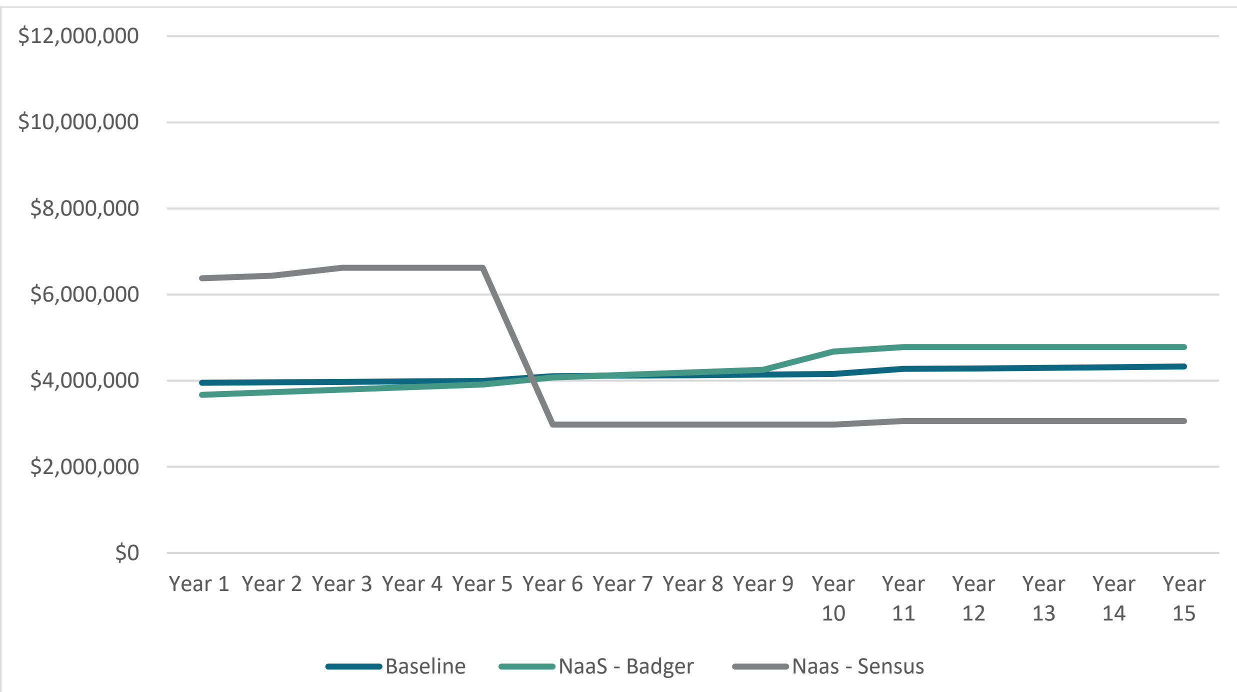
One option for the CoS is to lower its Badger ORION SE system O&M costs by incrementally expanding its number of Badger ORION LTE connections. It has an opportunity to leverage better Consortium unit cost pricing ($0.68 per connection compared to its current $0.85 per connection). It could, for example, eliminate one or more DCUs and populate the coverage area with Badger ORION LTE endpoints.

If, in the future, the CoS elects to investigate alternatives to its current Badger ORION SE system meter reading configuration, the key to the comparison will be the annual unit fees associated with the NaaS options (Badger ORION cellular and Sensus FlexNet NaaS scenarios) compared to the cost of operating and maintaining its existing Badger ORION SE system. Because the CoS purchased so many endpoints, the unit cost associated with each scenario must be considered (Table 18).

Table 18. 15-Year Financial Analysis Summary Information for the CoS

Item	Scenario 1: BAU	Scenario 2: Badger ORION Cellular (NaaS)	Scenario 3: Sensus FlexNet (NaaS)
Meter Hardware			
Small Meters	$22,838,619	$22,838,619	$22,838,619
Intermediate Meters	$4,000,475	$4,000,475	$4,000,475
Large Meters	$3,332,891	$3,332,891	$3,332,891
Endpoints	$19,341,435	$19,341,435	$18,805,498
Sales Tax (8.75%)	$2,270,757	$2,270,757	$2,242,500
Material Recycling Fee	$1,129,137	$1,129,137	$2,444,207
Subtotal Meter Hardware	**$52,913,313**	**$52,913,313**	**$53,664,190**
Meter Reading			
Communications	$9,101,842	$11,276,320	$9,116,465
Data Analytics	$0	$0	$0
Setup Cost	$0	$0	$120,000
Subtotal Meter Reading	**$9,101,842**	**$11,276,320**	**$9,236,465**
Total Cost	**$62,015,155**	**$64,189,633**	**$62,900,654**
Net Present Value	**($44,758,463)**	**($45,699,870)**	**($48,847,213)**

Notes: BAU = business as usual; NaaS = network as a service



4.2.5 Sacramento County Water Agency

The SCWA has already established a meter reading strategy, which is to fully deploy the Sensus FlexNet AMI system across its service area. It is currently in the process of deploying its fourth DCU (Q4, 2020). Once the system is in place, the SCWA's priority is to transition its meters to be read through its Sensus FlexNet AMI system. The financial scenario indicates that, without major modifications to the strategy, significant potential costs savings through joint hardware purchasing exist.

The SCWA's Sensus FlexNet AMI system is owned and operated by the SCWA; therefore, the costs of putting the system in place has not been included in the analysis. The analysis compared the costs of the Badger ORION cellular, Sensus FlexNet NaaS, and Sensus FlexNet agency-owned scenarios in which the SCWA would benefit from better pricing through joint hardware purchasing. Joint hardware purchasing is feasible with the Sensus FlexNet AMI system because it is capable of reading meters produced by other vendors, such as Badger.

As stated earlier for all scenarios, small meters are recommended to be replaced on a 25-year schedule, with intermediate and large meters rebuilt or replaced according to the results of testing—every five years for intermediate meters and every two years for large meters. As stated in Technical Memorandum No. 3, it is assumed that 15 percent of meters tested will need to be rebuilt or replaced. Endpoints are on a 15-year replacement schedule, which means that half are deployed when meters are replaced, and half are deployed separately each year. A new lid is assumed to be needed for the first round of deployments (over the first 15 years). Since some of the Agency's meters are already fitted with Sensus FlexNet endpoints, it can expect all of its connections to be on its AMI system within 9 years at this rate. A faster endpoint deployment schedule is also presented (Scenario 1) in which it could fully convert to AMI within 6 years if it increased its annual investment in endpoints over the first 6 years of the planning period.

The SCWA currently has approximately 31,505 meters that need to be modified in order to function effectively in the Sensus FlexNet system. The majority of these meters have older registers with 4 or 5 digit dials. In order to support the hourly reads associated with the FlexNet AMI system, the meters that will be read on the Sensus FlexNet system should have 7 to 9 dials. Many of the registers in these meters are also programmed to read in 100 CF whereas, they should read in 1 CF so there is consistency across the system.

The best solution is to replace the register of these meters when the Sensus FlexNet endpoint is installed with a 7-9 dial register set to 1 CF units (See Table 19). For meters deployed before 2000, it is recommended to replace the meter and the register because of the age of the meter. For meters deployed from 2001 or later, the register can be replaced at the discretion of the Agency. There are a subset of these meters that have 6 dial programmable registers that were installed after 2000. For these meters, the Agency has an alternate option of reprogramming them to output in 1CF.

Table 19. Register Replacement Quantities for Sensus FlexNet Compatibility

	4,5, or 6 Dial, 100 CF Unprogrammable Registers		4,5, or 6 Dial, 100 CF Programmable Registers		
	Meter installed before 2001	Meter installed after 2001	Meter installed before 2001	Meter installed after 2001 (4 or 5 Dial)	Meter installed after 2001 (6 Dial)
Currently have Endpoint	700	71	257	5284	33
Currently have no Endpoint	12430	1339	5155	5862	374
	Replace Meter and Register	Replace Register	Replace Meter & Register	Replace Register	Reprogram or Replace Register

The register change-out can be done at the time the Sensus endpoint is installed for a portion of these meters, which will require minimal additional installation costs. For meters already equipped with Sensus FlexNet endpoints, the replacement or reprogramming will need to be done independently. These change-outs would, therefore, include additional labor and truck-roll costs. Assuming a unit register cost of $85, the total cost of parts for 31,098 registers can be anticipated to be $2,643,330.

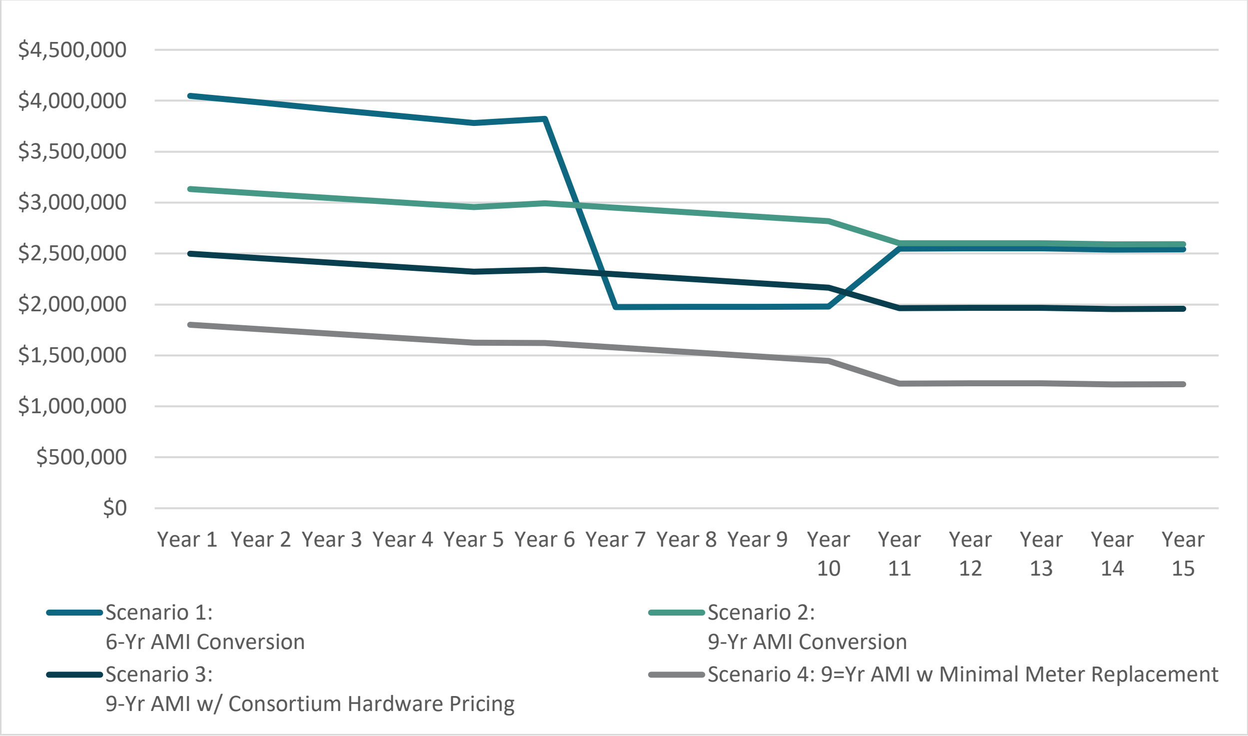
The analysis indicates that the Badger ORION cellular and Sensus FlexNet NaaS scenarios are not as cost effective over the planning period compared to the existing deployment of its Sensus FlexNet agency-owned AMI system. This is primarily due to both the initial investments the SCWA has already made in its network and the comparatively higher annual unit cost of connecting meters to the Badger ORION cellular network.

The financial analysis indicates that there is potential for significant costs savings through joint hardware purchasing. The greatest potential is with small meter and endpoint purchasing. Consortium-based pricing for small meters can potentially save the SCWA over $7.5 million over the 20-year planning period. This is a viable option for the SCWA because the Sensus FlexNet AMI system is compatible with meters produced by competing vendors, such as Badger. Consortium-based pricing for Sensus FlexNet endpoints can potentially save the SCWA over $7.5 million over the 20-year planning period (Table 20).

Table 20. 15-Year Financial Analysis Summary Information for the SCWA

Item	Scenario 1: 6-Yr AMI Conversion	Scenario 2: 9-Yr AMI Conversion	Scenario 3: 9-Yr AMI with Consortium Hardware Pricing	Scenario 4: 9-Yr AMI with Consortium Hardware Pricing, Minimal Meter PM
Meter Hardware				
Small Meters	$17,361,797	$17,361,797	$13,709,940	$0
Intermediate Meters	$2,651,859	$2,651,859	$2,487,933	$380,384
Large Meters	$719,581	$719,581	$719,574	$719,574
Endpoints	$18,718,438	$17,113,110	$11,980,392	$17,272,491
Sales Tax (8.75%)	$1,569,100	$1,553,565	$1,039,466	$631,727
Material Recycling Fee	$828,547	$553,235	$395,884	$550,623
Subtotal Hardware	**$41,849,323**	**$39,953,148**	**$30,333,189**	**$19,554,799**
Meter Reading				
Communications	$1,544,140	$2,152,928	$2,152,928	$2,152,928
Data Analytics	$639,065	$639,065	$639,065	$639,065
Setup Cost	$0	$0	$0	$0
Subtotal Meter Reading	**$2,183,205**	**$2,791,993**	**$2,791,993**	**$2,791,993**
Total Cost	**$44,032,528**	**$42,745,141**	**$33,125,182**	**$22,346,792**
Net Present Value	**($33,418,356)**	**($31,479,855)**	**($24,491,894)**	**($16,697,825)**

Notes: BAU = business as usual; NaaS = network as a service



4.2.6 Placer County Water Agency

The Badger ORION cellular scenario presents the lowest net cost alternative compared to the BAU and Sensus FlexNet scenarios. Although the costs are higher in the Badger ORION cellular and Sensus FlexNet scenarios compared to the BAU scenario, the benefits associated with AMI are larger as well. The benefits are associated with the PCWA's ability to collect meter data remotely rather than dispatching a crew to read on site. The benefits are slightly higher in the Sensus FlexNet NaaS scenario because they start faster.

The biggest difference between the Sensus FlexNet and Badger ORION scenarios relate to the speed of rollout. In the Sensus scenario, endpoints must be purchased and installed in the first 3 years of the planning period. In the Badger ORION cellular scenario, the endpoints can be purchased and deployed at any pace the Agency prefers. This is because the cost of communications for the Badger system are built into a subscription fee, which relies on commercial towers that are already deployed. As a result, costs can be better distributed over the planning period in the Badger scenario.

The PCWA is already acquiring fairly competitive pricing compared to other Consortium agencies, particularly for endpoints. As a result, the financial analysis does not indicate significant savings in hardware costs through joint purchasing. However, some savings may be realized, and since a conservative estimate has been provided, it may be possible for the PCWA to secure better pricing in a joint public bidding process than what is used in this analysis.

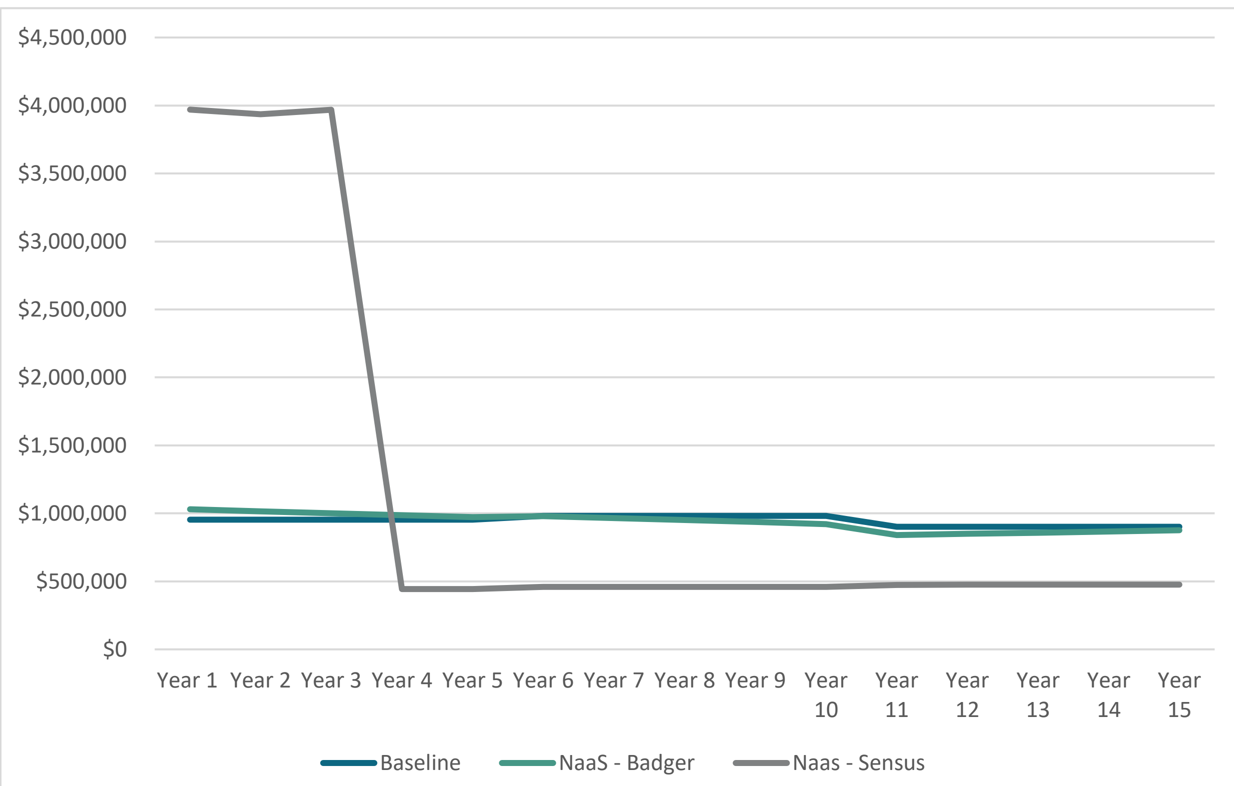
Meter reading costs are higher in both the Badger ORION cellular and Sensus FlexNet NaaS scenarios compared to the BAU scenario. This is because the additional costs relate to both managing the endpoints and paying AMI fees compared to the cost of collecting radio reads. However, benefits can be derived from the AMI system, and when benefits are included, the Badger ORION cellular scenario has a better NPV compared to the BAU scenario.

Overall, the financial analysis indicates a potential for cost savings through the Badger ORION cellular scenario. There are other benefits to having all the PCWA's connections on an AMI system that have not been quantified here, such as using the data collected through an AMI system for engineering planning purposes. However, the analysis shows that it is important to consider both the costs and benefits in the analysis in order for the Badger ORION cellular scenario to compare favorably to the BAU scenario (Table 21). If the Agency adds Badger ORION endpoints at the rate of meter replacement (4% per year), it will not be completely Badger AMI until approximately year 15. If the Agency were interested in shifting to Badger ORION more quickly it could install endpoints in addition to the ones that are deployed when meters are replaced.

Table 21. 15-Year Financial Analysis Summary Information for the PCWA

Item	Scenario 1: BAU	Scenario 2: Badger ORION Cellular (NaaS)	Scenario 3: Sensus FlexNet (NaaS)
Meter Hardware			
Small Meters	$6,635,781	$6,493,951	$6,493,951
Intermediate Meters	$625,033	$623,337	$623,337
Large Meters	$170,815	$169,940	$169,940
Endpoints	$4,945,958	$4,900,308	$9,489,211
Sales Tax (7.25%)	$399,514	$385,735	$624,398
Material Recycling Fee	$114,125	$114,125	$184,615
Subtotal Meter Hardware	**$12,891,227**	**$12,687,397**	**$17,585,452**
Meter Reading			
Communications	$1,291,254	$3,854,344	$2,762,653
Data Analytics	$0	$0	$0
Setup Cost	$0	$0	$68,800
Total Benefit	$0	($2,491,610)	($2,990,106)
Subtotal Meter Reading	**$1,291,254**	**$1,362,735**	**($158,654)**
Total Cost	**$14,182,481**	**$14,050,132**	**$20,416,905**
Net Present Value	**($10,346,415)**	**($10,342,105)**	**($15,022,939)**

Notes: BAU = business as usual; NaaS = network as a service



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Section 5 Conclusions & Recommendations

Technical Memorandum No. 4 provides long-term planning options for Consortium agencies that are intended to balance responsiveness to the priorities and preferences of each individual agency with opportunities to leverage collective efficiencies of scale through Consortium-level cooperative action.

5.1 Meter Replacement

Consortium agencies are recommended to replace or rebuild all deployed meters on either a fixed replacement or test schedule (See Table 22). Small meter recommendations are based on an analysis of a meter testing dataset provided by the CoS and additional meter testing data provided by the SJWD, SSWD, and PCWA.

- **Small Meters –** On an annual basis, agencies are recommended to replace small meters that have either exceeded five MG of total registered consumption or 25 years of deployment. As a result, agencies can expect small meters to last up to 25 years.
- **Intermediate Meters –** Agencies are recommended to rebuild or replace intermediate meters every 10 years. In the future, agencies should consider updating this criteria with either consumption- or age-based criteria based on test data.
- **Large Meters –** Agencies are recommended to test large meters on a one- or two-year schedule. For planning purposes and assuming a two-year schedule is used, agencies can, on average, anticipate replacing or rebuilding 7.5 percent of their large meters per year (based on Technical Memorandum No. 3).

Table 22. Estimated Annual Meter Replacement or Rebuild Quantities

Type	CHWD	CoS	PCWA	SCWA	SJWD	SSWD	Total
Small Meters (4%–5%)	798–998	4,876–6,095	1,433–1,791	2,003–2,504	412–515	1,466–1,832	10,988–13,735
Intermediate Meters (10%)	119	719	97	304	27	244	1,510
Large Meters (7.5%)	7	182	9	26	2	32	233

As a Consortium, the annual quantity of meter replacements should provide considerable economy of scale for more advantageous unit pricing compared to what many agencies are currently securing.

5.2 Meter Reading

Among several potential options, the analysis of the propagation studies revealed that Badger ORION cellular and Sensus FlexNet systems are capable of providing benefits at both the Consortium level and within a relatively short time frame compared to the other assessed systems. The Badger and Sensus systems are widely deployed across the Consortium. Both systems offer comparable capabilities for their managed network (i.e., NaaS), including customer portals and data analytic systems. Both systems also continuously add new capabilities such as pressure and water quality monitoring that, in the future, could assist agencies in hydraulic modeling, water loss analysis and response, and distribution system operations.

It is also important to clarify that final decisions about the least cost alternative will depend on formal bid processes. The financial analysis performed in this Study does not employ a formal bid process. Thus, the costs discussed here are not considered final offerings from the participating vendors and are meant to compare the differences between types of options and potential economies of scale as follows:

- The **Sensus system** offers the potential for agencies to share DCUs as a result of their comparatively large geographical and topographical service range. The configuration developed by Sensus for this Study covers the Consortium-wide service area with a total of 42 DCUs, which is significantly fewer than the other systems that were evaluated. The advantage of the Consortium-level network configuration is that most of the DCUs could provide coverage to more than one agency, which would provide a more cost-effective and redundant network. In addition, the endpoint pricing and NaaS unit service fees are lower than what was provided by Badger for the purpose of this Study. According to the best available information, this indicates that, over time, the Sensus network may currently provide the least costly alternative from a total Consortium perspective. However, it should also be noted that the pricing provided in this Study is not based on a formal bid process and assumes all Consortium agencies opt into a Consortium NaaS agreement together. If fewer agencies participate, the unit costs would likely increase.
- The **Badger system** offers flexibility in coverage area and the speed at which agencies connect their meters. This is because it employs existing commercial cellular networks for collecting meter data and does not require additional investments in network hardware by Badger or the agencies. This flexibility is an important advantage of this system over the alternatives. However, according to the best available information, the endpoint pricing and unit service fee provided for the purposes of this Study are higher than the alternatives. This must be factored in when considering costs over time for each agency's system needs. The other factor to consider is that over time, Badger's unit service fee has trended downward. This trend is expected to continue over time. Therefore, it may be the case that, in the near future, the Badger system may compare more favorably to the alternatives.

One hybrid approach for some agencies could be to deploy Sensus endpoints at their pace of meter replacements. This would have the benefit of a more cost-efficient endpoint replacement schedule (similar to what would be possible with the Badger system). It would be possible for the SJWD, SSWD, and SCWA to scale up the Sensus system at their pace of meter replacement because they already deploy Sensus endpoints for either AMR or AMI systems. The CHWD could also adopt this hybrid approach by converting its radio-read meters to Sensus AMR immediately. Then, in several years, when the majority of its meters are equipped with AMR/AMI Sensus endpoints, it could make a broader conversion to the Sensus FlexNet AMI system. This would be a similar approach to one that the SJWD could take as a least cost option. The downside for the CHWD and SJWD is that they would not reap the benefits of or gain experience using an AMI system as early if they employed an AMR system for several years before switching to an AMI system. The benefit would be that this approach is less costly compared to BAU and would require fewer endpoint purchases over the next 10 years. This hybrid approach is least feasible for the CoS and PCWA because these agencies would need to make a much more significant investment to scale up a Sensus network.

5.3 Financial Planning

A financial analysis was performed for each participating agency relative to BAU and the Badger and Sensus meter reading scenarios described in Section 3. The meter replacement strategy described in Section 2 underpins the financial analysis by dictating how many meters and endpoints need to be purchased each year. Table 24 shows projected annualized hardware costs based on the financial analysis performed for each agency for the 15-year planning period.

Table 24. Estimated Annualized Meter Hardware Replacement Costs

Item	CHWD	CoS	PCWA	SCWA	SJWD	SSWD
Meters	$274,865	$2,011,466	$485,815	$1,127,830	$171,301	$537,785
Endpoints	$275,647	$1,289,429	$326,687	$798,693	$119,438	$223,616
Sales Tax	$24,256	$151,384	$25,716	$69,298	$14,284	$35,549
Material Recycling Fee	$7,918	$75,276	$7,608	$26,392	$3,295	*
Total	**$582,68**	**$3,527,554**	**$845,826**	**$2,022,213**	**$308,319**	**$796,950**

* The SSWD currently incorporates the material recycling fees into its hardware purchasing contracts

The individual agency financial analyses indicate that, for the recommended replacement scheduling, there is significant potential for cost savings related to the joint purchasing of meters and endpoints. Table 25 shows projected savings based on the financial analysis performed for each agency over the 15-year planning period. The key assumption is that, collectively, agencies will be able to secure pricing that is the same or better than what Consortium agencies are already receiving without any minimum purchase commitments. However, this should be considered a conservative estimate. The results of a joint bidding process may provide better cost savings than what are indicated below, particularly if agencies are willing to commit to minimum purchase quantities.

Table 25. Estimated Meter Hardware Cost Savings over 15 Years

Item	CHWD	CoS	PCWA	SCWA	SJWD	SSWD
Meters	$2,314,725	$0	$144,401	$3,815,791	$349,344	$503,165
Endpoints	$2,547,159	$0	$45,650	$5,132,718	$1,036,804	$0
Total	**$4,861,884**	**$0**	**$190,051**	**$8,948,509**	**$1,386,147**	**$503,165**

For planning purposes, the total annualized labor projections by agency for meter replacement and meter reading are shown in Table 26 based on the most efficient meter and endpoint replacement strategies for each agency. Labor projections include meter and endpoint replacements, endpoint troubleshooting and maintenance, pickup reads, and other meter reading needs in the case of some agencies that currently employ manual, touch, or AMR methods.

Table 26. Estimated Annual Labor Hours for Meter Replacement and Meter Reading

Item	CHWD	CoS	PCWA	SCWA	SJWD	SSWD
Annualized Labor (hours)	2,826	15,669	5,219	9,026	1,444	3,485

5.4 Next Steps

The final phase of this Study will be implementation planning. Each participating agency will chart a five-year plan to implement the set of recommended meter replacement, meter reading, and meter testing strategies based on the information and analysis provided in Technical Memorandums No. 1, 2, 3, and 4. A set of key performance indicators will be established for Consortium agencies to measure progress and revise their selected strategies over time. Importantly, the next phase will include implementation plans for strategies at the Consortium level composed of joint purchasing and service options and information management systems.

Appendix E. Technical Memorandum No. 5 - Implementation

SUBMITTAL DRAFT

Meter Replacement Program Planning Study

Technical Memorandum No. 5
Implementation Planning

July 2022

Prepared for:

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Appendix A. Agency Implementation Plan Executive Summaries

AMI	**Advanced metering infrastructure** is a collection of wireless communication equipment that enables a utility to remotely collect meter data at regular intervals.
AMR	**Automatic meter reading** is a method of collecting meter data through radio frequencies by walking or driving near the deployed meters.
CHWD	**Citrus Heights Water District**
CIS	**customer information system**
CMMS	**Computerized maintenance management information system**
Consortium	**Water Meter Replacement Program Consortium** includes Carmichael Water District, Citrus Heights Water District, City of Folsom, City of Sacramento, Fair Oaks Water District, Golden State Water Company, Orange Vale Water Company, Placer County Water Agency, the Regional Water Authority, Sacramento County Water Agency, Sacramento Suburban Water District, and San Juan Water District.
CoS	**City of Sacramento**
CSR	**Customer Service Representative**
Endpoint	An **endpoint** is a device that is connected by wires to an encoder and transmits digitized water use data to a meter reading system.
Folsom	**City of Folsom**
GIS	**Geographic Information Systems**
Harris	**Harris & Associates**
Intermediate Meters	**Intermediate Meters** are meters that have a 1.5-inch or two-inch water flow capacity.
Large Meters	**Large Meters** are meters that have a three-inch flow capacity or larger.
MRP	**Meter Replacement Program**
PCWA	**Placer County Water Agency**

RFP	**Request for Proposal**
RWA	**Regional Water Authority**
SCADA	**Supervisory Control and Data Acquisition**
SCWA	**Sacramento County Water Agency**
SJWD	**San Juan Water District**
Small Meters	**Small Meters** are meters that can have a one-inch water flow capacity or smaller.
SSWD	**Sacramento Suburban Water District**
Study	**MRP Planning Study**

Phase 4 Overview

Phase 4 of the Meter Replacement Program (MRP) Planning Study (Study) entailed developing meter implementation programs for several members of the Water Meter Replacement Program Consortium (Consortium). Each participating agency was provided with its own Implementation Plan, which included recommendations for meter replacement, installation or replacement of data endpoints, and meter testing. Estimated costs, staffing requirements, and a five-year implementation timeline were also included.

Phase 4 Results and Conclusions

Based on the projected increase in the volume of meter and equipment purchases among the Consortium member agencies, along with a substantial increase in meter testing needs and other technical support, analysis suggested that there would likely be a number of benefits by developing a coordinated program among Consortium members. In particular, the areas of support that would benefit nearly all Consortium members include joint purchasing of meters and supporting equipment, coordinated meter testing, and coordinated technical assistance. Estimated cost savings from joint purchasing alone averaged over $1 million per year across all Consortium members. Meanwhile, significant savings in agency staff time could be realized by having coordinated technical assistance and meter testing support programs.

Regional Program Recommendation

With a significant opportunity to save cost and reduce duplicative efforts among Consortium members, a regional meter program has been outlined. This program, envisioned to be managed through the Regional Water Authority (RWA), would provide four support services: (1) coordination, (2) joint purchasing, (3) meter testing, and (4) technical assistance. The program is proposed to begin by the middle of 2022 as a subscription program.

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Section 1 Phase 4 Introduction

1.1 Study Overview

The Meter Replacement Program (MRP) Planning Study (Study) presents a unique opportunity for neighboring water agencies in the greater Sacramento area to explore the potential benefits of working together. Water MRP Consortium (Consortium) agencies understand that the utilities of the future will operate in a different paradigm—one that is largely built on public and stakeholder trust, along with cooperation and collaboration with adjoining entities with common interests and economic benefits.

The purposes of the Study are as follows:

- Develop a water meter replacement strategy for participating water agencies
- Determine the feasibility and a strategy, as appropriate, for long-term, full, or partial integration of MRPs for participating water agencies

Figure 1 shows the range of potential individual versus cooperative development and implementation of water meter and water meter reading technology replacement for the participating water agencies.

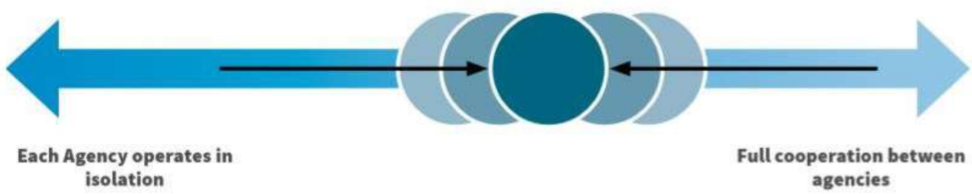


Figure 1. The purpose of the Study is to determine how participating water agencies can sensibly integrate their MRPs over time.

The following agencies participated in this Phase 4 Implementation Planning of the Study:

- Citrus Heights Water District (CHWD)
- City of Sacramento (CoS)
- Placer County Water Agency (PCWA)
- Sacramento County Water Agency (SCWA)
- Sacramento Suburban Water District (SSWD)
- San Juan Water District (SJWD)

The following agencies are members of the Consortium but are not directly participating in this phase of the Study:

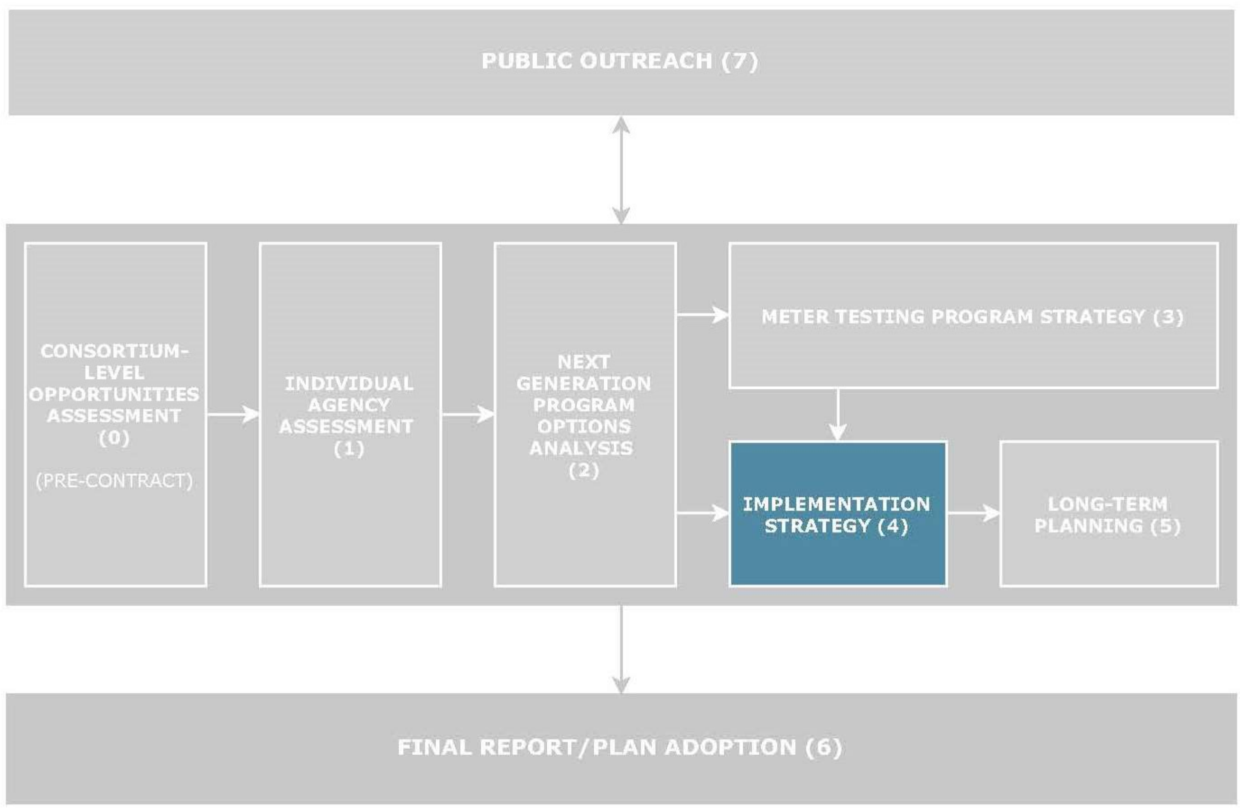
- Carmichael Water District
- Fair Oaks Water District
- Golden State Water Company

- City of Folsom (Folsom)
- Orange Vale Water Company
- Regional Water Authority (RWA)

1.2 Introduction to Phase 4

The purpose of this phase is to develop a meter replacement implementation strategy for participating agencies that evaluates and recommends actions for each agency individually and as a Consortium. The alternative strategies and evaluations are based on information received and assessed by Harris & Associates (Harris), as described in Phases 1 through 3, relating to meter technology and meter reading technology (Figure 2).

Figure 2. Overall Meter Study Activities



1.3 Methodology for Phase 4

The following tasks and methodologies were used for individual agency-specific plans and applied to each participating agency.

1.3.1 Elements of the Strategic Meter Replacement Plan

Harris conducted a workshop and individual agency interviews to obtain consensus regarding implementation strategy elements and assumptions. Additional information not requested in Phase 1 was required in this phase to better define the strategic meter and meter reading technologies to be evaluated and the associated evaluation criteria and economic assumptions.

Harris, working collaboratively with each agency, identified the following specific elements of the potential meter replacement plan:

- Hardware assets
- Water meters
- Meter registers
- Meter box lids
- Endpoint technologies
- Data collectors/repeaters
- Collector mounting towers
- Data storage hardware
- Meter testing facility and equipment
- Software assets
- Meter reading
- Billing (customer information system [CIS])
- Data storage
- Data analytics
- Network performance/status
- CIS integration
- Computerized maintenance management information system (CMMS) integration
- Other desirable integration (supervisory control and data acquisition [SCADA], geographic information systems [GIS], hydraulic modeling)
- Customer web-based portal
- Organization and staffing assets
- Customer service representatives (CSRs)
- Meter readers
- Meter testing staff (individually and collectively)
- New advanced metering infrastructure (AMI) technologies
- Financial assets
- Revenue sources (rates, connection fees, bonds, loans, grants)
- Life cycle costs
    - Initial capital costs

- Recurring operational costs
- Recurring licensing and data hosting costs
- Communication costs
- Avoided costs
- Economies of scale

1.3.2 Develop the Recommended Implementation Strategy

Harris developed a meter replacement and meter reading implementation strategy for each agency based on evaluations of the information collected in Phases 1 and 2, described previously, assuming individual agency implementation and funding. The following alternative implementation strategies were developed:

1. Replacement of all meters at once (most capital and staffing intensive)
2. Phased replacement of meters and meter reading technology, including the multiple hardware, software, staffing, and financial elements
3. Methods for handling combined new and existing meter and meter reading systems
4. Alternative funding and financing methods
5. Staffing and organizational changes affected by alternative strategies

1.3.3 Opportunities for Cost Efficiencies

Harris developed Consortium-level meter program strategies based on Phase 0 dialogue and project collaboration with participating agencies. Consortium-level opportunities were fully evaluated for agency consideration through inter-agency meetings providing a complete analysis of efficiencies. The following elements offer cost efficiencies:

- Meter and meter component purchases
- Meter reading system purchases (hardware and software)
- Meter accuracy testing facility and staffing
- Program funding options
- Installation contracting
- Database integration software and long-term maintenance
- Data hosting services
- AMI technology staff

1.3.4 Policies, Programs, and Tasks Necessary to Accomplish the MRP as a Consortium

Subsequent to the identification of potential cost efficiencies in Section 1.3.3, Opportunities for Cost Efficiencies, Harris identified and evaluated current abilities and barriers to accomplish specific efficiencies through joint rather than individual action. A summary of potential Consortium approach advantages and methods for successful achievement was prepared.

1.3.5 Implementation Plan for Meter Replacement Phasing – Agency and Consortium Strategies

Harris worked with support agency staff to evaluate the tradeoffs for different meter replacement phasing strategies and to determine an optimal time frame to phase in next generation meter technologies. The evaluation incorporated findings from the previous phases, including both technical and financial factors. Additionally, the phasing strategy incorporated financing options and the organizational changes required.

A Phase 4 Implementation Plan for each individual participating agency was created for distribution, discussion, and review/comment before finalization. Contents of the Implementation Plan included the following:

- A detailed description of the key elements that underpin the implementation strategy, including all relevant hardware, software, staffing, and financial elements
- A detailed meter replacement and meter reading implementation strategy, including piloting, for each agency and the Consortium
- A full analysis of Consortium-level opportunities for efficiency and the policies, programs, and tasks necessary to implement them
- A full assessment and Implementation Plan for meter replacement phasing at the individual agency and Consortium level
- An implementation schedule and funding program for each participating agency and consideration of individual agency metering needs, wants, internal capabilities, available staff, financial resources, Consortium opportunities, and plan risks and unknowns

Summary matrices of alternative Implementation Plan elements and costs were also prepared for individual agency study and decision-making relative to unilateral or joint funding.

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Section 2 Individual Agency Implementation Planning

2.1 Overview

Based on the results of other project phases and several discussions with participating agencies, individual Draft Implementation Plans were prepared for the following agencies:

Each Draft Implementation Plan provides analysis and recommendations for the following activities:

1. Meter testing
2. Meter rebuilding or replacement
3. Meter reading
4. Meter data management

The executive summary for each agency's Draft Implementation Plan is provided in Appendix A. The following sections provide a high-level overview of key aspects and recommendations from the Implementation Plans.

2.2 Implementation Summary for Each Agency

Each agency's Implementation Plan illustrates a range of current meter program statuses and needs. Below is an overall summary of findings, recommendations, and key decisions/considerations still to be addressed. The following sections provide an overview for each participating agency.

2.2.1 Citrus Heights Water District

The primary step the CHWD will be taking in 2022 is implementing a robust testing program. Once that decision is made, the CHWD expects to proceed with purchasing AMI endpoints and purchasing and replacing small meters possibly beginning in 2024. As its replacement plans begin to take further shape, CHWD will embark on implementing a comprehensive meter testing program (Table 1).

Table 1. Implementation Summary for Citrus Heights Water District

Activities	Summary
Meter Testing	• Implement a small meter testing plan via outsourcing. • Expand testing of intermediate and large meters.
Meter Rebuilding or Replacement	• Full replacement of small meters over next 15 years. Initial purchasing possibly beginning in 2024.
Meter Reading	• Complete current assessment of Badger ORION cellular AMI and Sensus FlexNet AMI. • Full implementation of AMR and then transition to AMI over time. Initial purchasing possibly beginning in 2024.
Meter Data Management	• Establish a meter data and asset management program.

Notes: AMI = advanced metering infrastructure; AMR = automatic meter reading

2.2.2 City of Sacramento

The upcoming focus for the CoS will be to continue to improve and expand its in-house meter testing program, complete installation of its AMI network, and improve its meter data management. The CoS is not expecting to begin replacing small meters en masse until after 2026 (Table 2).

Table 2. Implementation Summary for City of Sacramento

Activities	Summary
Meter Testing	Continue to refine and optimize in-house meter testing program. Develop process to provide testing services to other Consortium members.
Meter Rebuilding or Replacement	Begin annual replacement of approximately 5,000 small meters per year after 2026. Replace or rebuild approximately 700 intermediate meters and 180 large meters per year, respectively.
Meter Reading	Complete installation of AMI using a mix of cellular and fixed network.
Meter Data Management	Develop system to integrate billing/usage meter data with asset management data.

Notes: AMI = advanced metering infrastructure

2.2.3 Placer County Water Agency

The PCWA intends to replace the existing deployed meters with the greatest total registered flow and longest deployment periods. The PCWA's other primary goal is to convert its entire network of deployed meters to the Badger ORION cellular AMI to extend its current AMI approach and to leverage advantages of a full AMI solution for meter reading and interval read data collection (Table 3).

Table 3. Implementation Summary for Placer County Water Agency

Activities	Summary
Meter Testing	Begin implementing small meter testing program. Develop an intermediate meter evaluation program. Continue field testing larger meters.
Meter Rebuilding or Replacement	Replace meters as needed to complete AMI implementation. Once AMI implementation is completed, begin annual replacement of approximately 1,500 small meters per year. Replace or rebuild approximately 100 intermediate meters and 10 large meters per year, respectively.
Meter Reading	Complete installation of Badger ORION cellular AMI system.
Meter Data Management	Develop system to integrate billing/usage meter data with asset management data.

Notes: AMI = advanced metering infrastructure

2.2.4 Sacramento County Water Agency

The SCWA intends to replace the existing deployed meters with the greatest total registered flow and longest deployment periods. The SCWA's other primary five-year goal is to leverage its interval reading data from its Sensus FlexNet radio automatic meter reading (AMR)/AMI system (Table 4).

Table 4. Implementation Summary for Sacramento County Water Agency

Activities	Summary
Meter Testing	Begin implementing small meter testing program once AMI expansion is underway. Outsource and begin large meter testing in 2022. Develop a plan for intermediate meter testing and/or replacement.
Meter Rebuilding or Replacement	No bulk purchasing and replacement of meters until after 2028. Meanwhile, undertake necessary meter replacement associated with AMI installation.
Meter Reading	Expand AMI implementation to cover remainder of the system by 2028 (approximately 30,000 endpoints).
Meter Data Management	Develop system to integrate billing/usage meter data with asset management data.

Notes: AMI = advanced metering infrastructure

2.2.5 Sacramento Suburban Water District

The SSWD will continue to replace the existing deployed meters with the greatest total registered flow and longest deployment periods, eventually transitioning to an ongoing program of regular replacement of small meters and rebuild or replacement of intermediate and large meters. The SSWD has the option to leverage its interval reading data from its balanced Badger ORION cellular AMI and its Sensus FlexNet radio AMI system (Table 5.).

Table 5. Implementation Summary for Sacramento Suburban Water District

Activities	Summary
Meter Testing	Continue with current testing program for small and large meters. Consider implementing intermediate meter testing as new meters with sample ports are installed to replace existing meters.
Meter Rebuilding or Replacement	No bulk purchasing and replacement of meters until after 2028. Meanwhile, undertake necessary meter replacement associated with AMI installation.
Meter Reading	Complete installation of AMI system.
Meter Data Management	Develop system to integrate billing/usage meter data with asset management data. Update water meter asset management plan.

Notes: AMI = advanced metering infrastructure

2.2.6 San Juan Water District

The SJWD currently intends to replace the existing deployed meters with the greatest total registered flow and longest deployment periods. The SJWD's other primary five-year goal is to ensure compatibility of deployed AMR drive-by endpoints with future AMI, should the SJWD choose to implement it (Table 6).

Table 6. Implementation Summary for San Juan Water District

Activities	Summary
Meter Testing	Begin implementing small meter testing program. Develop an intermediate and large meter testing program.
Meter Rebuilding or Replacement	Begin implementing a proactive meter monitoring and performance program through testing and asset management that informs decisions based on cost-effective economics.
Meter Reading	Continue with already established meter reading strategy, which is to fully deploy a drive-by AMR system across its service area.
Meter Data Management	Develop system to integrate billing/usage meter data with asset management data.

Notes: AMR = automatic meter reading

2.3 Implications for Consortium-Level Opportunities

2.3.1 Interests of Consortium Members

Based on the implementation guidance developed for the Consortium members, several opportunities to collaborate are apparent. Three broad areas for further focus and development are as follows:

1. **Bulk purchasing:** Coordinated and pooled purchasing of like metering products, such as meters, endpoints, and accessories or spare parts, to obtain volume discounts from supplier.
2. **Bench testing:** Use of bench testing equipment and available capacity of some Consortium members to assist those lacking such bench testing equipment.
3. **Technical assistance:** Provision of meter support services that can be shared among Consortium members to reduce agencies having to perform the same work for themselves.

In early 2021, a survey of Consortium members found most interested in participating in several Consortium-level activities as summarized in Table 7.

Table 7. Consortium Member Interest in Regional Meter Program Support

	1. Bulk Purchasing			2. Bench Testing	3. Technical Assistance	
	Meters	Endpoints	Accessories		Qualified Vendors	Standard Operating Procedures
CHWD	X	X	X	X	X	X
CoS	X[1]	—	X	X	—	X
PCWA	X	—	X	X	X	X
SCWA	—	X	X	X	X	X
SJWD	X	X	X	X	X	X
SSWD	X	X[2]	X	X	—	X
Folsom	X	—	X	X	—	X

Notes: Based on survey and discussions from December 2020 – March 2021.

1 CoS: Currently under purchasing contract through 2027.

2 SSWD: Currently under purchasing contract through 2028.

2.3.2 Potential Consortium Member Benefits

As part of the Implementation Plan development for each participating Consortium member, the potential benefit of using Consortium-level support and resources was estimated. Table 8 lists the range of benefits that could be realized through these Consortium-level services. An estimated $17 million could be saved through bulk purchasing by at least four of the Consortium members, averaging about $1 million per year over 15 years. Meanwhile, regional support to help Consortium members handle more than 2,000 recommended additional meter tests per year could help reduce testing costs and coordination, thus promoting more testing (and greater accuracy). Lastly, technical assistance coordinated regionally will reduce potential duplicative efforts rather than each agency performing its own vendor qualification and developing its own standard operating procedures.

Table 8. Benefits of Consortium-Level Meter Services

Types of Support	Estimated Benefits
Bulk Purchasing	**Cost savings over 15 years:** CHWD: ~$3 million PCWA: ~$2 million SCWA: ~$9 million SJWD: ~$1.4 million **Total: ~$15.4 million**
Bench Testing Capacity	**Additional meter tests planned per year:** CHWD: >600 PCWA: >200 SCWA: >1,000 SJWD: >400 **Total: >2,200**
Technical Assistance	Save agency staff time (undetermined) qualifying vendors and preparing standard operating procedures for testing and maintenance.

Notes: CHWD = Citrus Heights Water District; PCWA = Placer County Water Agency; SCWA = Sacramento County Water Agency; SJWD = San Juan Water District

The actual benefits of these services will need to be evaluated on an ongoing basis.

2.3.3 Timing of Consortium Needs

Several member agencies expect to move forward with meter implementation improvements over the next five years. While each agency is currently incorporating their Implementation Plans into their capital purchasing and staffing plans, Table 9 provides a general characterization of expected activities and needs over the next five years.

Table 9. Expected Timing of Consortium Member Needs

Year	Purchasing	Technical Assistance	Meter Testing
2022	Most Consortium members refining their future purchasing plans.	Consortium members determine their level of in-house support versus outsourcing.	Most Consortium members will continue with existing meter testing efforts.
2023	Sizable increase in meter and endpoint purchasing among several Consortium members.	Need for assistance will become better defined as installation and replacement plans become more firm.	Consortium members expected to confirm whether to proceed with in-house or outsourced testing.
2024	Meter and endpoint purchasing expected to continue.	Need for assistance expected to continue to grow with increased installation of new meters and endpoints.	Consortium members begin implementing new/expanded meter testing efforts.
2025	Meter and endpoint purchasing expected to continue.	Technical assistance support services should generally be in place.	Consortium members expand and refine meter testing efforts based on data analysis.
2026	Meter and endpoint purchasing expected to continue.	—	Consortium members continue to refine meter testing efforts.

Section 3 Consortium-Level Implementation Program

3.1 Overview

Based on the level of interest from Consortium members and significant potential cost savings from bulk purchasing and resource sharing, there appears to be a strong basis for implementing a regional meter program.

Preliminary discussions have been held with the RWA about administering such a program. The RWA has the organizational structure already in place along with the necessary procedures and policies to oversee such a program. The RWA has implemented similar programs in the past for other regional services, including water conservation and regional planning and advocacy. While RWA staffing may not be sufficient to initiate the program, in time, RWA staff could be hired to oversee implementation.

3.2 Proposed Consortium-Level Program Elements

Based on interest from Consortium members, the following four elements are proposed to form the basis of a regional program: (1) coordination, (2) purchasing, (3) testing, and (4) technical assistance. Given that the potential cost savings of joint purchasing is the most significant benefit of the program, it is recommended that the program first start with purchasing and then follow with testing and technical assistance.

3.2.1 Coordination

Coordination would occur through execution of a project agreement by RWA member agencies that wish to participate in the program. The project agreement will describe the support services to be provided, the estimated cost for the RWA to provide these services, and the subsequent cost share for each participating agency.

Each committed agency will participate on a regional water meter committee that will oversee the planning and execution of and budgeting for the regional meter program. The committee will also be responsible for proposing recommendations for improvements, additions, and/or modifications to the regional meter program over time.

3.2.2 Purchasing

At this time, the assumption is that material to be purchased jointly will include meters, endpoints, meter accessories, and spare parts. Purchasing support will entail ongoing tracking of member agencies' purchasing needs and upcoming plans. With this information, program staff will recommend joint purchasing opportunities, prepare specification and purchasing documentation, and negotiate pricing with vendors. Program staff will also coordinate material deliveries with participating agencies along with payment and invoicing.

3.2.3 Testing

Based on the findings of the Study, meter testing for several Consortium members should be expanded significantly to provide a greater degree of confidence in meter data and to improve timing for replacement of aging meters. Testing support provided by the regional program will entail working with participating agencies to review their proposed testing programs, determine volume and timing of additional testing, coordinate available bench testing capacity with regional partners (e.g., CoS and Folsom), develop/confirm bench testing protocols and standards, and facilitate testing agreements between agencies.

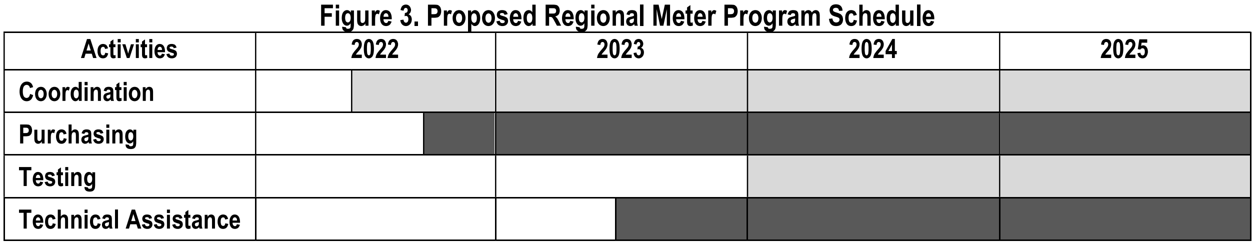
3.2.4 Technical Assistance

As the meter replacement and testing programs of several Consortium members are expanded, each agency will have a greater need for technical assistance. This assistance may include meter replacement and repair, endpoint installation and data integration, and field testing. The regional program will survey participating agencies regarding their upcoming technical needs and develop a technical assistance program to provide support. For example, support may include the coordination and development of standard operating procedures or vendor pre-qualification and price negotiation.

3.3 Proposed Program Schedule

Because all Consortium members will develop and update their Implementation Plans based on the results of Phase 4, it will be most valuable to Consortium members to initiate a regional meter program by mid-2022. Doing so will provide sufficient time for participating agencies to share their projected needs for 2023 and develop and implement a specific support plan during the remainder of 2022. Figure 3 illustrates an initial proposed timeline for when the regional program would provide support over the next few years.

Figure 3. Proposed Regional Meter Program Schedule



Section 4 Conclusions

The results from Phase 4 of the Study illustrate that several Consortium members expect to significantly expand their meter programs within the next five years. Many agencies will embark on significant replacement of existing water meters and installation of new or next generation data endpoints to improve data collection. Meanwhile, as agencies make significant metering investments, meter testing should be expanded by many of the Consortium members to improve data analysis and decision-making regarding meter precision and replacement.

Given the expanded volume of meter-related coordination, purchasing, testing, and technical assistance needed, analysis shows that consolidating and coordinating efforts among participating agencies could lead to significant cost savings while also reducing burden on individual agency staff performing duplicative activities.

The recommendation from Phase 4 is for the Consortium to establish a regional meter program to realize these cost saving and coordination benefits. The RWA appears to provide an excellent forum for implementing such a program.

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Appendix A. Agency Implementation Plan Executive Summaries

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A1 Citrus Heights Water District

This section of Technical Memorandum 5 is intended to be the presentation and description of a specific water meter asset management program for the Citrus Heights Water District (CHWD). Many elements of the program are common to all Water Meter Replacement Program Consortium (Consortium) agencies and require some customization by the individual Consortium agencies based on existing meter management, testing, and maintenance procedures; staffing and revenue resources; and customer service and operational goals of the water utility. These common elements are five-year implementation schedules for the components of the asset management program and sequential and similar schedule activities for each component. The proposed major asset management program components are meter testing, meter rebuild or replacement, meter reading, meter data management (MDM), and financial planning. Each of these components is presented and discussed below in individual subsections.

During the first year (2022), the focus of activities will be to develop (1) policies and procedures, (2) detailed schedules for annual operations and maintenance activities, and (3) contract vehicles (schedule contracts, indefinite delivery, indefinite quantity contracts, and Water Meter Replacement Program Consortium [Consortium]-wide acquisition contracts [CWAC]) for the activities that the CHWD elects to outsource. After the first year (2022), the CHWD will have the systems in place to implement the full meter program. The CHWD currently intends to replace the existing deployed meters with the greatest total registered flow and longest deployment periods. Particular attention should be paid to intermediate and large meters (see Technical Memorandum 4) because these meter sizes lose accuracy quicker than smaller meters and offer the greatest potential for revenue recovery.

After the initial five-year planning period suggested in this Technical Memorandum 5 (2022–2026), the CHWD will have collected sufficient meter testing data to revisit the meter replacement criteria recommended in the Meter Replacement Program Planning Study (Study) (see Technical Memorandum 4 and this Technical Memorandum 5). The CHWD's other primary five-year goal is to upgrade its primary manual reading system to automatic meter reading/advanced metering infrastructure (AMR/AMI) as cost-effectiveness analyses justify consistent with CHWD future functionality needs.

Summary of Key Recommendations

Based on the data collection and analysis tasks performed and documented in previous Technical Memoranda and in this Technical Memorandum 5, following are key recommendations for the CHWD.

Program Wide

- Water meters and their associated meter reading and data collection/analysis methodologies and hardware should be considered important water utility assets and incorporated into a water meter asset management program.
- Components of the meter asset management program should include meter testing, meter rebuild or replacement, meter reading, MDM, and financial planning.
- For all Consortium agencies to make informed decisions regarding their programs, each individual Consortium agency will need to collect vital meter testing, meter replacement, meter and endpoint performance, and economic data and share that information for the benefit and decision-making of the wider Consortium.
- Collaboration with the Regional Water Authority and other Consortium participants should occur to assess, confirm, and quantify the benefits of collaborative purchasing of water meters and other metering components.
- Strategies and recommendations herein for CHWD water meter management should be incorporated into utility-wide asset management plans.

Meter Testing

Based on the findings of Technical Memorandum 3 (Section 3.4, Meter Testing Cost Development), the CHWD is recommended to test meters at the following rates (Table 3-1, Annual Meter Testing Quantities and Costs).

Table 3-1. Annual Meter Testing Quantities and Costs

	Test Count	Estimated Annual Cost
Small Meters (≤ 1 Inch)	377	$23,500
Intermediate Meters (1.5–2 Inch)	297	$37,274
Large Meters (≥3 Inch)	86	$18,920
Total Cost	**—**	**$79,694**
Additional Required FTE Staff	—	1

Notes: FTE = full-time equivalent

The above cost estimations are based on $60 per hour labor cost, small meter testing at $40 per removal and re-install, $22 per small meter test, $126 per intermediate field test, and $220 per large meter field test. Based on existing resources and assigned functions, it is estimated that the CHWD would require one new staff member to perform recommended test bench and field accuracy testing functions.

Other specific meter testing recommendations include the following:

- Contract with the City of Sacramento (CoS) or the City of Folsom to use either test bench for small meter accuracy testing to achieve small meter testing objectives quantified in this Technical Memorandum 5.
- Within the next five years, develop statistically significant accuracy estimates for small meter age intervals and volumetric throughput intervals.

- Continue field testing of large and intermediate meters, consistent with American Water Works Association (AWWA) Manual M6 recommendations, with its own staff and its existing MUN-1 and MUN-4 portable large meter test equipment rather than contract, pending analysis of accuracy results for specific meter sizes that justify longer test intervals.

Meter Rebuild or Replacement

Based on the Technical Memorandum 4 assessment, for every one percent gain in overall CHWD meter accuracy, the CHWD will increase revenue by 0.30 percent. Based on 2018 revenue of approximately $13.5 million, a one percent improvement in overall meter accuracy would result in an increase in revenue of $40,500 per year. Estimated annual meter replacements or rebuilds are 798-998 small meters, 119 intermediate meters, and 7 large meters. Estimated annual labor hours are 2,826. Estimated annual costs for all meters replaced are approximately $290,000.

The following is recommended for meter rebuild or replacement:

- Instead of replacing or rebuilding meters following failure, implement a proactive meter monitoring and performance program through testing and asset management that informs decisions based on cost-effective economics.

Meter Reading

The CHWD primarily has a manual/touchread meter reading system. It has yet to decide on a future meter reading strategy to implement full AMR and provide flexibility to upgrade to AMI in the future or implement AMI initially. The existing Neptune AMR system is not a cost-effective long-term reading strategy for CHWD. The financial scenario indicates that either the Badger cellular or Sensus FlexNet solutions are preferable over the current approach. Major potential cost savings through joint hardware purchasing exist. CHWD should consider the AMI assessment approach discussed in section 3.4 of this Technical Memorandum.

Table 3-2, 15-Year Financial Analysis Summary, estimates potential cost savings over 15 years for collaborative purchasing of water meters and radio endpoints through a Consortium-based approach.

Table 3-2. 15-Year Financial Analysis Summary

Item	Scenario 1: BAU	Scenario 2: Badger ORION Cellular (NaaS)	Scenario 3: Sensus FlexNet (NaaS)	Scenario 4: Sensus FlexNet (Agency Owned)	Scenario 5: Sensus AMR to AMI
Meter Hardware					
Small Meters	$5,549,503	$3,290,144	$3,290,144	$3,290,144	$3,290,144
Intermediate Meters	$702,593	$660,583	$660,583	$660,583	$660,583
Large Meters	$185,600	$172,245	$172,245	$172,245	$172,245
Endpoints	$2,495,121	$3,409,679	$4,281,477	$4,281,477	$4,633,586
Sales Tax (7.75%)	$472,438	$307,655	$363,845	$363,845	$402,508
Material Recycling Fee	$161,528	$367,125	$111,176	$111,176	$118,776
Subtotal Hardware	*$9,566,784*	*$8,207,430*	*$8,879,469*	*$8,879,469*	*$9,277,841*
Meter Reading					
Communications	$2,630,532	$2,655,566	$1,594,516	$1,007,122	$1,280,569
Data Analytics	$0	$0	$0	$489,786	$529,689
Setup Cost	$0	$49,400	$34,400	$52,965	$52,965
Cost Savings	$0	($1,796,340)	($1,934,520)	($1,934,520)	($1,796,340)
Subtotal Meter Reading	*$2,630,532*	*$908,626*	*($305,604)*	*($384,648)*	*$66,882*
Total Cost	**$12,197,315**	**$9,116,056**	**$8,573,864**	**$8,494,821**	**$9,344,723**
Net Present Value	**($8,864,114)**	**($7,339,745)**	**($7,338,175)**	**($7,332,929)**	**($7,820,187)**

Notes: AMI = advanced metering infrastructure; AMR = automatic meter reading; BAU = business-as-usual; NaaS = network as a service

The following is recommended for meter reading:

- Consider the approaches and recommendations of this Technical Memorandum 5 for assessment of AMI alternatives and select either the Badger Orion Cellular or the Sensus FlexNet systems for long-term reading strategy.

Meter Data Management

Following are recommendations for MDM:

- Establish a regularly updated deployed meter asset registry that is searchable by attributes, such as type, size, age, accuracy test results, replacement or rebuild cost, rebuild date, and customer usage, to enable the CHWD to make smarter decisions over time.
- Use AMR/AMI interval read data for functionality beyond customer billing, including hydraulic modeling, physical asset sizing, optimization of system operations, and customer service.
- Use data to inform meter hardware replacement and rebuild criteria and technology selection decisions.

- Relate billing revenue and economic cost information with deployed meter and testing data. A higher confidence level in meter accuracy will provide a complete economic assessment of deployed meter assets, including potential revenue loss due to inaccuracy and meter replacement or rebuild cost.
- Develop and implement a Consortium-wide meter asset registry. It is recommended that Consortium agencies collectively write a specification for the registry (which would include inventory and accuracy testing data and asset cost data), evaluate and select a consensus platform for storing and analyzing the data, and use selected cohorts to inform Consortium agencies on relevant information for joint and individual decision-making.
- Develop and monitor key performance indicators (KPIs) for meter asset management plan elements. Examples for three elements include the following (Table 3-3, Table of Key Performance Indicators for Citrus Heights Water District Metering Strategies).

Table 3-3. Table of Key Performance Indicators for Citrus Heights Water District Metering Strategies

Meter Testing	Meter Rebuild or Replacement	Meter Reading
• Number of meter accuracy tests per month and year compared to planned quantities by size • Percent completeness of meter accuracy test form and testing data • Labor time for each meter accuracy test for each meter size • Cost per meter accuracy test by meter size • Percentage of accurate reporting of test results versus AWWA Manual M6 requirements	• Percentage of installations adhering to meter removal and installation specifications • Annual volumetric recovery per individual meter rebuild/replacement • Annual revenue recovery per individual meter rebuild/replacement • Cost of meter rebuilt or replaced divided by annual revenue recovery • Reported annual apparent loss due to meter inaccuracy • Labor time and cost for meter rebuild or replacement by meter size • Maximization of validity score of annual water audit	• Cost per monthly billing read and cost per used interval read • Percentage of successful billing reads within 3 days of read • Hourly interval read success rate (98.5 percent of all hourly interval reads within 3 days) • Errors per 1,000 meter reads • Number of customer service inquiries • Percentage of first call resolution • Time and cost to resolve meter reading and customer billing calls • CHWD customer satisfaction rating

Notes: AWWA = American Water Works Association; CHWD = Citrus Heights Water District

- Using the developed strategy for data management, gather existing meter asset and attribute information and load data into a standard Structured Query Language database or electronic spreadsheet in the format established in the strategy to establish a CHWD-specific water meter asset registry.
- Work closely with computerized maintenance management system, billing, and accounting software vendors to identify data linkages between databases; develop application

programming interfaces between databases; and load and update asset information individually in the CHWD registry and Consortium-wide in the broader registry.

- Complete assessment of AMI alternatives and select the Badger Orion cellular or the Sensus FlexNet AMI solution as a long-term meter reading strategy.

A2 City of Sacramento

This section of Technical Memorandum 5 is intended to be the presentation and description of a specific water meter asset management program for the City of Sacramento (CoS). Many elements of the program are common to all Water Meter Replacement Program Consortium (Consortium) agencies and require some customization by the individual Consortium agencies based on existing meter management testing and maintenance procedures, staffing and revenue resources, and customer service and operational goals of the water utility. These common elements are five-year implementation schedules for the components of the asset management program and sequential and similar schedule activities for each component. The proposed major asset management program components are meter testing, meter rebuild or replacement, meter reading, meter data management, and financial planning. Each of these components is presented and discussed below in individual subsections.

During the first year (2022) of the recommended plan, the focus of activities will be to develop (1) strategies and procedures, (2) detailed schedules for annual operations and maintenance activities, and (3) contract vehicles (schedule contracts, indefinite delivery, indefinite quantity contracts, and Consortium-wide acquisition contracts [CWAC]) for the activities that the CoS elects to outsource. After the first year (2022), the CoS will have the systems in place to implement the full meter asset management program, as desired.

The CoS currently intends to replace the existing deployed meters with the greatest total registered flow and longest deployment periods. The schedule and required resources to optimize this intention are dependent on the collection and analysis of actionable testing and economic data, some of which are CoS specific and some of which should be Consortium wide. Particular attention should be paid to intermediate and large meters (see Technical Memorandum 4) because these meter sizes lose accuracy quicker than smaller meters and offer the greatest potential for revenue recovery. After the initial five-year planning period suggested in this Technical Memorandum 5 (2022–2026), the CoS will have collected sufficient meter testing data to revisit the meter replacement criteria recommended in this Meter Replacement Program Planning Study (Study) (see Technical Memorandum 4 and this Technical Memorandum 5). The CoS's other primary five-year goal is to leverage its interval reading data from its Badger ORION radio and cellular advanced metering infrastructure (AMI) systems. Optimizing use of AMI interval data includes enhanced customer service, proactive utility notification of impending high bills, theft and tampering identification, shutoff monitoring, district metered area leakage analysis, determination of peaking factors for meter and distribution system sizing, and more.

Summary of Key Recommendations

Based on the data collection and analysis tasks performed and documented in previous Technical Memoranda and in this Technical Memorandum 5, following are key recommendations for the CoS.

Program Wide

- Water meters and their associated meter reading and data collection/analysis methodologies and hardware should be considered important water utility assets and incorporated into a water meter asset management program.
- Components of the meter asset management program should include meter testing, meter rebuild or replacement, meter reading, meter data management, and financial planning.
- For all Consortium agencies to make informed decisions regarding their programs, each individual Consortium agency will need to collect vital meter testing, meter replacement, meter and endpoint performance, and economic data and share that information for the benefit and decision-making of the wider Consortium.
- Collaboration with the Regional Water Authority and other Consortium participants should occur to assess, confirm, and quantify the benefits of joint purchasing of water meters and other metering components.
- Strategies and recommendations herein for CoS water meter management should be incorporated into utility-wide asset management plans.

Meter Testing

Based on the findings of Technical Memorandum 3 (Section 3.4, Meter Testing Cost Development), the CoS is recommended to test meters annually at the following rates (Table 4-1, Annual Meter Testing Quantities and Costs).

Table 4-1. Annual Meter Testing Quantities and Costs[1]

	Test Count	Estimated Annual Cost
Small Meters (≤ 1 Inch)	383	$23,100
Intermediate Meters (1.5–2 Inch)	1,799	$242,541
Large Meters (≥3 Inch)	1,211	$286,678
Total Cost	**—**	**$552,319**
Additional Required FTE Staff	—	6

Notes: FTE = full-time equivalent

[1] Excerpt from Table 4-2.

The above cost estimations are based on $59 per hour labor cost, in-house test bench small meter testing at $50 per removal and re-install, $136 per intermediate field test, and $236 per large meter field test. Based on existing resources and assigned functions, it is estimated that the CoS would require six new staff members to perform recommended field accuracy testing functions.

Other specific meter testing recommendations include the following:

- Use its small meter test bench to achieve small meter testing objectives quantified in this Technical Memorandum 5.
- Initiate negotiations with other Consortium utilities to establish conditions and quantities for providing small meter testing services.
- Within the next five years, develop statistically significant accuracy estimates for small meter age intervals and volumetric throughput intervals.
- Implement field testing of large and intermediate meters, consistent with American Water Works Association (AWWA) Manual M6 recommendations, with its own staff rather than contract, pending analysis of accuracy results for specific meter sizes that justify longer test intervals.

Meter Rebuild or Replacement

Based on the Technical Memorandum assessment, for every one percent gain in overall CoS small meter accuracy, the CoS will increase revenue by 0.30 percent. Based on 2018 revenue of almost $75 million, a one percent improvement in overall small meter accuracy will result in an increase in revenue of $225,000 per year. Estimated annual meter replacements or rebuilds are 4,876–6,095 small meters (four to five percent), 719 intermediate meters (10 percent), and 182 large meters (7.5 percent). Estimated annual labor hours are 15,669. Estimated annual costs for all meters replaced are approximately $2,200,000.

The following is recommended for meter rebuild or replacement:

- Develop and implement an annual meter rebuild and replacement schedule for each meter size group based on annual accuracy test results and economic evaluations

Meter Reading

Table 4-2, 15-Year Financial Analysis Summary, estimates potential cost savings over 15 years for collaborative purchasing of water meters through a Consortium-based approach. The amount shown is $0 based on the size of the CoS water system and the presumption that the best pricing has already been offered, although this may change based on future orders from other Consortium participants. The business-as-usual (BAU) alternative is the lowest total cost and net present value cost for the CoS.

Table 4-2. 15-Year Financial Analysis Summary[1]

Item	BAU
Meter Hardware	
Small Meters (≤ 1 Inch)	$22,838,619
Intermediate Meters (1.5–2 Inch)	$4,000,475
Large Meters (≥3 Inch)	$3,332,891
Endpoints	$19,341,435
Sales Tax (8.75%)	$2,270,757
Material Recycling Fee	$1,129,137
Subtotal Meter Hardware	*$52,913,313*
Meter Reading	
Communications	$9,101,842
Data Analytics	$0
Subtotal Meter Reading	*$9,101,842*
Total Cost	**$62,015,155**
Net Present Value	*$44,758,463*

Notes: BAU = business-as-usual

[1] Excerpt from Table 4-7.

The following is recommended for meter reading:

- Complete full implementation of AMI using the current CoS balanced radio/cellular endpoint approach

Meter Data Management

Following are recommendations for meter data management:

- Establish a regularly updated deployed meter asset registry that is searchable by attributes, such as type, size, age, accuracy test results, replacement or rebuild cost, rebuild date, and customer usage, to enable the CoS to make smarter decisions over time.
- Use AMI interval read data for functionality beyond customer billing, including hydraulic modeling, physical asset sizing, optimization of system operations, and customer service.
- Use data to inform meter hardware replacement and rebuild criteria and technology selection decisions.
- Relate billing revenue and economic cost information with deployed meter and testing data. A higher confidence level in meter accuracy will provide a complete economic assessment of deployed meter assets, including potential revenue loss due to inaccuracy and meter replacement or rebuild cost.
- Develop and implement a Consortium-wide meter asset registry. It is recommended that Consortium agencies collectively write a specification for the registry (which

would include inventory and accuracy testing data and asset cost data), evaluate and select a consensus platform for storing and analyzing the data, and use selected cohorts to inform Consortium agencies on relevant information for joint and individual decision-making.

- Develop and monitor key performance indicators (KPIs) for meter asset management plan elements. Examples for three elements include the following (Table 4-3, Table of Key Performance Indicators for City of Sacramento Metering Strategies).

Table 4-3. Table of Key Performance Indicators for City of Sacramento Metering Strategies

Meter Testing	Meter Rebuild or Replacement	Meter Reading
• Number of meter accuracy tests per month and year compared to planned quantities by size • Percent completeness of meter accuracy test form and testing data • Labor time for each meter accuracy test for each meter size • Cost per meter accuracy test by meter size • Percent of accurate reporting of test results versus AWWA Manual M6 requirements	• Percent of installations adhering to meter removal and installation specifications • Annual volumetric recovery per individual meter rebuild/replacement • Annual revenue recovery per individual meter rebuild/replacement • Cost of meter rebuilt or replaced divided by annual revenue recovery • Reported annual apparent loss due to meter inaccuracy • Labor time and cost for meter rebuild or replacement by meter size • Maximization of validity score of annual water audit	• Cost per monthly billing read and cost per used interval read • Percent of successful billing reads within three days of read • Hourly interval read success rate (98.5 percent of all hourly interval reads within three days) • Errors per 1,000 meter reads • Number of customer service inquiries • Percentage of first call resolution • Time and cost to resolve meter reading and customer billing calls • CoS customer satisfaction rating

Notes: AWWA = American Water Works Association; CoS = City of Sacramento

- Using the developed strategy for data management, gather existing meter asset and attribute information and load data into a standard Structured Query Language database or electronic spreadsheet in the format established in the strategy to establish a CoS-specific water meter asset registry.
- Work closely with computerized maintenance management system, billing, and accounting software vendors to identify data linkages between databases; develop application programming interfaces between databases; and load and update asset information individually in the CoS registry and Consortium-wide in the broader registry.
- Monitor and compare performance of radio and cellular endpoint implementation of AMI.

A3 Placer County Water District

This section of Technical Memorandum 5 is intended to be the presentation and description of a specific water meter asset management program for the Placer County Water Agency (PCWA). Many elements of the program are common to all Water Meter Replacement Program Consortium (Consortium) agencies and require some customization by the individual Consortium agencies based on existing meter management, testing, and maintenance procedures; staffing and revenue resources; and customer service and operational goals of the water utility. These common elements are five-year implementation schedules for the components of the asset management program and sequential and similar schedule activities for each component. The proposed major asset management program components are meter testing, meter rebuild or replacement, meter reading, meter data management (MDM), and financial planning. Each of these components is presented and discussed below in individual subsections.

During the first year (2022), the focus of activities will be to develop (1) strategies and procedures, (2) detailed schedules for annual operations and maintenance activities, and (3) contract vehicles (schedule contracts, indefinite delivery, indefinite quantity contracts, and Water Meter Replacement Program Consortium [Consortium]-wide acquisition contracts [CWAC]) for the activities that the PCWA elects to outsource. After the first year (2022), the PCWA will have the systems in place to implement the full meter program. The PCWA currently intends to replace the existing deployed meters with the greatest total registered flow and longest deployment periods. Particular attention should be paid to intermediate and large meters (see Technical Memorandum 4), because these meter sizes lose accuracy quicker than smaller meters and offer the greatest potential for revenue recovery.

After the initial five-year planning period suggested in this Technical Memorandum 5 (2022–2026), the PCWA will have collected sufficient meter testing data to revisit the meter replacement criteria recommended in the Meter Replacement Program Planning Study (Study) (see Technical Memorandum 4 and this Technical Memorandum 5). The PCWA's other primary five-year goal is to convert its entire network of deployed meters to the Badger ORION cellular advanced metering infrastructure (AMI) to extend its current AMI approach and to leverage advantages of a full AMI solution for meter reading and interval read data collection.

Summary of Key Recommendations

Based on the data collection and analysis tasks performed and documented in previous Technical Memoranda and in this Technical Memorandum 5, following are key recommendations for the PCWA.

Program Wide

- Water meters and their associated meter reading and data collection/analysis methodologies and hardware should be considered important water utility assets and incorporated into a water meter asset management program.
- Components of the meter asset management program should include meter testing, meter rebuild or replacement, meter reading, MDM, and financial planning.
- For all Consortium agencies to make informed decisions regarding their programs, each individual Consortium agency will need to collect vital meter testing, meter replacement, meter and endpoint performance, and economic data and share that information for the benefit and decision-making of the wider Consortium.
- Collaboration with the Regional Water Authority and other Consortium participants should occur to assess, confirm, and quantify the benefits of collaborative purchasing of water meters and other metering components.
- Strategies and recommendations herein for PCWA water meter management should be incorporated into utility-wide asset management plans.

Meter Testing

Based on the findings of Technical Memorandum 3 (Section 3.4, Meter Testing Cost Development), the PCWA is recommended to test meters at the following rates (Table 5-1, Meter Testing Quantities and Costs).

Table 5-1. Meter Testing Quantities and Costs

	Test Count	Estimated Annual Cost
Small Meters (≤ 1 Inch)	381	$23,231
Intermediate Meters (1.5–2 Inch)	244	$30,005
Large Meters (≥3 Inch)	115	$24,748
Total Cost	**—**	**$77,984**
Additional Required FTE Staff	—	1

Notes: FTE = full-time equivalent

The above cost estimations are based on $60 per hour labor cost, small meter testing at $40 per removal and re-install, $21 per small meter test, $123 per intermediate field test, and $215 per large meter field test. Based on existing resources and assigned functions, it is estimated that the PCWA would require one new staff member to perform recommended test bench and field accuracy testing functions.

Other specific meter testing recommendations include the following:

- Use the existing Ford four-stand manual small meter test bench to achieve small meter testing objectives quantified in this Technical Memorandum 5.
- Within the next five years, develop statistically significant accuracy estimates for small meter age intervals and volumetric throughput intervals.
- Continue field testing of large and intermediate meters, consistent with American Water Works Association (AWWA) Manual M6 recommendations, with its own staff rather than contract, pending analysis of accuracy results for specific meter sizes that justify longer test intervals.

Meter Rebuild or Replacement

Based on the Technical Memorandum assessment, for every one percent gain in overall PCWA meter accuracy, the PCWA will increase revenue by 0.50 percent. Based on 2018 revenue of approximately $36 million, a one percent improvement in overall meter accuracy would result in an increase in revenue of $180,000 per year. Estimated annual meter replacements or rebuilds are 1,433–1,791 small meters, 97 intermediate meters, and nine large meters. Estimated annual labor hours are 5,219. Estimated annual costs for all meters replaced are approximately $505,815.

The following is recommended for meter rebuild or replacement:

- Instead of replacing or rebuilding meters following failure, implement a proactive meter monitoring and performance program through testing and asset management that informs decisions based on cost-effective economics.

Meter Reading

The PCWA has already established a meter reading strategy, which is to fully deploy the Badger cellular AMI system across its service area. It is currently in the process of replacing its Itron drive by radio endpoints with Badger Orion cell endpoints. The financial scenario indicates that, without major modifications to the strategy, some potential cost savings through joint hardware purchasing exist.

Table 5-2, 15-Year Financial Analysis Summary, estimates potential cost savings over 15 years for collaborative purchasing of water meters and radio endpoints through a Consortium-based approach.

Table 5-2. 15-Year Financial Analysis Summary

Item	Scenario 1: BAU	Scenario 2: Badger ORION Cellular (NaaS)	Scenario 3: Sensus FlexNet (NaaS)
Meter Hardware			
Small Meters	$6,635,781	$6,493,951	$6,493,951
Intermediate Meters	$625,033	$623,337	$623,337
Large Meters	$170,815	$169,940	$169,940
Endpoints	$4,945,958	$4,900,308	$9,489,211
Sales Tax (7.25%)	$399,514	$385,735	$624,398
Material Recycling Fee	$114,125	$114,125	$184,615
Subtotal Meter Hardware	*$12,891,226*	*$12,687,396*	*$17,585,452*
Meter Reading			
Communications	$1,291,254	$3,854,344	$2,762,653
Data Analytics	$0	$0	$0
Setup Cost	$0	$0	$68,800
Total Benefit	$0	($2,491,610)	($2,990,106)
Subtotal Meter Reading	*$1,291,254*	*$1,362,734*	*($158,653)*
Total Cost	**$14,182,480**	**$14,050,130**	**$17,426,799**
Net Present Value	**($10,346,415)**	**($10,342,105)**	**($15,022,939)**

Notes: BAU = business-as-usual; NaaS = network as a service

The following is recommended for meter reading:

- Complete full implementation of AMI using the current PCWA Badger Orion cellular endpoint approach.

Meter Data Management

Following are recommendations for MDM:

- Establish a regularly updated deployed meter asset registry that is searchable by attributes, such as type, size, age, accuracy test results, replacement or rebuild cost, rebuild date, and customer usage, to enable the PCWA to make smarter decisions over time.
- Use AMI interval read data for functionality beyond customer billing, including hydraulic modeling, physical asset sizing, optimization of system operations, and customer service.
- Use data to inform meter hardware replacement and rebuild criteria and technology selection decisions.
- Relate billing revenue and economic cost information with deployed meter and testing data. A higher confidence level in meter accuracy will provide a complete economic assessment of deployed meter assets, including potential revenue loss due to inaccuracy and meter replacement or rebuild cost.

- Develop and implement a Consortium-wide meter asset registry. It is recommended that Consortium agencies collectively write a specification for the registry (which would include inventory and accuracy testing data and asset cost data), evaluate and select a consensus platform for storing and analyzing the data, and use selected cohorts to inform Consortium agencies on relevant information for joint and individual decision-making.
- Develop and monitor key performance indicators (KPIs) for meter asset management plan elements. Examples for three elements include the following (Table 5-3, Table of Key Performance Indicators for Placer County Water Agency Metering Strategies).

Table 5-3. Table of Key Performance Indicators for Placer County Water Agency Metering Strategies

Meter Testing	Meter Rebuild or Replacement	Meter Reading
• Number of meter accuracy tests per month and year compared to planned quantities by size • Percent completeness of meter accuracy test form and testing data • Labor time for each meter accuracy test for each meter size • Cost per meter accuracy test by meter size • Percentage of accurate reporting of test results versus AWWA Manual M6 requirements	• Percentage of installations adhering to meter removal and installation specifications • Annual volumetric recovery per individual meter rebuild/replacement • Annual revenue recovery per individual meter rebuild/replacement • Cost of meter rebuilt or replaced divided by annual revenue recovery • Reported annual apparent loss due to meter inaccuracy • Labor time and cost for meter rebuild or replacement by meter size • Maximization of validity score of annual water audit	• Cost per monthly billing read and cost per used interval read • Percentage of successful billing reads within 3 days of read • Hourly interval read success rate (98.5 percent of all hourly interval reads within 3 days) • Errors per 1,000 meter reads • Number of customer service inquiries • Percentage of first call resolution • Time and cost to resolve meter reading and customer billing calls • PCWA customer satisfaction rating

Notes: AWWA = American Water Works Association; PCWA = Placer County Water Agency

- Using the developed strategy for data management, gather existing meter asset and attribute information and load data into a standard Structured Query Language database or electronic spreadsheet in the format established in the strategy to establish an PCWA-specific water meter asset registry.
- Work closely with computerized maintenance management system, billing, and accounting software vendors to identify data linkages between databases; develop application programming interfaces between databases; and load and update asset information individually in the PCWA registry and Consortium-wide in the broader registry.
- Complete full implementation of AMI using a Badger cellular endpoint approach.

The following text presents the context for the major recommendations for the PCWA meter asset management program.

A4 Sacramento County Water Agency

This section of Technical Memorandum 5 is intended to be the presentation and description of a specific water meter asset management program for the Sacramento County Water Agency (SCWA). Many elements of the program are common to all Water Meter Replacement Program Consortium (Consortium) agencies and require some customization by the individual Consortium agencies based on existing meter management, testing, and maintenance procedures; staffing and revenue resources; and customer service and operational goals of the water utility. These common elements are five-year implementation schedules for the components of the asset management program and sequential and similar schedule activities for each component. The proposed major asset management program components are meter testing, meter rebuild or replacement, meter reading, meter data management (MDM), and financial planning. Each of these components is presented and discussed below in individual subsections.

During the first year (2022) of the recommended plan, the focus of activities will be to develop (1) strategies and procedures, (2) detailed schedules for annual operations and maintenance activities, and (3) contract vehicles (schedule contracts, indefinite delivery, indefinite quantity contracts, and Consortium-wide acquisition contracts [CWAC]) for the activities that the SCWA elects to outsource. After the first year (2022), the SCWA will have the systems in place to implement the full meter asset management program, as desired.

The SCWA currently intends to replace its existing deployed meters with the greatest total registered flow and longest deployment periods. The schedule and required resources to optimize this intention are dependent on the collection and analysis of actionable testing and economic data, some of which are SCWA specific and some of which should be Consortium wide. Particular attention should be paid to intermediate and large meters (see Technical Memorandum 4) because these meter sizes lose accuracy quicker than smaller meters and offer the greatest potential for revenue recovery. After the initial five-year planning period suggested in this Technical Memorandum 5 (2022–2026), the SCWA will have collected sufficient meter testing data to revisit the meter replacement criteria recommended in this Meter Replacement Program Planning Study (Study) (see Technical Memorandum 4 and this Technical Memorandum 5). The SCWA's other primary five-year goal is to leverage its interval reading data from its Sensus FlexNet radio automatic meter reading/advanced metering infrastructure (AMR/AMI) system. Optimizing use of AMI interval data includes enhanced customer service, proactive utility notification of impending high bills, theft and tampering identification, shutoff monitoring, agency metered area leakage analysis, determination of peaking factors for meter and distribution system sizing, and more.

Summary of Key Recommendations

Based on the data collection and analysis tasks performed and documented in previous Technical Memoranda and in this Technical Memorandum 5, following are key recommendations for the SCWA.

Program Wide

- Water meters and their associated meter reading and data collection/analysis methodologies and hardware should be considered important water utility assets and incorporated into a water meter asset management program.
- Components of the meter asset management program should include meter testing, meter rebuild or replacement, meter reading, MDM, and financial planning.
- For all Consortium agencies to make informed decisions regarding their programs, each individual Consortium agency will need to collect vital meter testing, meter replacement, meter and endpoint performance, and economic data and share that information for the benefit and decision-making of the wider Consortium.
- Collaboration with the Regional Water Authority and other Consortium participants should occur to assess, confirm, and quantify the benefits of collaborative purchasing of water meters and other metering components.
- Strategies and recommendations herein for SCWA water meter management should be incorporated into utility-wide asset management plans.

Meter Testing

Based on the findings of Technical Memorandum 3 (Section 3.4, Meter Testing Cost Development), the SCWA is recommended to test meters at the following rates (Table 6-1, Meter Testing Quantities and Costs).

Table 6-1. Meter Testing Quantities and Costs

	Test Count	Estimated Annual Cost
Small Meters (≤ 1 Inch)	383	$23,874
Intermediate Meters (1.5–2 Inch)	762	$95,763
Large Meters (≥3 Inch)	334	$73,480
Total Cost	**—**	**$193,177**
Additional Required FTE Staff	—	2

Notes: FTE = full-time equivalent

The above cost estimations are based on $60 per hour labor cost, contracted small meter testing at $40 per removal and re-install, $22 per small meter test, $126 per intermediate field test, and $220 per large meter field test. Based on existing resources and assigned functions, it is estimated that the SCWA would require two new staff members to perform recommended field accuracy testing functions.

Other specific meter testing recommendations include the following:

- Contract with the City of Sacramento (CoS) or similar economical and convenient private testing facility to use its small meter test bench to achieve small meter testing objectives quantified in this Technical Memorandum 5.
- Within the next five years, develop statistically significant accuracy estimates for small meter age intervals and volumetric throughput intervals.
- Implement field testing of large and intermediate meters, consistent with American Water Works Association (AWWA) Manual M6 recommendations, with its own staff rather than contract, pending analysis of accuracy results for specific meter sizes that justify longer test intervals.

Meter Rebuild or Replacement

Based on the Technical Memorandum assessment, for every one percent gain in overall SCWA meter accuracy, the SCWA will increase revenue by 0.58 percent. Based on 2018 revenue of approximately $23 million, a one percent improvement in overall meter accuracy would result in an increase in revenue of $133,400 per year. Estimated annual meter replacements or rebuilds are 2,003–2,504 small meters, 304 intermediate meters, and 26 large meters. Estimated annual labor hours are 9,026. Estimated annual costs for all meters replaced are approximately $1,184,000.

The following is recommended for meter rebuild or replacement:

- Instead of replacing or rebuilding meters following failure, implement a proactive meter monitoring and performance program through testing and asset management that informs decisions based on cost-effective economics.

Meter Reading

The SCWA has already established a meter reading strategy, which is to fully deploy the Sensus FlexNet AMI system across its service area. It is currently in the process of deploying its fourth Sensus data collector unit (DCU) (Q4, 2020). Once the system is in place, the SCWA's priority will be to transition its meters to be read through its Sensus FlexNet AMI system. The financial scenario indicates that, without major modifications to the strategy, significant potential cost savings through joint hardware purchasing exist.

Table 6-2, 15-Year Financial Analysis Summary, estimates potential cost savings over 15 years[1] (financial analysis from Technical Memorandum 4) for collaborative purchasing of water meters and radio endpoints through a Consortium-based approach.

[1] Table 6-2 covers six- and nine-year implementation periods; however, the financial analysis was conducted over a 15-year period.

Table 6-2. 15-Year Financial Analysis Summary

Item	Scenario 1: 6-Yr AMI Conversion	Scenario 2: 9-Yr AMI Conversion	Scenario 3: 9-Yr AMI with Consortium Hardware Pricing	Scenario 4: 9-Yr AMI with Consortium Hardware Pricing, Minimal Meter PM
Meter Hardware				
Small Meters	$17,361,797	$17,361,797	$13,709,940	$0
Intermediate Meters	$2,651,859	$2,651,859	$2,487,933	$380,384
Large Meters	$719,581	$719,581	$719,574	$719,574
Endpoints	$18,718,438	$17,113,110	$11,980,392	$17,272,491
Sales Tax (8.75%)	$1,569,100	$1,553,565	$1,039,466	$631,727
Material Recycling Fee	$828,547	$553,235	$395,884	$550,623
Subtotal Hardware	*$41,849,323*	*$39,953,148*	*$30,333,189*	*$19,554,799*
Meter Reading				
Communications	$1,544,140	$2,152,928	$2,152,928	$2,152,928
Data Analytics	$639,065	$639,065	$639,065	$639,065
Setup Cost	$0	$0	$0	$0
Subtotal Meter Reading	*$2,183,205*	*$2,791,993*	*$2,791,993*	*$2,791,993*
Total Cost	**$44,032,528**	**$42,745,141**	**$33,125,182**	**$22,346,792**
Net Present Value	**($33,418,356)**	**($31,479,855)**	**($24,491,894)**	**($16,697,825)**

Notes: AMI = advanced metering infrastructure

The following is recommended for meter reading:

- Complete full implementation of AMI using the current SCWA Sensus/Flexnet Scenario 1 endpoint approach.

Meter Data Management

Following are recommendations for MDM:

- Establish a regularly updated deployed meter asset registry that is searchable by attributes, such as type, size, age, accuracy test results, replacement or rebuild cost, rebuild date, and customer usage, to enable the SCWA to make smarter decisions over time.
- Use AMI interval read data for functionality beyond customer billing, including hydraulic modeling, physical asset sizing, optimization of system operations, and customer service.
- Use data to inform meter hardware replacement and rebuild criteria and technology selection decisions.
- Relate billing revenue and economic cost information with deployed meter and testing data. A higher confidence level in meter accuracy will provide a complete economic

assessment of deployed meter assets, including potential revenue loss due to inaccuracy and meter replacement or rebuild cost.

- Develop and implement a Consortium-wide meter asset registry. It is recommended that Consortium agencies collectively write a specification for the registry (which would include inventory and accuracy testing data and asset cost data), evaluate and select a consensus platform for storing and analyzing the data, and use selected cohorts to inform Consortium agencies on relevant information for joint and individual decision-making.
- Develop and monitor key performance indicators (KPIs) for meter asset management plan elements. Examples for three elements include the following (Table 6-3, Table of Key Performance Indicators for Sacramento County Water Agency Metering Strategies).

Table 6-3. Table of Key Performance Indicators for Sacramento County Water Agency Metering Strategies

Meter Testing	Meter Rebuild or Replacement	Meter Reading
• Number of meter accuracy tests per month and year compared to planned quantities by size • Percent completeness of meter accuracy test form and testing data • Labor time for each meter accuracy test for each meter size • Cost per meter accuracy test by meter size • Percentage of accurate reporting of test results versus AWWA Manual M6 requirements	• Percentage of installations adhering to meter removal and installation specifications • Annual volumetric recovery per individual meter rebuild/replacement • Annual revenue recovery per individual meter rebuild/replacement • Cost of meter rebuilt or replaced divided by annual revenue recovery • Reported annual apparent loss due to meter inaccuracy • Labor time and cost for meter rebuild or replacement by meter size • Maximization of validity score of annual water audit	• Cost per monthly billing read and cost per used interval read • Percentage of successful billing reads within 3 days of read • Hourly interval read success rate (98.5 percent of all hourly interval reads within 3 days) • Errors per 1,000 meter reads • Number of customer service inquiries • Percentage of first call resolution • Time and cost to resolve meter reading and customer billing calls • SCWA customer satisfaction rating

Notes: AWWA = American Water Works Association; SCWA = Sacramento County Water Agency

- Using the developed strategy for data management, gather existing meter asset and attribute information and load data into a standard Structured Query Language database or electronic spreadsheet in the format established in the strategy to establish an SCWA-specific water meter asset registry.
- Work closely with computerized maintenance management system, billing, and accounting software vendors to identify data linkages between databases; develop application programming interfaces between databases; and load and update asset information individually in the SCWA registry and Consortium-wide in the broader registry.
- Complete full implementation of AMI using a balanced radio/cellular endpoint approach.

A5 Sacramento Suburban Water District

This section of Technical Memorandum 5 is intended to be the presentation and description of a specific water meter asset management program for the Sacramento Suburban Water District (SSWD). Many elements of the program are common to all Water Meter Replacement Program Consortium (Consortium) agencies and require some customization by the individual Consortium agencies based on existing meter management testing and maintenance procedures, staffing and revenue resources, and customer service and operational goals of the water utility. These common elements are five-year implementation schedules for the components of the asset management program and sequential and similar schedule activities for each component. The proposed major asset management program components are meter testing, meter rebuild or replacement, meter reading, meter data management, and financial planning. Each of these components is presented and discussed below in individual subsections.

During the first year (2022) of the recommended plan, the focus of activities will be to develop (1) strategies and procedures, (2) detailed schedules for annual operations and maintenance activities, and (3) contract vehicles (schedule contracts, indefinite delivery, indefinite quantity contracts, and Consortium-wide acquisition contracts) for the activities that the SSWD elects to outsource. After the first year (2022), the SSWD will have the systems in place to implement the full meter asset management program, as desired.

The SSWD currently intends to replace the existing deployed meters with the greatest total registered flow and longest deployment periods eventually transitioning to an ongoing program of regular replacement of small meters and rebuild or replacement of intermediate and large meters. The schedule and required resources to optimize this intention are dependent on the collection and analysis of actionable testing and economic data, some of which are SSWD specific and some of which should be Consortium wide. Particular attention should be paid to intermediate and large meters (see Technical Memorandum 4) because these meter sizes lose accuracy quicker than smaller meters and offer the greatest potential for revenue recovery. After the initial five-year planning period suggested in this Technical Memorandum 5 (2022–2026), the SSWD will have collected sufficient meter testing data to revisit the meter replacement criteria recommended in this Meter Replacement Program Planning Study (Study) (see Technical Memorandum 4 and this Technical Memorandum 5). The SSWD has the option to leverage its interval reading data from its balanced Badger ORION cellular advanced metering infrastructure (AMI) and its Sensus FlexNet radio AMI system. Optimizing use of AMI interval data includes enhanced customer service, proactive utility notification of impending high bills, theft and tampering identification, shutoff monitoring, district metered area leakage analysis, determination of peaking factors for meter and distribution system sizing, and more.

Summary of Initial Planning Level Recommendations

Based on the data collection and analysis tasks performed and documented in previous Technical Memoranda and in this Technical Memorandum 5, following are initial planning level recommendations for the SSWD.

Program Wide

- Water meters and their associated meter reading and data collection/analysis methodologies and hardware should be considered important water utility assets and incorporated into a water meter asset management program.
- Components of the meter asset management program should include meter testing, meter rebuild or replacement, meter reading, meter data management, and financial planning.
- For all Consortium agencies to make informed decisions regarding their programs, each individual Consortium agency will need to collect vital meter testing, meter replacement, meter and endpoint performance, and economic data and share that information for the benefit and decision-making of the wider Consortium.
- Collaborate with the Regional Water Authority and other Consortium participants to assess, confirm, and quantify the benefits of collaborative purchasing of water meters and other metering components.
- Incorporate strategies and recommendations herein for SSWD water meter management into utility-wide asset management plans.

Meter Testing

Based on the findings of Technical Memorandum 3 (Section 3.4, Meter Testing Cost Development), the SSWD is recommended to test meters at the following rates (Table 7-1, Meter Testing Quantities and Costs).

Table 7-1. Meter Testing Quantities and Costs[1]

	Test Count	Estimated Annual Cost
Small Meters (≤ 1 Inch)	381	$35,323
Intermediate Meters (1.5–2 Inch)	609	$82,964
Large Meters (≥3 Inch)	447	$142,086
Total Cost	**—**	**$260,373**
Additional Required FTE Staff	—	1

Notes: FTE = full-time equivalent

1 Excerpt from Table 7-2.

The above cost estimations are based on $60 per hour labor cost, contracted small meter testing at $50 per removal and replacement, $40 per small meter test, $136 per intermediate field test, and $238 per large meter field test. Based on existing resources and assigned functions, initial planning level estimates are that the SSWD would require one new staff member to perform recommended field accuracy testing functions.

Other specific meter testing recommendations include the following:

- Contract with an economical and convenient testing facility to use its small meter test bench to achieve small meter testing objectives quantified in this Technical Memorandum 5.
- Within the next five years, develop statistically significant accuracy estimates for small meter age intervals and volumetric throughput intervals.
- Implement additional field testing of large and intermediate meters, consistent with American Water Works Association (AWWA) Manual M6 recommendations, with its own staff rather than contract, pending analysis of accuracy results for specific meter sizes that justify longer test intervals.

Meter Rebuild or Replacement

Based on the Technical Memorandum assessment, for every one percent gain in overall SSWD meter accuracy, the SSWD will increase revenue by 0.27 percent. Based on 2018 revenue of almost $30 million, a one percent improvement in overall meter accuracy would result in an increase in revenue of $81,000 per year. Estimated annual meter replacements or rebuilds are 1,466–1,832 small meters, 244 intermediate meters, and 32 large meters. Estimated annual labor hours are 3,485. Estimated annual costs for all meters replaced are approximately $573,000.

The following is recommended for meter rebuild or replacement:

- Continue with existing meter rebuild and replacement schedules unless additional accuracy and economic data suggest modification. At the reduced rate of testing currently conducted by SSWD, statistically significant accuracy estimates may not be achieved in the recommended five-year study period.

Meter Reading

Table 7-2, 15-Year Financial Analysis Summary, estimates potential cost savings over 15 years for collaborative purchasing of water meters through a Consortium-based approach. The amount shown is $542,160, or approximately $36,000 per year.

Table 7-2. 15-Year Financial Analysis Summary[1]

Item	Difference from BAU
Meter Hardware	
Small Meters (≤ 1 Inch)	($428,398)
Intermediate Meters (1.5–2 Inch)	($37,148)
Large Meters (≥3 Inch)	($37,619)
Endpoints	$0
Sales Tax (7.75%)	($38,995)
Subtotal Meter Hardware	*($542,160)*
Meter Reading	
Communications	$0
Data Analytics	$0
Subtotal Meter Reading	*$0*
Total Cost	**($542,160)**
Net Present Value	*$2,161,643*

Notes: BAU = business-as-usual

1 Excerpt from Table 7-5.

The following is recommended for meter reading:

- Complete full implementation of AMI using the current SSWD balanced radio/cellular endpoint approach

Meter Data Management

Following are recommendations for meter data management:

- Establish a regularly updated deployed meter asset registry that is searchable by attributes, such as type, size, age, accuracy test results, replacement or rebuild cost, rebuild date, and customer usage, to enable the SSWD to make smarter decisions over time.
- Use AMI interval read data for functionality beyond customer billing, including hydraulic modeling, physical asset sizing, optimization of system operations, and customer service.
- Use testing data, maintenance and operations data, and billing data to inform meter hardware replacement and rebuild criteria and technology selection decisions.
- Relate billing revenue and economic cost information with deployed meter and testing data. A higher confidence level in meter accuracy will provide a complete economic assessment of deployed meter assets, including potential revenue loss due to inaccuracy and meter replacement or rebuild cost.
- Develop and implement a Consortium-wide meter asset registry. It is recommended that Consortium agencies collectively write a specification for the registry (which would include inventory and accuracy testing data and asset cost data), evaluate and

select a consensus platform for storing and analyzing the data, and use selected cohorts to inform Consortium agencies on relevant information for joint and individual decision-making.

- Develop and monitor key performance indicators (KPIs) for meter asset management plan elements. Examples for three elements include the following (Table 7-3, Table of Key Performance Indicators for Sacramento Suburban Water District Metering Strategies).

Table 7-3. Table of Key Performance Indicators for Sacramento Suburban Water District Metering Strategies

Meter Testing	Meter Rebuild or Replacement	Meter Reading
• Number of meter accuracy tests per month and year compared to planned quantities by size • Percent completeness of meter accuracy test form and testing data • Labor time for each meter accuracy test for each meter size • Cost per meter accuracy test by meter size • Percent of accurate reporting of test results versus AWWA Manual M6 requirements	• Percent of installations adhering to meter removal and installation specifications • Annual volumetric recovery per individual meter rebuild/replacement • Annual revenue recovery per individual meter rebuild/replacement • Cost of meter rebuilt or replaced divided by annual revenue recovery • Reported annual apparent loss due to meter inaccuracy • Labor time and cost for meter rebuild or replacement by meter size • Maximization of validity score of annual water audit	• Cost per monthly billing read and cost per used interval read • Percent of successful billing reads within three days of read • Hourly interval read success rate (98.5 percent of all hourly interval reads within three days) • Errors per 1,000 meter reads • Number of customer service inquiries • Percentage of first call resolution • Time and cost to resolve meter reading and customer billing calls • SSWD customer satisfaction rating

Notes: AWWA = American Water Works Association; SSWD = Sacramento Suburban Water District

- Using the developed strategy for data management, gather existing meter asset and attribute information and load data into a standard Structured Query Language database or electronic spreadsheet in the format established in the strategy to establish an SSWD-specific water meter asset registry.
- Work closely with computerized maintenance management system, billing, and accounting software vendors to identify data linkages between databases, develop application programming interfaces between databases, and load and update asset information individually in the SSWD registry and Consortium-wide in the broader registry.
- Complete full implementation of AMI using a balanced radio/cellular endpoint approach.

The following sections present the context for the major recommendations for the SSWD meter asset management program.

A6 San Juan Water District

This section of Technical Memorandum 5 is intended to be the presentation and description of a specific water meter asset management program for the San Juan Water District (SJWD). Many elements of the program are common to all Water Meter Replacement Program Consortium (Consortium) agencies and require some customization by the individual Consortium agencies based on existing meter management, testing, and maintenance procedures; staffing and revenue resources; and customer service and operational goals of the water utility. These common elements are five-year implementation schedules for the components of the asset management program and sequential and similar schedule activities for each component. The proposed major asset management program components are meter testing, meter rebuild or replacement, meter reading, meter data management (MDM), and financial planning. Each of these components is presented and discussed below in individual subsections.

The San Juan Water District's primary goal is to continue to strengthen a customer water metering program. During the first year (2022), the focus of activities will be to develop (1) strategies and procedures, (2) detailed schedules for annual operations and maintenance activities, and (3) contract vehicles (schedule contracts, indefinite delivery, indefinite quantity contracts, and Consortium-wide acquisition contracts [CWAC]) for the activities that the SJWD elects to outsource. After the first year (2022), the SJWD will have the systems in place to implement the full meter program. The SJWD currently intends to replace the existing deployed meters with the greatest total registered flow and longest deployment periods. Particular attention should be paid to intermediate and large meters (see Technical Memorandum 4) because these meter sizes lose accuracy quicker than smaller meters and offer the greatest potential for revenue recovery. After the initial five-year planning period suggested in this Technical Memorandum 5 (2022–2026), the SJWD will have collected sufficient meter testing data to revisit the meter replacement criteria recommended in the Meter Replacement Program Planning Study (Study) (see Technical Memorandum 4 and this Technical Memorandum 5). The SJWD's other primary five-year goal is to ensure compatibility of deployed automatic meter reading (AMR) drive-by endpoints with future advanced metering infrastructure (AMI), should the SJWD choose to implement.

Summary of Initial Planning Level Recommendations

Based on the data collection and analysis tasks performed and documented in previous Technical Memoranda and in this Technical Memorandum 5, following are key recommendations for the SJWD.

Common to All Consortium Agencies

- Water meters and their associated meter reading and data collection/analysis methodologies and hardware should be considered important water utility assets and incorporated into a water meter asset management program.

- Components of the meter asset management program should include meter testing, meter rebuild or replacement, meter reading, MDM, and financial planning.
- For all Consortium agencies to make informed decisions regarding their programs, the SJWD will need to collect vital meter testing, meter replacement, meter and endpoint performance, and economic data and share that information for the benefit and decision-making of the wider Consortium.
- The SJWD should consider collaboration with the Regional Water Authority and other Consortium participants to assess, confirm, and quantify the benefits of collaborative purchasing of water meters and other metering components.
- Strategies and recommendations herein for SJWD water meter management should be incorporated into utility-wide asset management plans.

Meter Testing

Based on the findings of Technical Memorandum 3 (Section 3.4, Meter Testing Cost Development), the SJWD is recommended to test meters at the following rates (Table 8-1, Meter Testing Quantities and Costs).

Table 8-1. Meter Testing Quantities and Costs

	Test Count	Estimated Annual Cost
Small Meters (≤ 1 Inch)	371	$22,504
Intermediate Meters (1.5–2 Inch)	84	$10,184
Large Meters (≥3 Inch)	14	$5,994
Total Cost	**—**	**$38,682**
Additional Required FTE Staff	—	0

Notes: FTE = full-time equivalent

The above cost estimations are based on $60 per hour labor cost, SJWD small meter testing at $40 per removal and re-install, $20 per small meter test, $123 per intermediate field test, and $215 per large meter field test. Based on existing resources and assigned functions, it is estimated that the SJWD will require new resources to perform recommended field accuracy testing functions along with the rest of the program. This may be additional staffing or contractor assistance or a combination of the two.

Other specific meter testing recommendations include the following:

- Use the SJWD's own existing Mars automatic small meter test bench to achieve small meter testing objectives quantified in this Technical Memorandum 5.
- Within the next five years, develop statistically significant accuracy estimates for small meter age intervals and volumetric throughput intervals.
- Implement field testing of large and intermediate meters, consistent with American Water Works Association (AWWA) Manual M6 recommendations, with its own staff rather than contract, pending analysis of accuracy results for specific meter sizes that justify longer test intervals.

Meter Rebuild or Replacement

Based on the Technical Memorandum assessment, for every one percent gain in overall SJWD meter accuracy, the SJWD will increase revenue by 0.33 percent. Based on 2018 revenue of approximately $11 million, a one percent improvement in overall meter accuracy would result in an increase in revenue of $36,300 per year. Estimated annual meter replacements or rebuilds are 412–515 small meters, 27 intermediate meters, and two large meters. Estimated annual labor hours are 1,444. Estimated annual costs for all meters replaced are approximately $185,000.

The following is recommended for meter rebuild or replacement:

- Instead of replacing or rebuilding meters following failure, implement a proactive meter monitoring and performance program through testing and asset management that informs decisions based on cost-effective economics.

Meter Reading

The SJWD has already established a meter reading strategy, which is to fully deploy a drive-by AMR system across its service area. It is unknown if the SJWD will upgrade to a fixed network AMI in the future. The financial scenario indicates that, without major modifications to the strategy, significant potential cost savings through joint hardware purchasing exist.

Table 8-2, 15-Year Financial Analysis Summary, estimates potential cost savings over 15 years for collaborative purchasing of water meters and radio endpoints through a Consortium-based approach.

Table 8-2. 15-Year Financial Analysis Summary[1]

Item	Scenario 1: BAU	Scenario 2: Badger ORION Cellular (NaaS)	Scenario 3: Sensus FlexNet (NaaS)	Scenario 4: Sensus FlexNet (Agency Owned)	Scenario 5: Sensus AMR to AMI
Meter Hardware					
Small Meters (≤ 1 Inch)	$2,656,112	$2,317,796	$2,317,796	$2,317,796	$2,317,796
Intermediate Meters (1.5–2 Inch)	$226,719	$218,703	$218,703	$218,703	$218,703
Large Meters (≥3 Inch)	$36,021	$33,010	$33,010	$33,010	$33,010
Endpoints	$2,828,375	$1,819,424	$1,919,932	$1,919,932	$1,791,572
Sales Tax (8.75%)	$319,144	$213,876	$220,235	$220,235	$214,267
Material Recycling Fee	$52,930	$52,930	$52,930	$52,930	$49,430
Subtotal Hardware	*$6,119,302*	*$4,655,738*	*$4,762,605*	*$4,762,605*	*$4,624,778*

Table 8-2. 15-Year Financial Analysis Summary[1]

Item	Scenario 1: BAU	Scenario 2: Badger ORION Cellular (NaaS)	Scenario 3: Sensus FlexNet (NaaS)	Scenario 4: Sensus FlexNet (Agency Owned)	Scenario 5: Sensus AMR to AMI
Meter Reading					
Communications	$1,740,022	$1,677,087	$1,087,912	$814,901	$961,138
Data Analytics	$0	$0	$0	$380,182	$335,588
Setup Cost	$0	$49,400	$34,400	$238,371	$238,371
Cost Savings	$0	($1,796,340)	($1,934,520)	($1,934,520)	($1,381,800)
Subtotal Meter Reading	*$1,740,022*	*($69,853)*	*($812,208)*	*($501,066)*	*$153,296*
Total Cost	**$7,859,324**	**$4,585,885**	**$3,950,397**	**$4,261,539**	**$4,778,074**
Net Present Value	($6,254,822)	($3,793,135)	($3,427,044)	($3,714,441)	($4,035,275)

Notes: AMI = advanced metering infrastructure; AMR = automatic meter reading; BAU = business as usual; NaaS = network as a service

1 A full analysis can be found in Technical Memorandum 4, Section 4.2.2.

The following is recommended for meter reading:

- Complete full implementation of AMR.
- Assess the potential benefits and costs of implementing AMI in the future.

Meter Data Management

Following are recommendations for MDM:

- Establish a regularly updated deployed meter asset registry that is searchable by attributes, such as type, size, age, accuracy test results, replacement or rebuild cost, rebuild date, and customer usage, to enable the SJWD to make smarter decisions over time.
- Use AMR interval read data for functionality beyond customer billing, including hydraulic modeling, physical asset sizing, optimization of system operations, and customer service.
- Use data to inform meter hardware replacement and rebuild criteria and technology selection decisions.
- Relate billing revenue and economic cost information with deployed meter and testing data. A higher confidence level in meter accuracy will provide a complete economic assessment of deployed meter assets, including potential revenue loss due to inaccuracy and meter replacement or rebuild cost.
- Participate in and contribute to a Consortium-wide meter asset registry. It is recommended that Consortium agencies collectively write a specification for the registry (which would include inventory and accuracy testing data and asset cost data), evaluate and select a consensus platform for storing and analyzing the data, and use

selected cohorts to inform Consortium agencies on relevant information for joint and individual decision-making.

- Develop and monitor key performance indicators (KPIs) for meter asset management plan elements. Examples for three elements include the following (Table 8-3, Table of Key Performance Indicators for San Juan Water District Metering Strategies).

Table 8-3. Table of Key Performance Indicators for San Juan Water District Metering Strategies

Meter Testing	Meter Rebuild or Replacement	Meter Reading
• Number of meter accuracy tests per month and year compared to planned quantities by size • Percent completeness of meter accuracy test form and testing data • Labor time for each meter accuracy test for each meter size • Cost per meter accuracy test by meter size • Percentage of accurate reporting of test results versus AWWA Manual M6 requirements	• Percentage of installations adhering to meter removal and installation specifications • Annual volumetric recovery per individual meter rebuild/replacement • Annual revenue recovery per individual meter rebuild/replacement • Cost of meter rebuilt or replaced divided by annual revenue recovery • Reported annual apparent loss due to meter inaccuracy • Labor time and cost for meter rebuild or replacement by meter size • Maximization of validity score of annual water audit	• Cost per monthly billing read and cost per used interval read • Percentage of successful billing reads within 3 days of read • Hourly interval read success rate (98.5 percent of all hourly interval reads within 3 days) • Errors per 1,000 meter reads • Number of customer service inquiries • Percentage of first call resolution • Time and cost to resolve meter reading and customer billing calls • SJWD customer satisfaction rating

Notes: AWWA = American Water Works Association; SJWD = San Juan Water District

- Using the developed strategy for data management, gather existing meter asset and attribute information and load data into a standard Structured Query Language database or electronic spreadsheet in the format established in the strategy to establish an SJWD-specific water meter asset registry.
- Work closely with computerized maintenance management system, billing, and accounting software vendors to identify data linkages between databases, develop application programming interfaces between databases, and load and update asset information individually in the SJWD registry and Consortium-wide in the broader registry.
- Complete full implementation of AMR.

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