DISCLAIMER

This project was conducted with financial assistance from a grant from the Metropolitan Water District of Southern California (Metropolitan) and the Southern California Gas Company through Metropolitan's Innovative Conservation Program (ICP). The ICP provides funding for research to help document water savings and reliability of innovative water savings devices, technologies, and strategies. The findings of this project, summarized in this report, are solely from the project proponent.

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City of Fullerton Meter Health Analytics Pilot Project

Deliverable #2: Final Report
Agreement No. 213918
City of Fullerton
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Project Description

Olea Edge Analytics deployed their Meter Health Analytics hardware onto the City of Fullerton's 50 largest commercial/industrial water meters. These 50 meters were manufactured by Hersey, Rockwell and Sensus and of varying models and diameters, refer to **Project Site Map** on the following page for locations of the selected meters with Olea devices.

The installation process required Olea to install a sensor cap and sensor pod with three types of sensors on the meter, as well as an edge computer and cellular antenna. The sensors consist of a vibration sensor, a camera, and a magnetic sensor. The sensors were mounted on the outside of the meter and do not interfere with the operation of the meter.

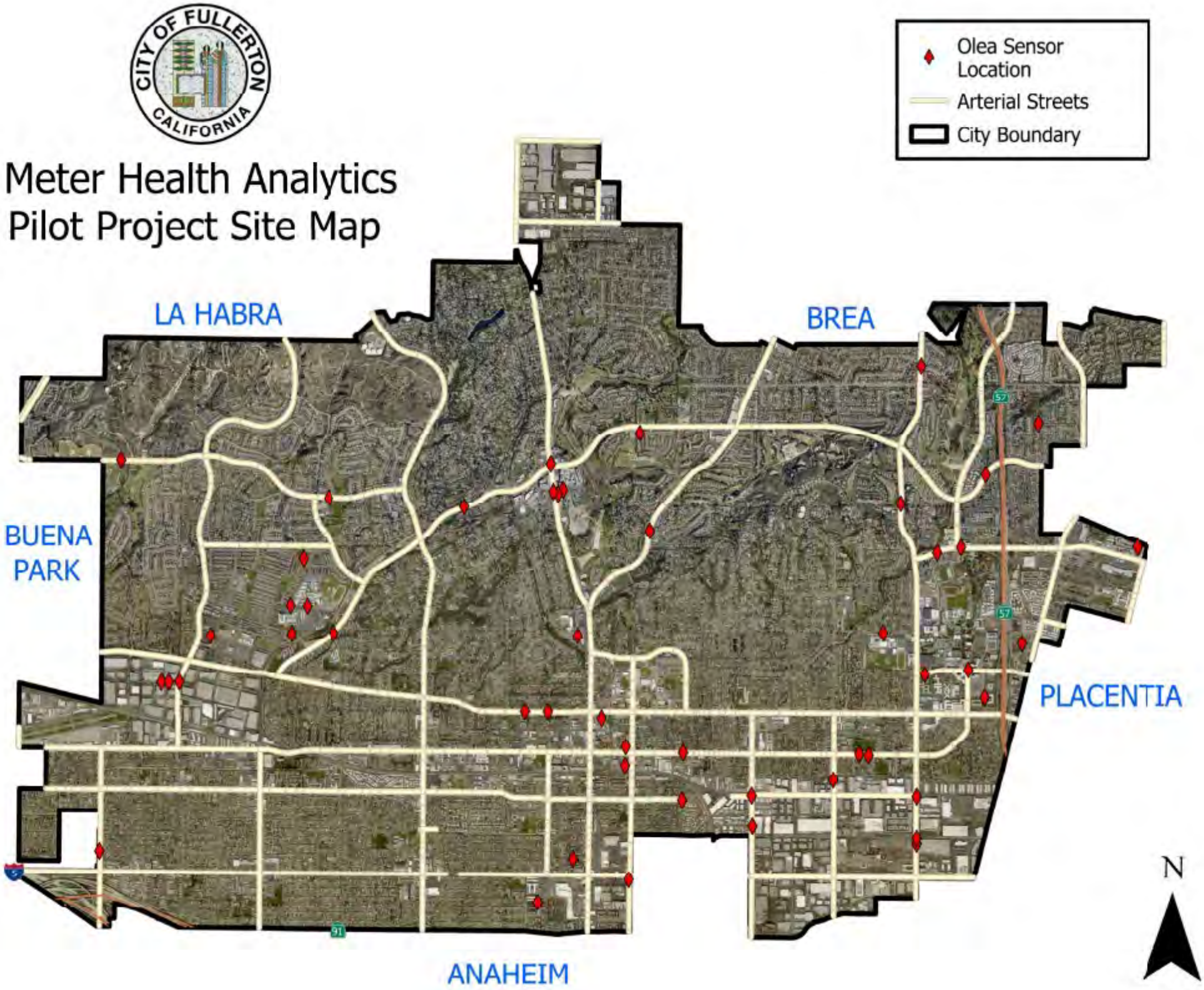
During the installation, Olea collects data about the customer and property location, the water meter and its accessibility, valves, power accessibility and cellular coverage, as well as several images of the site, water meter and hardware.

The installed Olea devices or sensors will perform diagnostics to monitor health and performance of each meter which include the following objectives:

- Identify underperforming large commercial/industrial meters to assist in reducing apparent losses
- Determine specific cause of meter failure or defect
- Make recommendation(s) to repair deficient meters

A final report will be prepared and submitted after the meters have been repaired and post-repair analysis has been completed. This report will document findings, validate the repairs completed have returned the meter back to proper operating condition with samples of data presented to support report findings. The final report will also provide calculations and estimates of the additional water measured due to the repairs.

Meter Health Analytics
Pilot Project Site Map



ICP Final Report

City of Fullerton Meter Health Analytics Pilot Project

Olea™

Made possible by a grant from:
Innovation Conservation Program - MWD

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Introduction:

The City of Fullerton has a desire to explore new technology and approaches to improve and augment their ongoing water meter asset management program. The City of Fullerton's 3 inch and larger commercial and industrial meter portfolio serves its largest customers (approx 150 meters consume 10% of the water supply). Short-term meter failures contribute to their growing non-revenue water apparent losses (Approx 330 acre-ft/year in 2022) and have a significant adverse financial impact on revenue (Approx $418,000 loss in 2022). Flow testing all meters on a yearly basis is difficult to achieve with limited resources.

A new approach to monitoring large water meters has been developed by Olea Edge Analytics. The new approach, Meter Health Analytics (MHA), enables utilities to monitor the performance and accuracy of water meters in a simple way with minimum manpower requirements. MHA consists of a passive sensor array and an edge computer installed on the outside of a water meter. The sensors gather data which is analyzed using artificial intelligence and machine learning algorithms to identify inaccurate and poorly operating water meters. The analysis provides the specific cause(s) of failure and specific recommendation(s) to repair the meter. The MHA solution is provided in a turnkey service offering, enabling utilities to focus on repairing and maintaining assets without the burden of installing and maintaining a sensor and edge computing network, collecting data, analyzing data, identifying broken meters or determining the right corrective action. MHA allows utilities to identify broken and poorly performing water meters faster and easier than traditional approaches to meter asset management.

The goals of this pilot program are to:

1. Demonstrate and validate a new approach to identifying inaccurate large water meters.
2. Demonstrate and validate a new approach to identifying the specific cause/s of failure.
3. Demonstrate and validate the accuracy of the specific repair recommendations provided by the new approach.
4. Demonstrate and validate a new approach to identifying accurate and properly performing large water meters.

Methodology:

The steps below outline the procedure to successfully start and complete the Meter Health Analytics (MHA) pilot program for the City of Fullerton.

1. Meter selection - Fullerton selected and prioritized 60 meters of their largest and highest revenue generating water meters. Olea deployed MHA on the first 50 prioritized meters with the option of skipping a meter if they are unable to install due to safety, access, or hardware compatibility. If a meter is skipped, the next meter on the prioritized list would be selected.

2. Hardware installation - Olea installed a sensor cap and sensor pod with three types of sensors on the meter. The sensors are a vibration sensor, a camera, and a magnetic sensor. The sensors are mounted on the outside of the meter and do not touch water or require modification of the meter in any way. The sensors are passive and do not interfere with the operation of the meter.

3. Data collection and analysis - Meter asset data is collected at the time of hardware installation. Sensor data is collected for a minimum of 7 days after the hardware is installed. The data is analyzed using a combination of automated AI, machine learning algorithms, and manually applied approaches. All data and findings are reviewed by an Olea data analyst as part of an intensive quality assurance process.

4. Initial reporting and presentation - The initial analysis results report containing meter health results and repair recommendations were presented to the City of Fullerton. The City and Olea mutually agreed to a scope of repairs and a repair timeline.

5. Perform repairs - City of Fullerton repaired and/or replaced meters as recommended by the analysis.

6. Validations - Olea installed the MHA sensors and hardware on the repaired meters. Data is collected and analyzed for a minimum of 7 days after the hardware is installed. The data is analyzed using a combination of automated AI, machine learning algorithms, and manually applied approaches. All data and findings are reviewed by a data analyst as part of an intensive quality assurance process.

7. Validation reporting and presentation - The validation results reports were delivered and presented to the City of Fullerton. The validation is completed to verify that the repaired/replaced water meters are now healthy and accurate.

Technology & Data Analytics:

The Meter Health Analytics (MHA) hardware consists of 3 different types of sensors, an edge computer, an antenna and a power source. The data collecting sensors are made up of two hall effect (electromagnetic) sensors to capture the forward and backward rotations of the water meter's measuring element. An acoustic sensor which captures the magnitude of the flow vibrations passing through the meter. And the other sensor is a camera that captures images of the water meter register's consumption information (either digital or analog registers), and converts these images of water consumption into digital numbers (Figure 1). The continuous data that these 3 sensors are collecting is sent to the edge computer, which is housed in a rugged box that can handle water and extreme temperatures (Figure 2). The data is then sent from the edge computer to the cloud via a cellular agnostic antenna. Once the data is in the cloud, Olea uses its own proprietary artificial intelligence and machine learning algorithms to identify inaccurate and poorly operating water meters. The analysis provides the specific cause(s) of meter failure and the specific recommendation(s) to repair the meter. The MHA hardware is powered by either battery, or via solar, depending on the location of the water meter (Figure 3). For the City of Fullerton pilot project, battery power was utilized.

Figure 1 - Camera and sensor pack containing the hall effect and acoustic sensors.

Figure 2 - Edge computer connected to the sensors, with the cellular antenna.

Figure 3 - Example of a solar powered MHA unit.

The MHA solution is provided in a turnkey service, offering and enabling the City of Fullerton to focus on repairing and maintaining their water meter assets. MHA will allow the City to identify broken and poorly performing water meters faster and easier than traditional approaches to meter asset management and will deliver this data via reports and presentations that will help the utility understand their water meter network, and prioritize workflows to ensure non-revenue water loss is minimized.

The MHA technology can identify up to 46 different error conditions that occur within a mechanical water meter. Some of the more prevalent error conditions that can contribute to significant non-revenue water include ‘measuring element malfunction’, ‘register failure’, ‘backflow detected’, ‘early crossover’, ‘late crossover valve’, ‘undersized meter’, ‘oversized meter’.

As mentioned in previous sections, Olea's MHA sensors collect acoustic data, electromagnetic data and consumption data. Figure 4 below shows 7 days worth of data, collected from June 1 to June 8. The orange line represents the flow in gallons per minute (Y-axis), this is obtained from the camera capturing images of the consumption data from the meter register. The light blue line represents the electromagnetic sensor data which is capturing the rotations of the water meter's measuring element (secondary Y-axis). The purple line represents the MEMS sensor, also known as the acoustic sensor, this represents the vibration of flow passing through the water meter (secondary Y-axis). It can be seen that all three sensor data are in harmony, Olea's data analytics capabilities flags this water meter as 'No Problem Found (NPF)', meaning that it is a healthy water meter and billing for every drop of water delivered to the client.

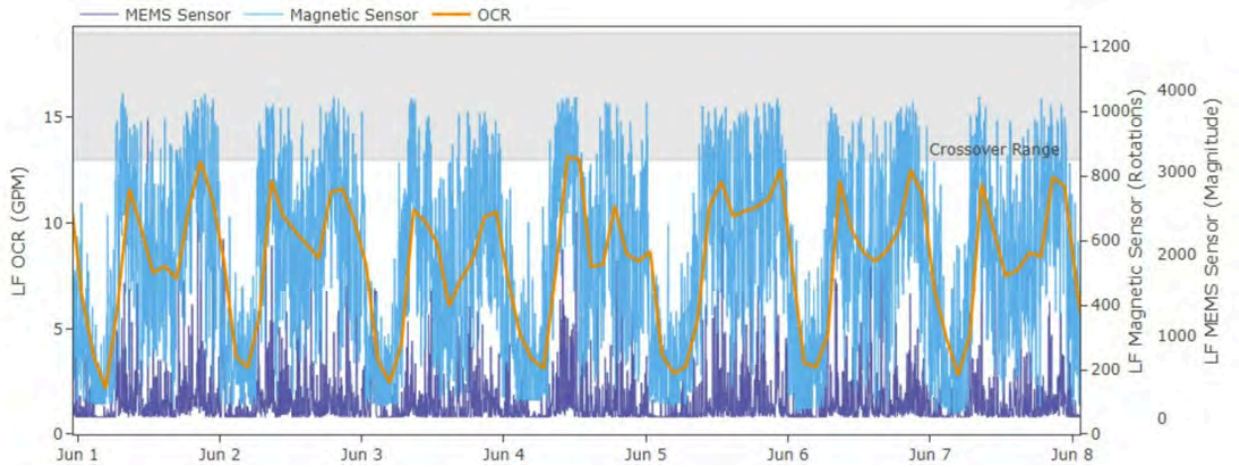

Figure 4 - Example of a healthy 'No Problem Found' meter

Beyond the 'proof of concept' pilot project, Olea offers two variations of Meter Health Analytics.

- The first option is the 'MHA Annual Subscription', in which the MHA hardware is installed on selected water meters for a 12 month period, and a 'meter health check' is performed every month for 12 months.
- The second option is the 'MHA Snapshot', where the MHA hardware is installed for a two week period, and the 'meter health check' is completed for this one period of time.

Pilot Project Results:

The Pilot project for the City of Fullerton was completed in two phases. The first phase being the 'Initial Meter Health Check' where Meter Health Analytics is applied to all 50 selected water meters. The second phase of the pilot is the 'Validation', where MHA is reapplied to all error meters that were repaired/replaced by Fullerton staff, for the purpose of validating that the repairs/replacements were successful. The following sections will present the results and corrective actions of both phases in detail.

Initial Meter Health Check Phase:

The initial meter health check phase took place between July 25 and August 16, 2023. With a minimum of 7 days data collection required to determine if the meters are healthy or not. The results are as follows:

- 15 meters contained error conditions (30%).
- 35 meters had no problem found (70%).

Zooming into the error conditions, Table 1 below shows a truncated version of the meter error report (customer information removed). Of the 50 meters, 15 are experiencing meter errors, and of these meter errors three have been assigned as 'High Priority' meters, 6 'Medium Priority' meters, and 6 'Low Priority' meters. Olea has defined these priority levels to assist water utilities in prioritizing which meters to give attention to.

Ref ID	Meter Type	Manufacturer	Model	Report Type	Error Condition	Priority
1000.F103	Compound	Sensus	Sensus W Compact FireLine 2.0" x 8.0"	ERROR	INCORRECT POSITION INLET VALVE & OUTLET VALVE, POTENTIAL HF MEASURING ELEMENT FAILURE,	HIGH
1000.SR03	Compound	Hersey	Hersey MCTII Compound 0.75" x 3"	ERROR	HF REGISTER FAILURE, LF REGISTER FAILURE	HIGH
1000.0414	Compound	Hersey	Hersey MCTII Compound 0.75" x 3"	ERROR	LF REGISTER FAILURE	HIGH
1000.F031	Compound	Sensus	Sensus W Compact FireLine 2.0" x 10.0"	ERROR	EARLY CROSSOVER	MEDIUM
1000.904R	Compound	Hersey	Hersey MCTII Compound 1" x 4"	ERROR	EARLY CROSSOVER	MEDIUM
1000.03R3	Compound	Hersey	Hersey MCTII Compound 1" x 4"	ERROR	EARLY CROSSOVER	MEDIUM
1000.0SR3	Compound	Sensus	Sensus W FireLine 2.0" x 10.0"	ERROR	HF REGISTER DAMAGED	MEDIUM
1000.R902	Compound	Hersey	Hersey MFMII Fire Line MVR 3" x 8"	ERROR	HF REGISTER DAMAGED, LF INSTALL MISMATCH	MEDIUM
1000.0712	Compound	Hersey	Hersey MCTII Compound 1" x 4"	ERROR	LF REGISTER DAMAGED	MEDIUM
1000.K011	Single	Sensus	Sensus W Turbo DR 4"	ERROR	OVERSIZED	LOW
1000.B019	Single	Sensus	Sensus W Turbo DRS 3"	ERROR	OVERSIZED	LOW
1000.303R	Single	Sensus	Sensus W Turbo DR 4"	ERROR	OVERSIZED	LOW
1000.0K11	Single	Sensus	Sensus W Turbo DRS 4"	ERROR	OVERSIZED	LOW
1000.Y039	Single	Neptune	Neptune High Performance (HP) Turbine 8"	ERROR	OVERSIZED	LOW
1000.8039	Single	Sensus	Sensus W Turbo DR 4"	ERROR	OVERSIZED, POTENTIAL CUSTOMER LEAK	LOW
1000.X210	Single	Sensus	Sensus W Turbo DR 6"	NPF	NPF	
1000.229	Single	Sensus	Sensus OMNI Compound C2 4.0"	NPF	NPF	
1000.S3R0	Single	Sensus	Sensus OMNI Compound C2 4.0"	NPF	NPF	
1000.W1R0	Single	Sensus	Sensus W Turbo DR 6"	NPF	NPF	
1000.B190	Single	Sensus	Sensus OMNI Compound C2 3.0"	NPF	NPF	
1000.61R0	Single	Sensus	Sensus OMNI Compound C2 3.0"	NPF	NPF	
1000.441	Compound	Sensus	Sensus W Compact FireLine 2.0" x 6.0"	NPF	NPF	
1000.4041	Compound	Hersey	Hersey MCTII Compound 1" x 4"	NPF	NPF	
1000.2029	Compound	Sensus	Sensus W Compact FireLine 2.0" x 6.0"	NPF	NPF	
1000.7021	Single	Sensus	Sensus OMNI Compound C2 3.0"	NPF	NPF	
1000.R290	Compound	Sensus	Sensus W Compact FireLine 2.0" x 6.0"	NPF	NPF	
1000.F310	Compound	Hersey	Hersey MCTII Compound 1.5" x 6"	NPF	NPF	
1000.Y390	Single	Sensus	Sensus OMNI Compound C2 6.0"	NPF	NPF	
1000.D2R0	Compound	Sensus	Sensus W FireLine 2.0" x 10.0"	NPF	NPF	
1000.K110	Single	Sensus	Sensus OMNI Compound C2 4.0"	NPF	NPF	
1000.R029	Single	Sensus	Sensus OMNI Compound C2 4.0"	NPF	NPF	
1000.S03R	Single	Sensus	Sensus OMNI Compound C2 3.0"	NPF	NPF	
1000.W01R	Single	Sensus	Sensus OMNI Compound C2 3.0"	NPF	NPF	
1000.B901	Single	Sensus	Sensus OMNI Compound C2 3.0"	NPF	NPF	
1000.2902	Compound	Sensus	Sensus W Compact FireLine 2.0" x 10.0"	NPF	NPF	
1000.X102	Single	Sensus	Sensus OMNI Compound C2 6.0"	NPF	NPF	
1000.Y903	Single	Sensus	Sensus OMNI Compound C2 4.0"	NPF	NPF	
1000.0F13	Single	Sensus	Sensus OMNI Compound C2 4.0"	NPF	NPF	
1000.0G94	Compound	Sensus	Sensus W Compact FireLine 2.0" x 6.0"	NPF	NPF	
1000.0R92	Single	Sensus	Sensus OMNI Fireline F2 6"	NPF	NPF	
1000.4104	Single	Sensus	Sensus OMNI Compound C2 3.0"	NPF	NPF	
1000.8903	Compound	Hersey	Hersey MCTII Compound 1" x 4"	NPF	NPF	
1000.7102	Single	Sensus	Sensus OMNI Compound C2 3.0"	NPF	NPF	
1000.WR01	Compound	Sensus	Sensus W Compact FireLine 2.0" x 6.0"	NPF	NPF	
1000.0893	Single	Sensus	Sensus OMNI Compound C2 4.0"	NPF	NPF	
1000.0292	Single	Sensus	Sensus OMNI Compound C2 3.0"	NPF	NPF	
1000.0WR1	Single	Sensus	Sensus OMNI Compound C2 4.0"	NPF	NPF	
1000.09R4	Single	Sensus	Sensus W Turbo DR 3"	NPF	NPF	
1000.721	Compound	Sensus	Sensus W FireLine 2.0" x 10.0"	NPF	NPF	
1000.D02R	Compound	Sensus	Sensus W Compact FireLine 2.0" x 8.0"	NPF	NPF	

Table 1 - Meter health report

In addition to the meter health report spreadsheet (Table 1), a meter health analysis presentation and report is delivered to the customer. This includes the meter health data, explanation of results and error conditions, and suggested corrective actions. The following pages of this report will summarize the 'Initial Meter Health Check Phase' results.

'No Problem Found' meter result examples - 35 in total, 3 examples included below:

Ref ID: 1000.2029
Meter: Compound, Sensus, W Compact FireLine 2" x 6"
Meter Health Status: No problem found

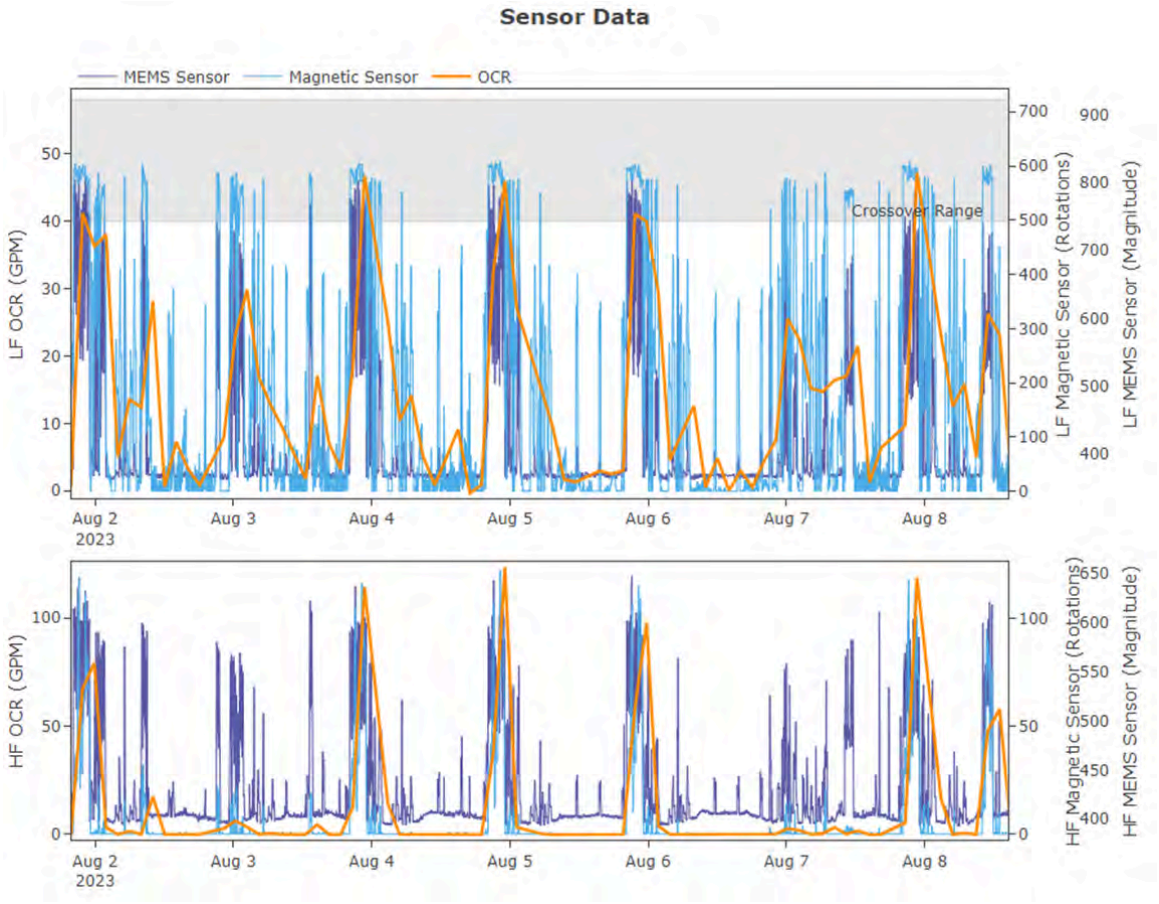

Figure 5 - 'No Problem Found' meter

FLOW RANGES AND ACCURACY LIMITS – 6"
6" Continuous Flows: 8 to 2000 GPM
Intermittent Flows: 2500 GPM
Low Flows: 2 GPM
Accuracy ±: ±1.5% of Actual Throughput–95% at Low Flow

Figure 6 - Meter specifications for a Sensus, W Compact FireLine 2" x 6"

- This is a compound meter (Figure 5), with the low flow meter represented in the upper graph and high flow meter on the lower graph. The sensor data (flow - orange, magnetic rotations - blue, vibration - purple) is in harmony, and the flow is crossing over from the low flow meter to the high flow meter correctly (crossover range in gray on the low flow meter graph). Analysis reveals that the meter is operating within the manufacturers specifications (Figure 6) and no problem is found.

Ref ID: 1000.4041
Meter: Compound, Hersey, MCTII Compound 1" x 4"
Meter Health Status: No problem found

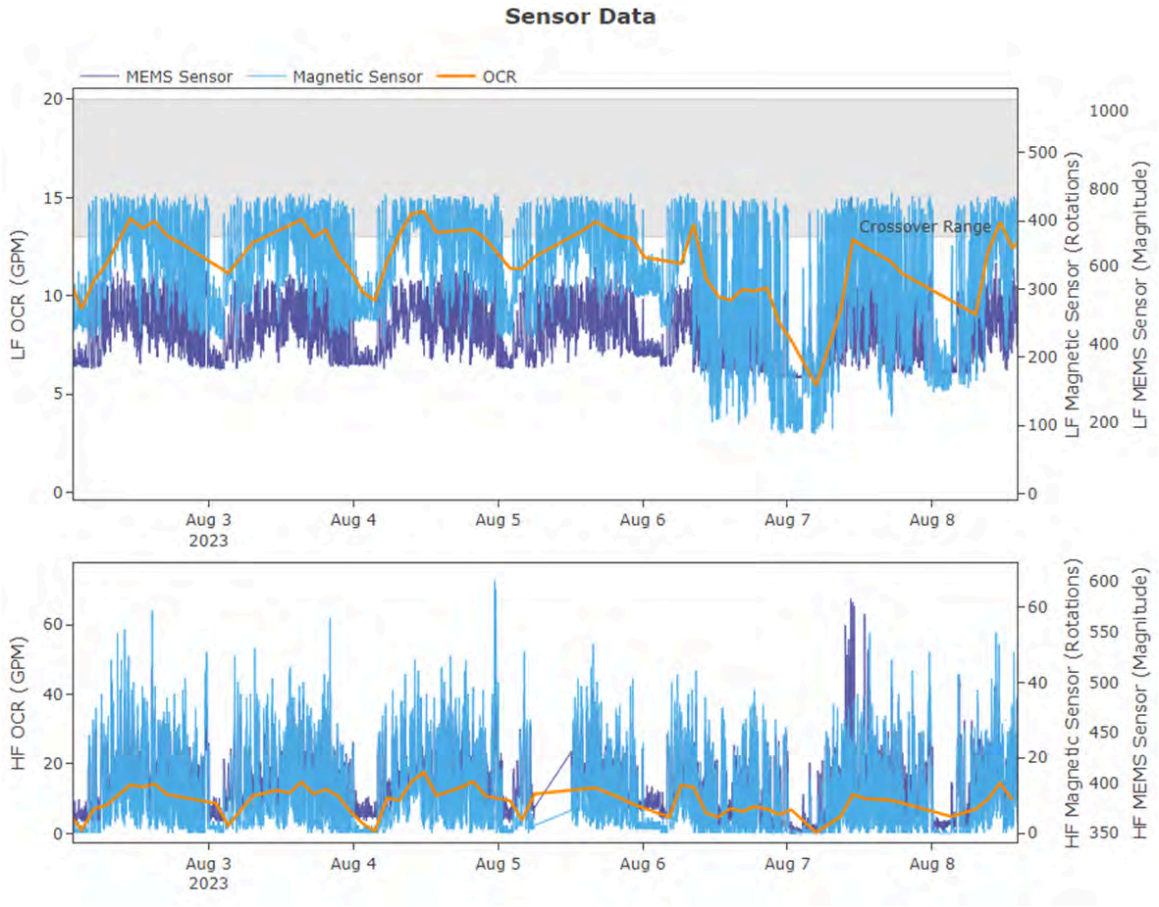

Figure 7 - 'No Problem Found' meter

Flow Characteristics

Meter Size	Typical Low Flow (95% Min.)	Typical Operating Range (100% ± 3%)	Maximum Continuous Operation
2"	1/4 GPM	1 to 160 GPM	80 GPM
3"	1/2 GPM	4 to 320 GPM	160 GPM
4"	3/4 GPM	6 to 500 GPM	250 GPM
6"	1-1/2 GPM	10 to 1000 GPM	500 GPM
8"	2 GPM	16 to 1600 GPM	800 GPM

Figure 8 - Meter specifications for a Hersey, MCTII Compound 1" x 4"

- This is a compound meter (Figure 7), with the low flow meter represented in the upper graph and high flow meter on the lower graph. The sensor data (flow - orange, magnetic rotations - blue, vibration - purple) is in harmony, and the flow is crossing over from the low flow meter to

the high flow meter correctly (crossover range in gray on the low flow meter graph). Analysis reveals that the meter is operating within the manufacturers specifications (Figure 8) and no problem is found.

Ref ID: 1000.09R4
Meter: Single, Sensus, W Turbo DR 3"
Meter Health Status: No problem found

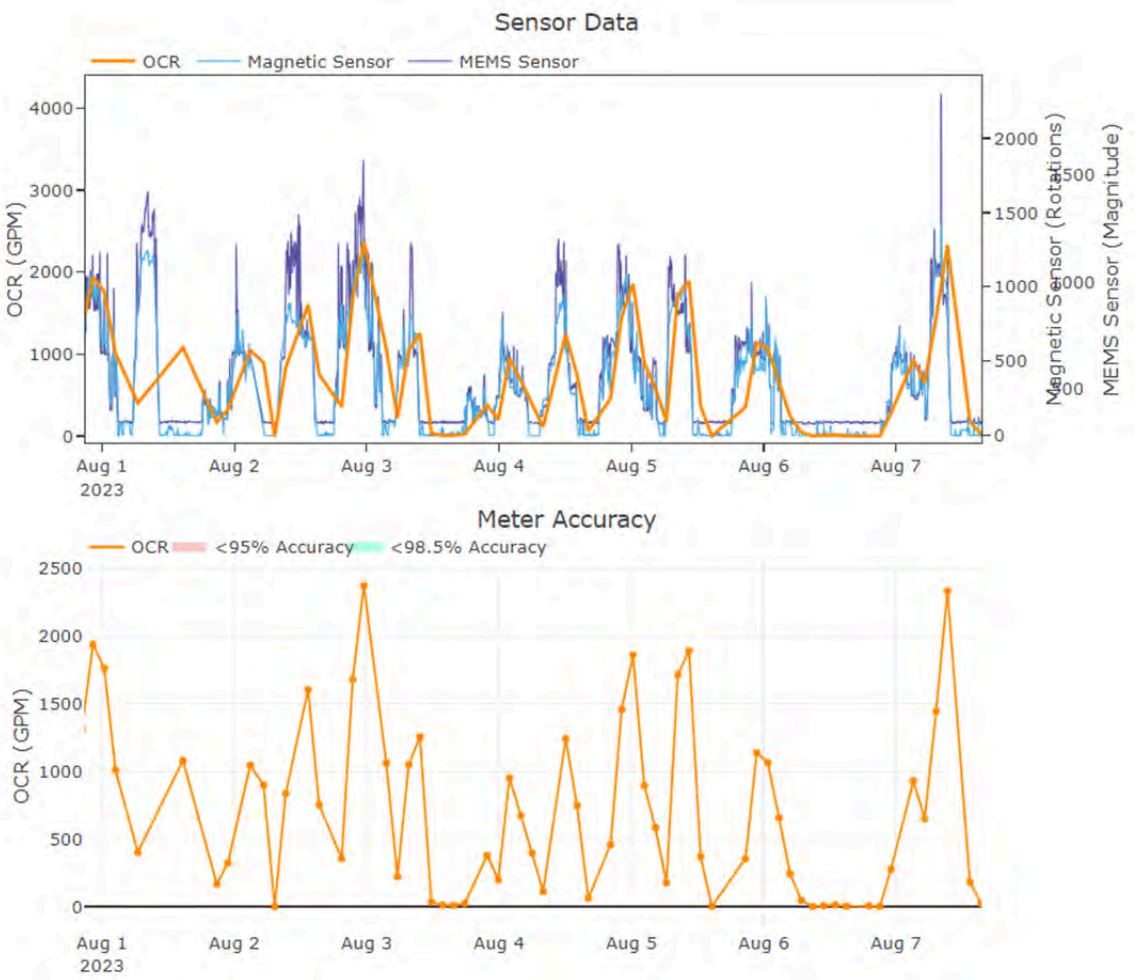

Figure 9 - 'No Problem Found' meter

Specifications

SERVICE	Measurement of cold water up to 80°F (27°C) with flow in one direction only.
OPERATING RANGE	Continuous Flows: 5 to 350 gpm (1.1 to 80 m^3/h) Intermittent Flows: 450 gpm max. (100 m^3/h)
ACCURACY	100% ± 1.5% of actual thruput
LOW FLOW	95% at 4 gpm (0.9 m^3/h)

Figure 10 - Meter specifications for a Sensus, W Turbo DR 3"

- This is a single meter (Figure 9). The sensor data (flow - orange, magnetic rotations - blue, vibration - purple) is in harmony. Analysis reveals that the meter is operating within the manufacturers specifications (Figure 10) and no problem is found.

‘High Priority Error’ meter results:

Ref ID: 1000.F103
Meter: Compound, Sensus, W Compact FireLine 2" x 8"
Meter Health Status: Error, Incorrect position of inlet valve and outlet valve, Potential high flow measuring element failure.

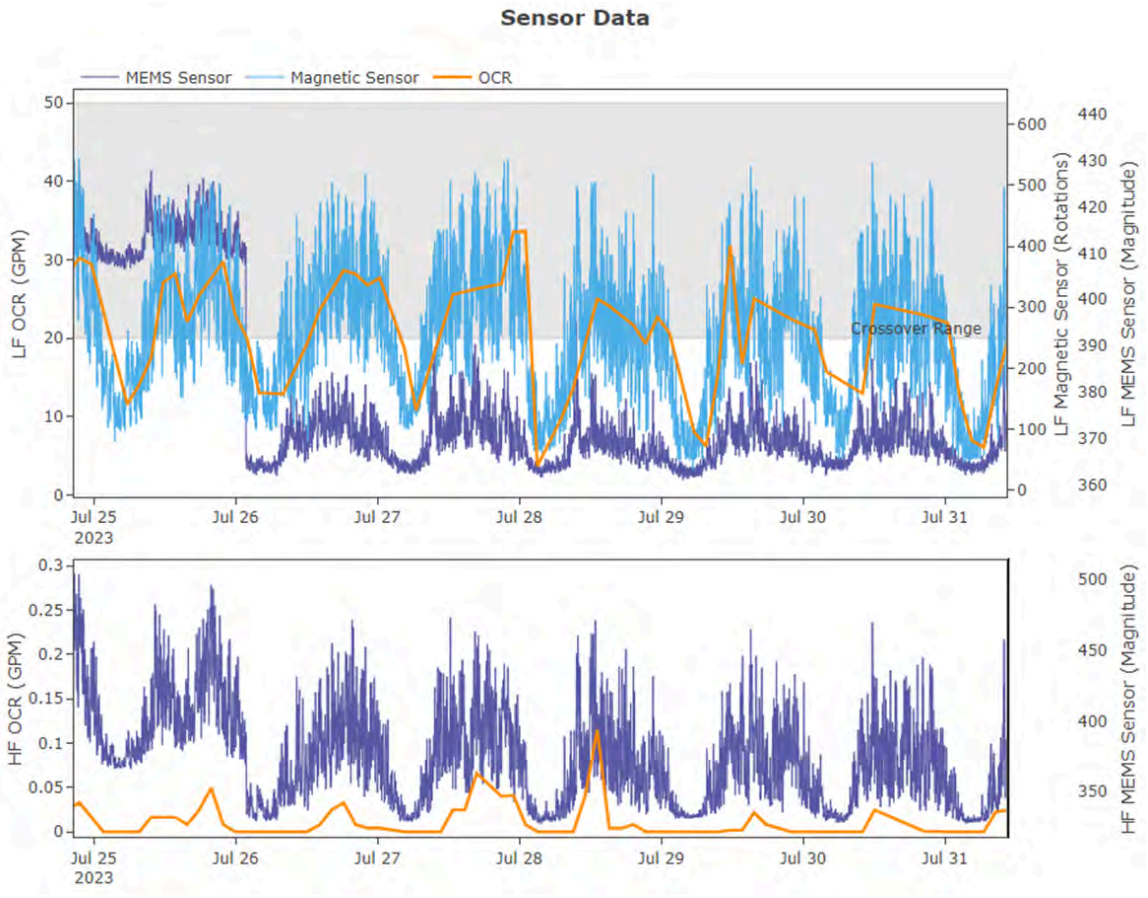

Figure 11 - Meter experiencing incorrect valve positions and a measuring element malfunction

- This meter is experiencing a high flow side measuring element malfunction, as well as incorrect valve positioning at the supply side and customer side valves.
- Observation (Figure 11): Flow is being recorded within the crossover range on the low flow side of the compound meter, but the high flow register data shows very low flows (<0.15 GPM), while Olea’s acoustic sensor indicates that higher flows are present. This is indicative of a measuring element failure/malfunction on the high flow side of the compound meter.
- Observation: While installing the MHA hardware, Olea’s deployment team identified that the City side supply valve is not fully open, and that the customer side supply valve is not fully open. These incorrect valve positions can potentially lead to turbulent flows at the meter. While this error type is not meter related, it is part of Olea’s service to check nearby valve positions as these can influence the performance of the water meter.

Suggested corrective actions:

- Both City and Customer side valves are not fully open, it is recommended that these be opened to the full position.
- The high flow side of the compound meter is not accurately representing flow because of a suspected malfunctioning measuring element. It is recommended that the measuring chamber be inspected for blockage or debris, or replaced.

Ref ID: 1000.SR03
Meter: Compound, Hersey, MCTII Compound 0.75" x 3"
Meter Health Status: Error, High flow register failure & low flow register failure.

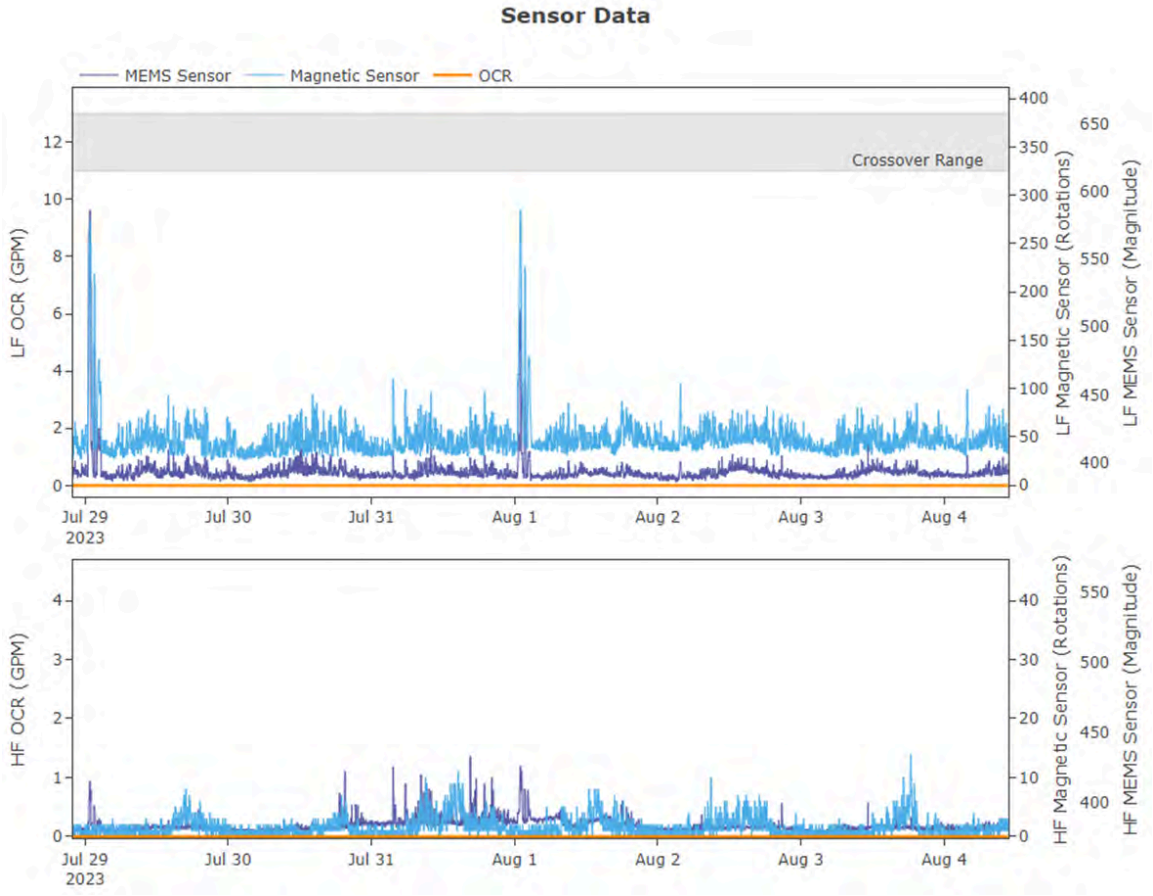

Figure 12 - Meter experiencing low flow register failure & high flow register failure

- This meter is experiencing failures on the low flow register and high flow register of the compound meter.
- Observation: The low flow side of the compound meter is not registering any flow. Olea's magnetic and acoustic sensors are picking up consistent flow through this meter. This is indicative of register failure.
- Observation: The high flow side of the compound meter is not registering any flow. Olea's magnetic and acoustic sensors are picking up consistent flow through this meter. This is indicative of register failure.
- There is also potential for there to be a crossover valve failure but Olea cannot confirm this until the low and high flow registers are fixed/replaced.

Suggested corrective actions:

- The low flow and high flow registers on this compound meter are not recording flow, despite Olea's sensors indicating that flow is present on both the low and high flow sides.
- It is recommended that both registers be replaced.
- Is it also recommended that the crossover valve mechanism be inspected for malfunction, damage or blockage.

Ref ID: 1000.0414
Meter: Compound, Hersey, MCTII Compound 0.75" x 3"
Meter Health Status: Error, Low flow register failure

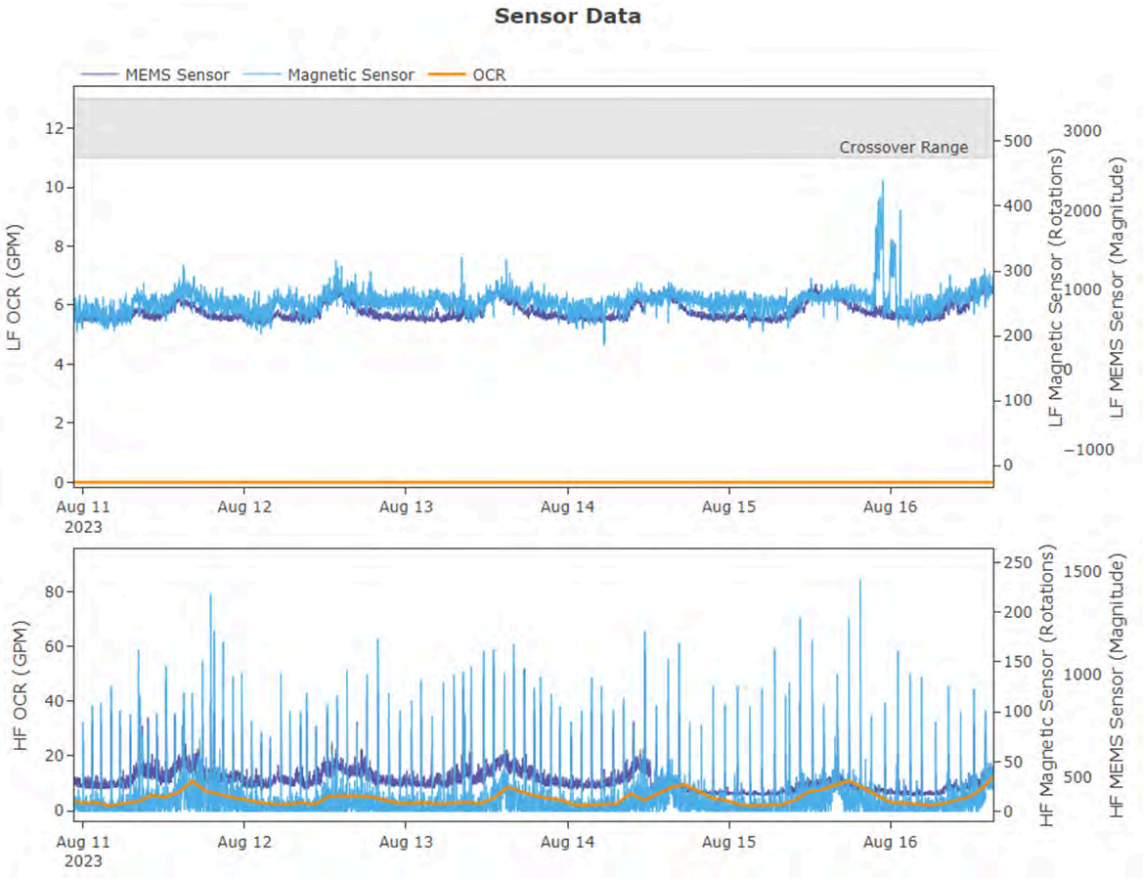

Figure 13 - Meter experiencing a low flow register failure

- This meter is experiencing a failure on the low flow register.
- Observation: The low flow side of the compound meter is not registering any flow. Olea's magnetic and acoustic sensors are picking up consistent flow through this meter. This is indicative of register failure.
- There is potential for there to be a crossover valve failure but Olea cannot confirm this until the low and high flow registers are fixed/replaced.

Suggested corrective actions:

- The low flow register on this compound meter is not recording flow, despite Olea's sensors indicating that flow is present. It is recommended that this register be replaced.
- Is it also recommended that the crossover valve mechanism be inspected for malfunction, damage or blockage.

‘Medium Priority Error’ meter results:

Ref ID: 1000.F031
Meter: Compound, Sensus, W Compact FireLine 2" x 10"
Meter Health Status: Error, Early crossover valve malfunction.

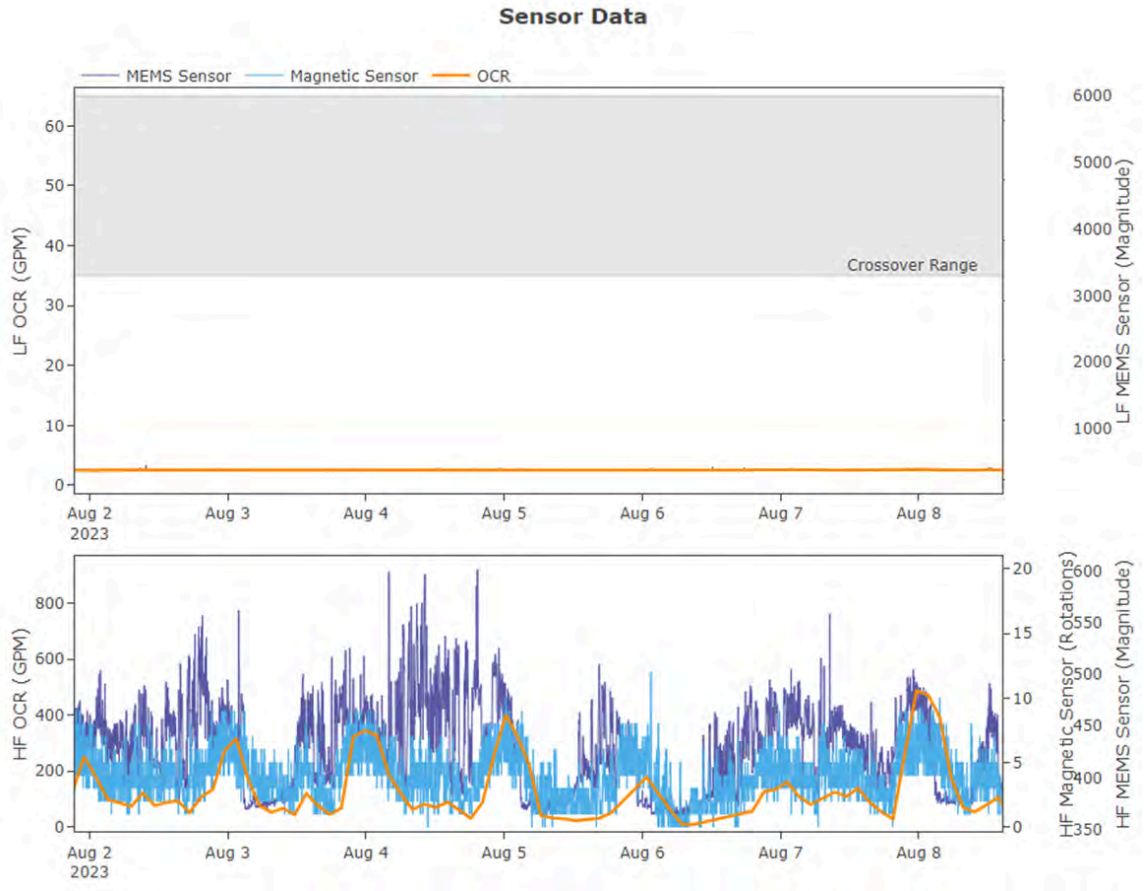

Figure 14 - Meter experiencing an early crossover valve error

- This meter is experiencing an early crossover valve error condition.
- Observation: 2.5 GPM is being consistently registered on the low flow side of the compound meter, this is nowhere near the crossover range of 35 GPM. Despite this, significant flow is being recorded on the high flow register. This is indicative of crossover valve malfunction.

Suggested corrective actions:

- Is it recommended that the crossover valve mechanism be inspected for damage or blockage.

Ref ID: 1000.904R
Meter: Compound, Hersey MCTII Compound 1" x 4"
Meter Health Status: Error, Early crossover valve malfunction

Figure 15 - Meter experiencing an early crossover valve error

- This meter is experiencing an early crossover valve error condition.
- Observation: A small amount of flow (0.13 GPM) is being recorded on the high flow register when the low flow is not in the crossover range (13 GPM). This is indicative of crossover valve failure.
- During higher flow periods the crossover valve appears to be operating correctly.

Suggested corrective actions:

- Although the early crossover error is allowing a very small amount of flow to enter the high flow side of the compound meter, this may be an early indication of a much larger crossover valve issue. It is recommended that the crossover valve mechanism be investigated for damage or blockage.

Ref ID: 1000.03R3
Meter: Compound, Hersey MCTII Compound 1" x 4"
Meter Health Status: Error, Early crossover valve malfunction

Figure 16 - Meter experiencing an early crossover valve error

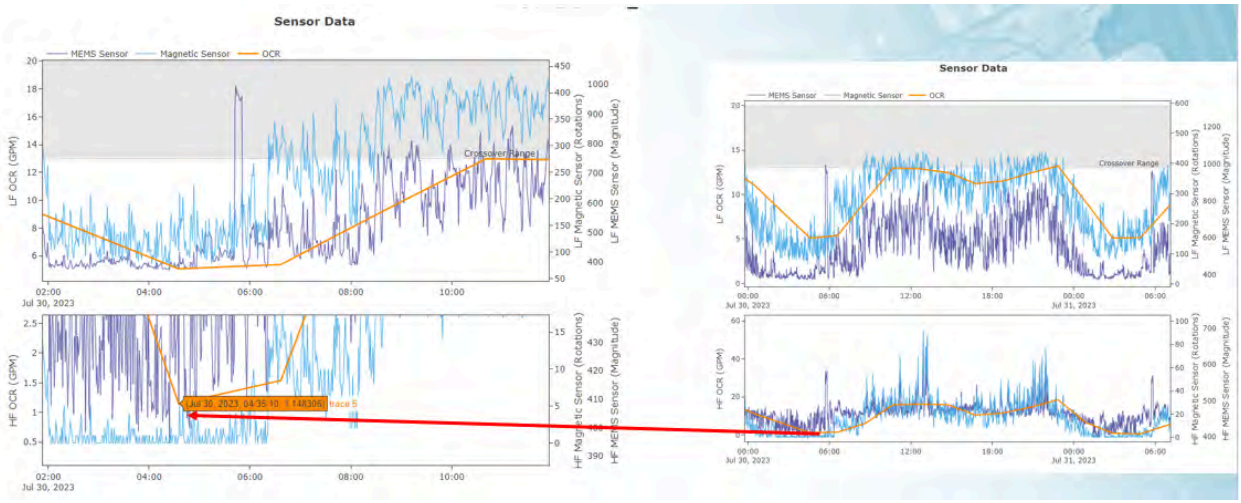

Figure 17 - 1.148 GPM being recorded on the high flow register despite the low flow side register recording 5 GPM, which is well under the crossover range of 13 GPM.

- This meter is experiencing an early crossover error condition.
- Observation: Flow is being recorded on the high flow register when the low flow register flow is not in the crossover range (13 GPM). This is indicative of crossover valve malfunction.
- During higher flow periods the crossover valve appears to be operating correctly.

Suggested corrective actions:

- The early crossover valve error is allowing a small amount of flow (~1 GPM) to enter the high flow side of the compound meter; this may be an early indication of a much larger crossover issue. It is recommended that the crossover valve mechanism be investigated for damage or blockage.

Ref ID: 1000.0SR3
Meter: Compound, Sensus W FireLine 2" x 10"
Meter Health Status: Error, Damaged Register

Figure 18 - Meter experiencing a damaged register

Figure 19 - Damaged register which makes meter reading difficult and prone to misreads.

- The high flow side of this compound meter has a damaged register.
- Observation: The high flow register is severely worn/scratched and has water residue inside of it.
- Olea's high flow side camera captured images of the register during the monitoring week. Our automated 'Optical Character Recognition' technology to convert images to digital numbers was unable to accurately capture consumption information due to the damaged register. Olea utilized manual procedures to capture the flow.
- While this is mostly a cosmetic issue, mistakes may occur with manual reading of the register. Water inside of the register may eventually lead to malfunction.

Suggested corrective actions:

- It is recommended that the high flow register be replaced so that accurate consumption readings can be completed, and to avoid potential future issues associated with water in the register.

Ref ID: 1000.R902
Meter: Compound, Hersey MFMII Fire Line MVR 3" x 8"
Meter Health Status: Error, Damaged register & incorrect meter configuration

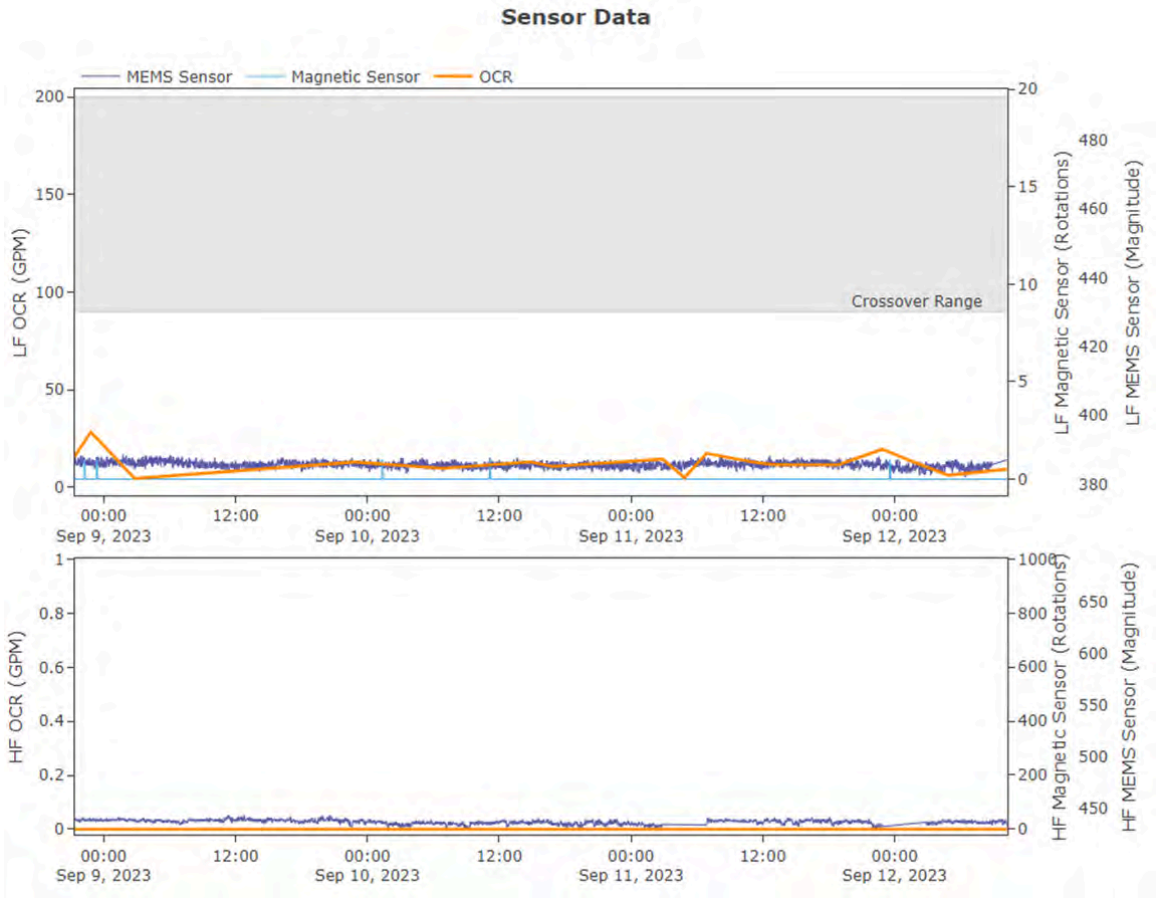

Figure 20 - Meter experiencing a damaged register and incorrect meter configuration

Figure 21 - Damaged register & incorrect meter configuration

- The high flow side of this compound meter has a damaged register, and there is an incorrect meter type installed on the low flow side of the compound meter.
- Observation: The high flow register has signs of corrosion and dirt inside of it, this may be due to water in the register. It should be noted that no flow is being recorded on this register due to the low flows on the low flow side meter. Olea cannot conclude if the register has failed or not.
- Observation: This is a Hershey brand compound meter. A Sensus Omni C2 meter has been installed on the low flow side, Olea flags this as an install error due to the setup conflicting with the meter manufacturers specifications.

Suggested corrective actions:

- It is recommended that the high flow side register be replaced.
- This Hershey compound meter has been configured with a Sensus meter on the low flow side. While this setup may operate without issue, it has been flagged as an error by Olea due to it conflicting with the meter manufacturers specifications.

Ref ID: 1000.0712
Meter: Compound, Hersey MCTII Compound 1" x 4"
Meter Health Status: Error, Damaged register

Figure 22 - Meter experiencing a damaged register

Figure 23 - Consumption numbers changing on the register but the dial is not moving

- The low flow side of this compound meter has a damaged register.
- Observation: The low flow meter register dial is not moving, despite the consumption numbers turning correctly. This is not a major error/failure, but could indicate deterioration of the register.

Suggested corrective actions:

- It is recommended that the low flow side register be replaced, although this is not a severe error it could be considered as preventative maintenance.

‘Low Priority Error’ meter results - 3 of 6 described below:

Ref ID: 1000.8039
Meter: Single, Sensus W Turbo DR 4"
Meter Health Status: Error, Oversized & Potential customer side leak

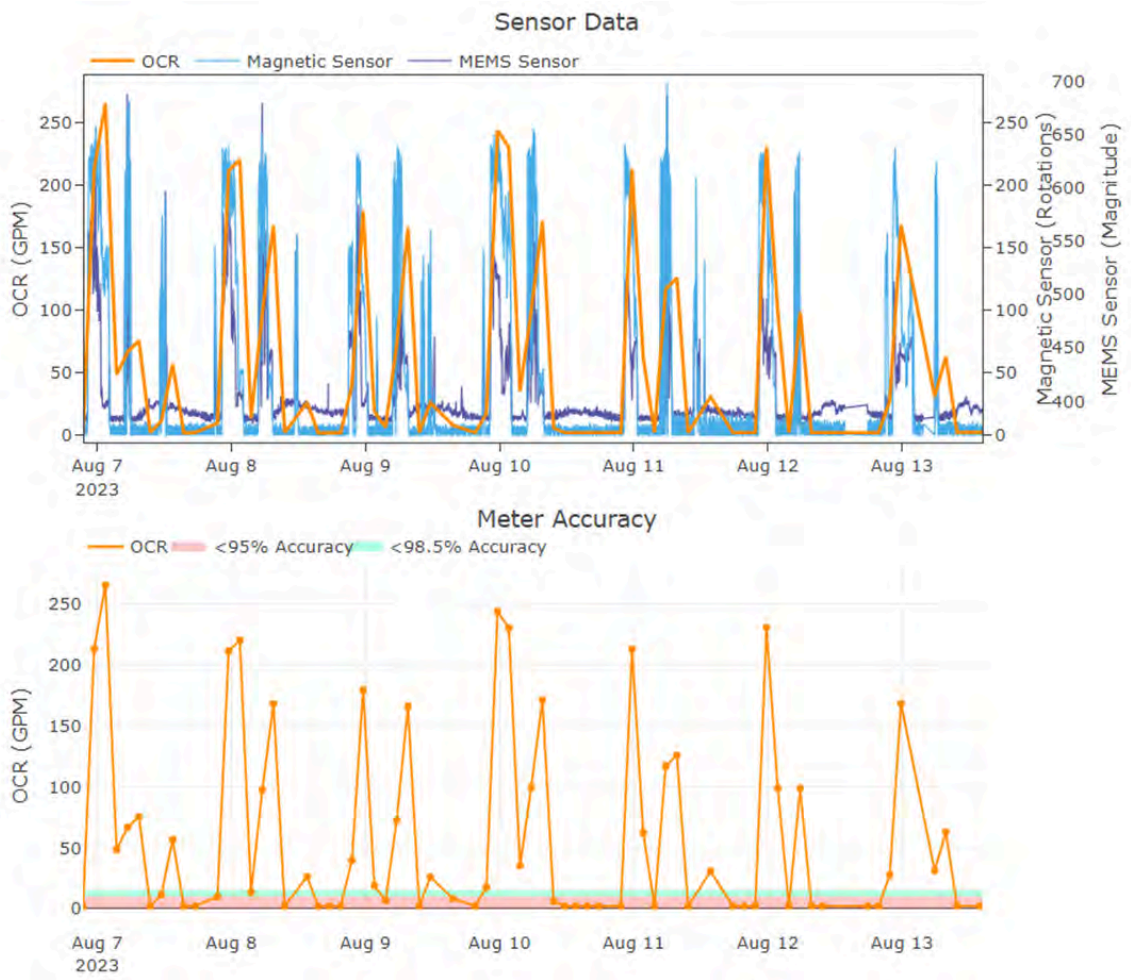

Figure 24 - Meter oversized and experiencing a potential customer side leak

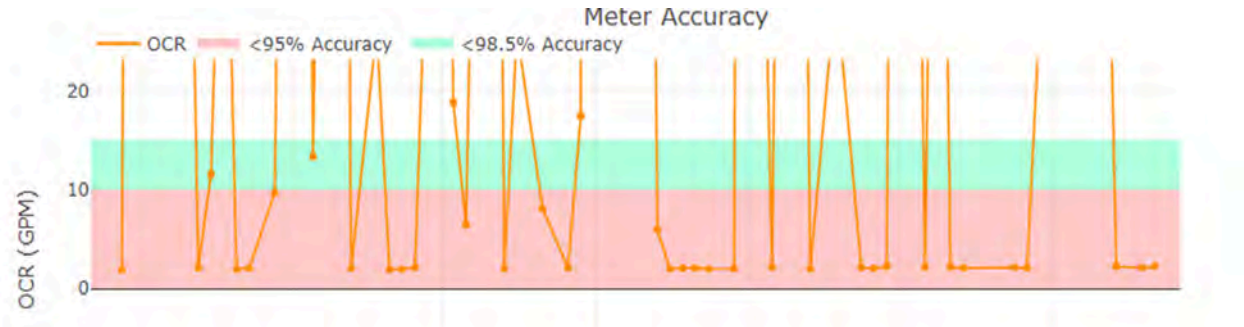

Figure 25 - Evidence of a Potential customer side leak, with low flow consistently at 2 GPM.

Meter and Pipe Size	Normal Operating Range GPM Minimum Maximum	
4" DN 100mm	15 3.4m³/h	1000① 225m³/h

Figure 26 - Meter specifications for a Sensus W Turbo DR 4"

- Analysis reveals that this meter is oversized, and that there is a potential customer side leak.
- Observation: Manufacturer suggested minimum flow is 15 GPM. During the analysis period, 50% of registered readings occur below AWWA standards of 95% accuracy and 53% under the normal operating range of 98.5% accuracy as cited by manufacturers specifications.
- This meter is intermittently operating between 2 and 265 GPM.
- Olea has reason to believe that there is a potential customer side leak at this location; the low flow never gets to 0 GPM, but consistently reaches 2 GPM.
- Mechanically there were no problems found with this meter.

Suggested corrective actions:

- It is recommended that Olea meter health analysis be continued for a few more months to see if water usage behavior changes.
- If intermittent low and high water usage continues, it may be worth considering exchanging this meter for one that can handle lower flows.
- It is recommended that the City communicate with this customer to determine whether they use water 24/7. If water is not being used 24/7 then it may be necessary to investigate a potential leak on their property.
- If the leak is identified and resolved, then this meter may not be oversized.

Ref ID: 1000.K011
Meter: Single, Sensus W Turbo DR 4"
Meter Health Status: Error, Oversized meter

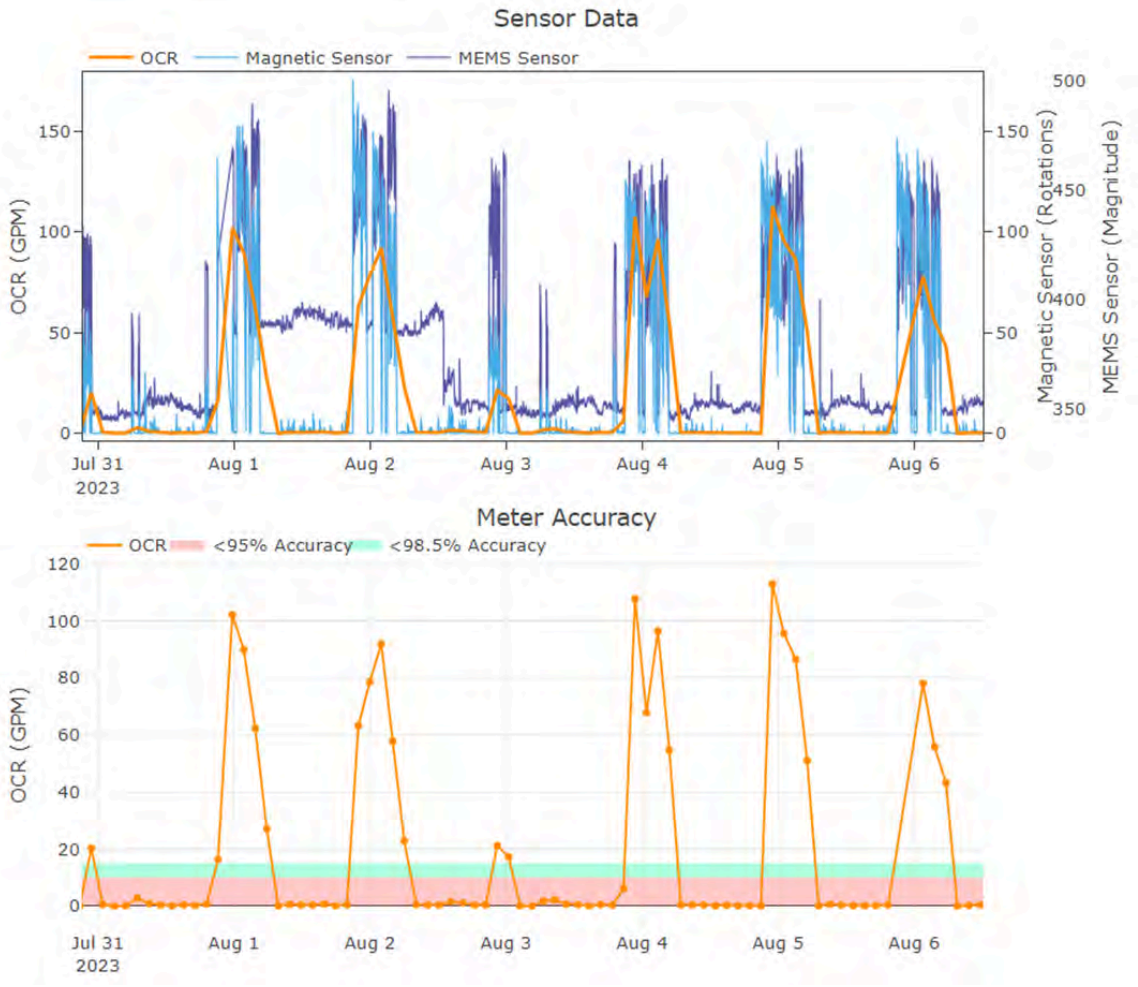

Figure 27 - Meter experiencing an oversized meter error condition

Figure 28 - Zoom showing flow outside of meter operating range

Meter and Pipe Size	Normal Operating Range GPM Minimum Maxi-mum	
4" DN 100mm	15 3.4m³/h	1000① 225m³/h

Figure 29 - Meter specifications for a Sensus W Turbo DR 4"

- Analysis reveals that this meter is oversized.
- Observation: Manufacturer suggested minimum flow is 15 GPM. During the analysis period, 64% of registered readings occur below AWWA standards of 95% accuracy and 64% under the normal operating range of 98.5% accuracy as cited by manufacturers specifications.
- This meter is intermittently operating between 0 and 112 GPM.
- Mechanically there were no problems found with this meter.

Suggested corrective actions:

- It is recommended that Olea meter health analysis be continued for a few more months to see if water usage behavior changes.
- If intermittent low and high water usage continues, it may be worth considering exchanging this meter for one that can handle lower flows.

Ref ID: 1000.B019
Meter: Single, Sensus W Turbo DRS 3"
Meter Health Status: Error, Oversized meter

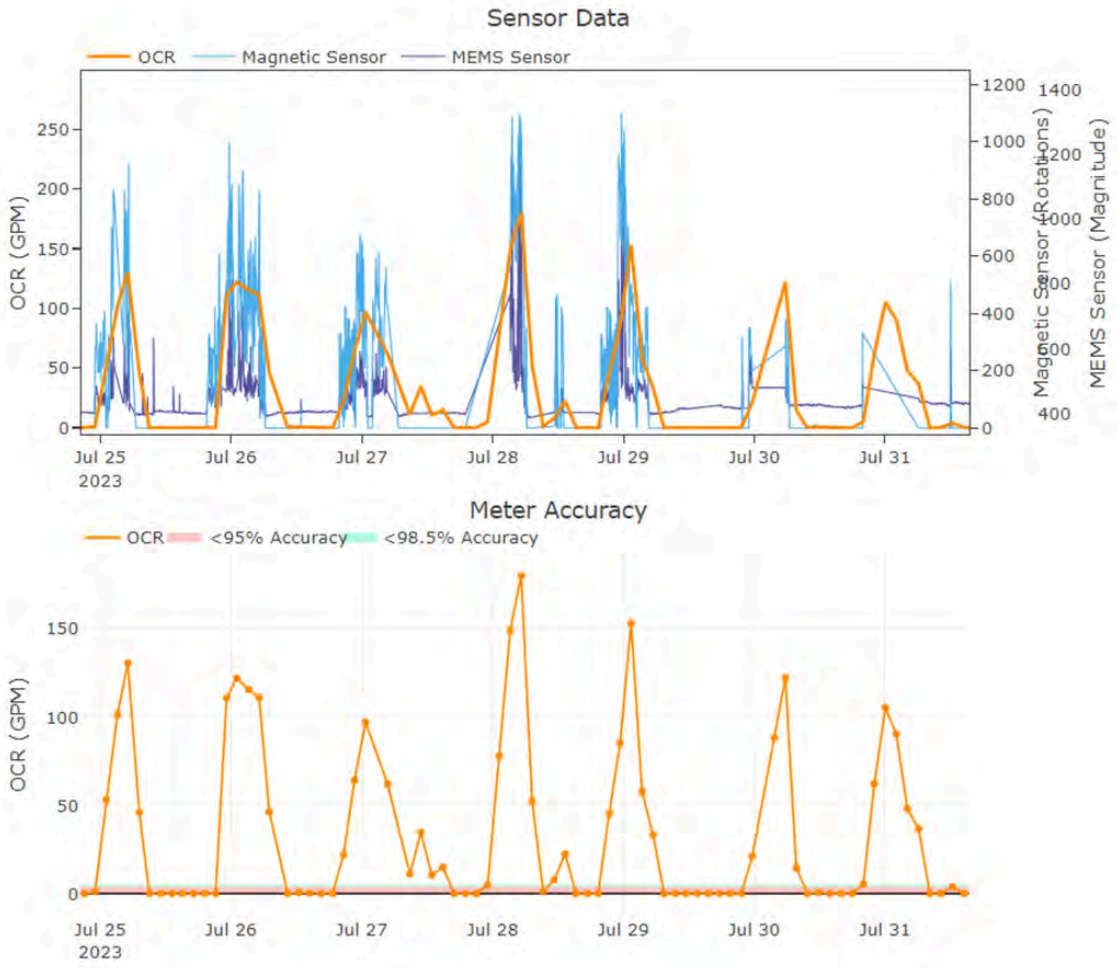

Figure 30 - Meter experiencing an oversized meter error condition

Meter and Pipe Size	Normal Operating Range GPM Minimum	Maximum
3" DN 80mm	5 1.1m³/h	350① 80m³/h

Figure 31 - Sensus W Turbo DRS 3"

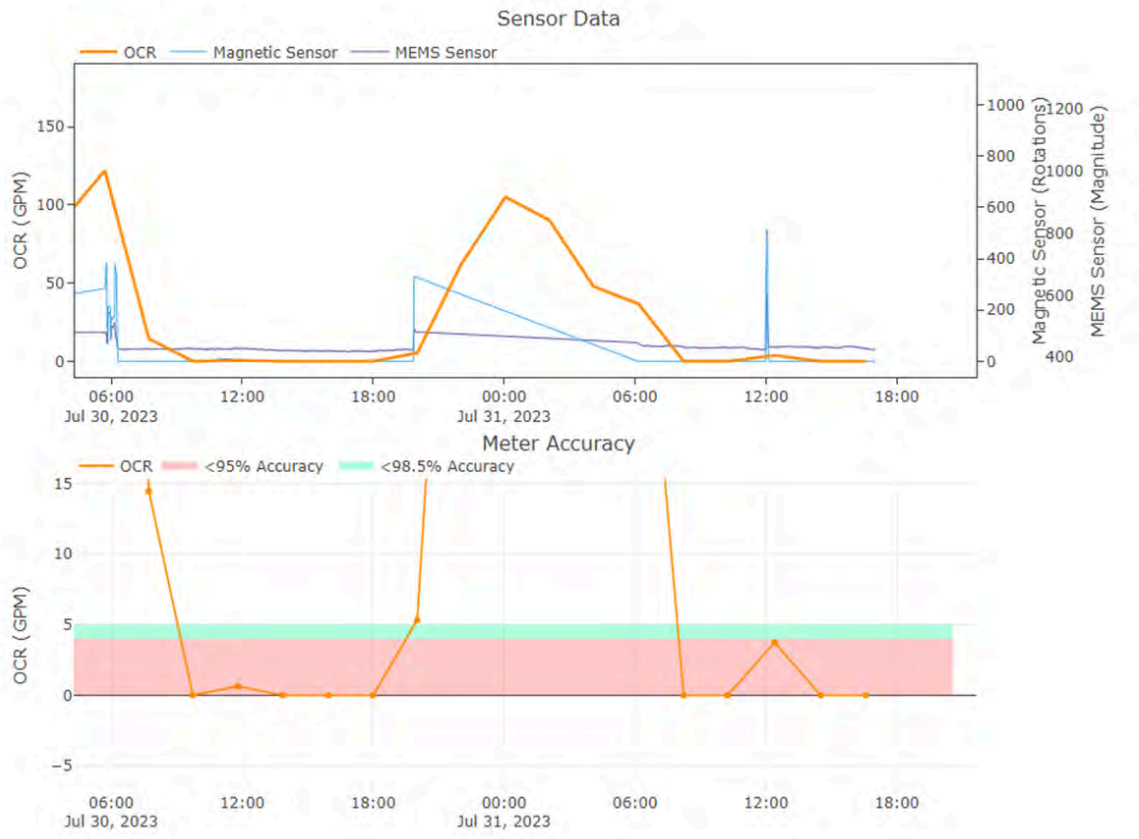

Figure 32 - Zoom showing flow outside of meter operating range

- Analysis reveals that this meter is oversized.
- Observation: Manufacturer suggested minimum flow is 5 GPM. During the analysis period, 20% of registered readings occur below AWWA standards of 95% accuracy and 22% under the normal operating range of 98.5% accuracy as cited by manufacturers specifications.
- This meter is intermittently operating between 0 and 180 GPM.
- Mechanically there were no problems found with this meter.

Suggested corrective actions:

- It is recommended that Olea meter health analysis be continued for a few more months to see if water usage behavior changes.
- If intermittent low and high water usage continues, it may be worth considering exchanging this meter for one that can handle lower flows.

Validation Phase:

The validation phase took place between March 1 and March 7, 2024. The purpose of the validation phase is to confirm that the repaired/replaced error meters are now without errors and are operating within the meter manufacturers specifications. The City of Fullerton was able to prioritize repairs/replacements on 10 out of the total 15 error meters. As seen in Table 2 below, all but one meter was replaced with a brand new meter.

Using Meter Health Analytics on the 10 repaired/replaced meters Olea was able to validate the following results:

- 7 meters were identified as 'No Problem Found'.
- 3 meters still have 'Low Priority' errors present.

Table 2 below shows a truncated version of the validated meter error report (customer information removed). Of the 10 meters, 7 have no problem found and 3 have 'low priority' errors.

ref_id	Initial Report Type	Initial Error Condition	Initial Priority	Action	Validation Report Type	Validation Error Condition	Validation Priority
1000.F103	ERROR	HF ME, INLET VALVE, OUTLET VALVE	High	**Valves Opened**	NPF	NPF	
1000.SR03	ERROR	HF REG FLOW, LF REG FLOW	High	**Replaced**	NPF	NPF	
1000.0414	ERROR	LF REG FLOW	High	**Replaced**	NPF	NPF	
1000.904R	ERROR	EARLY CROSSOVER	Medium	**Replaced**	NPF	NPF	
1000.03R3	ERROR	EARLY CROSSOVER	Medium	**Replaced**	NPF	NPF	
1000.0712	ERROR	LF REG DAMAGED	Medium	**Replaced**	NPF	NPF	
1000.K011	ERROR	OVERSIZED	Low	**Replaced**	NPF	NPF	
1000.B019	ERROR	OVERSIZED	Low	**Replaced**	NPF	NPF, NO FLOW	LOW
1000.0K11	ERROR	OVERSIZED	Low	**Replaced**	ERROR	OVERSIZED	LOW
1000.8039	ERROR	OVERSIZED, CUSTOMER LEAK	Low	**Replaced**	ERROR	CUSTOMER LEAK	LOW

Table 2 - Validation phase meter results

Validation meter results:

Ref ID: 1000.F103
Meter: Sensus W Compact FireLine 2" x 8"
Previous Meter Health Status: Error, High flow measuring element malfunction, partially closed inlet and outlet valves.
Current Meter Health Status: No Problem Found

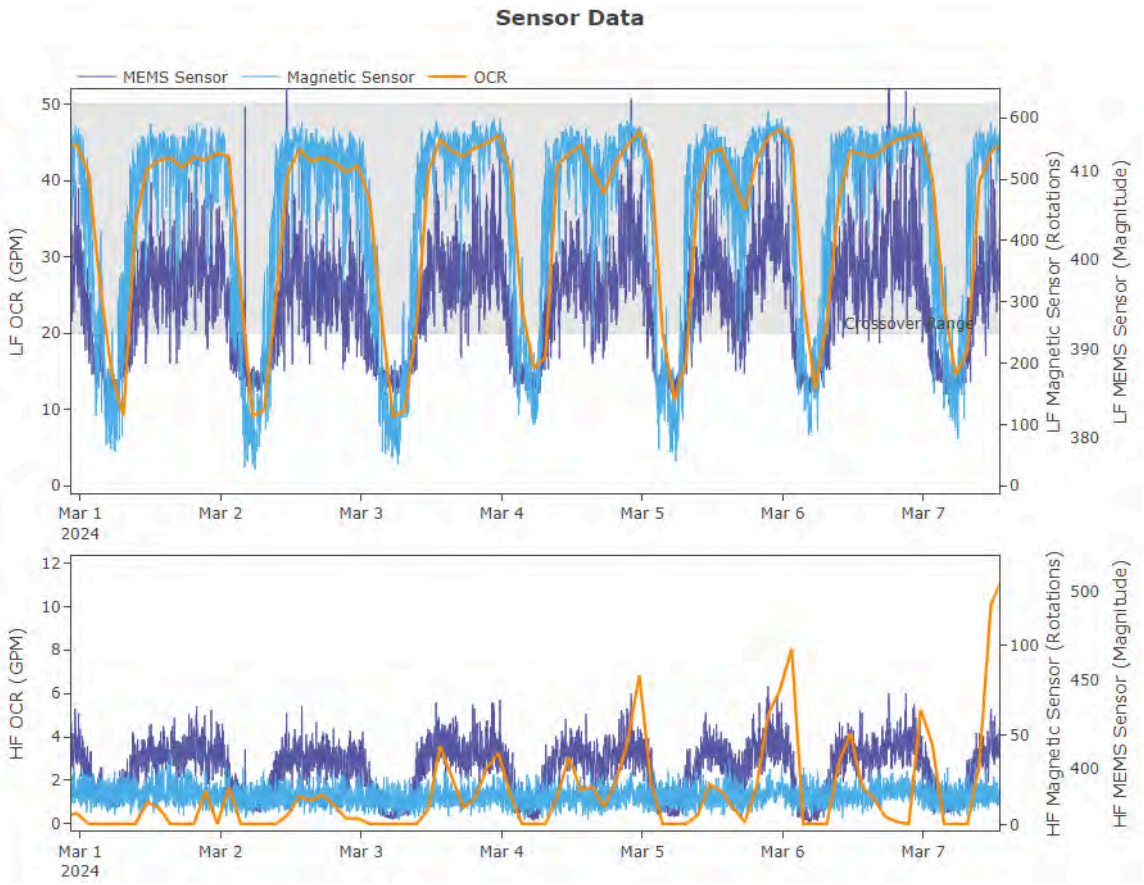

Figure 33 - No Problem Found meter

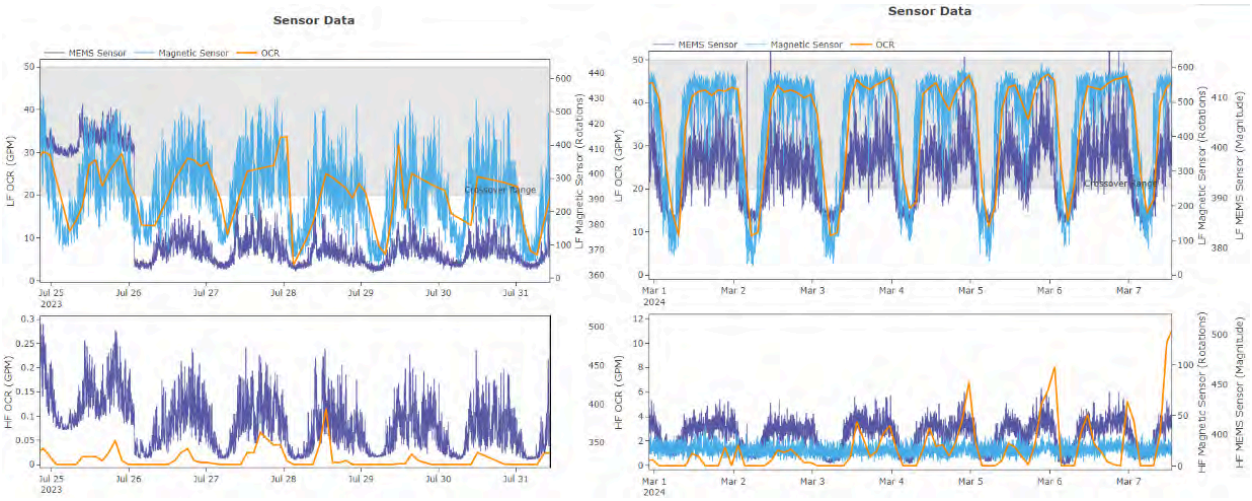

Figure 34 - Pre and post meter repair comparison

- This Sensus compound meter (Figure 33), previously had partially closed city and customer side valves. Now that Fullerton staff have completely opened both valves, the low flow and high flow side meters are operating within meter manufacturers specifications, and this meter is now identified as ‘No Problem Found’.
- The high flow side meters flow is now reaching 8 GPM, compared to its previous maximum level of 0.1 GPM (Figure 34).

Post repair takeaway:

- The main culprit for this previously underperforming water meter was partially closed upstream and downstream valves, which Olea had identified. The partially closed valves were likely creating turbulent flows in and around the meter, which degraded the meter operation.
- Olea had also suspected that the low flow side meter was experiencing a measuring element malfunction, but this can be disregarded.

Ref ID: 1000.SR03
Meter: Badger Recordall Compound Series 0.625" x 3"
Previous Meter Health Status: Error, High flow register failure, Low flow register failure
Current Meter Health Status: No Problem Found

Figure 35 - Post repair No Problem Found meter

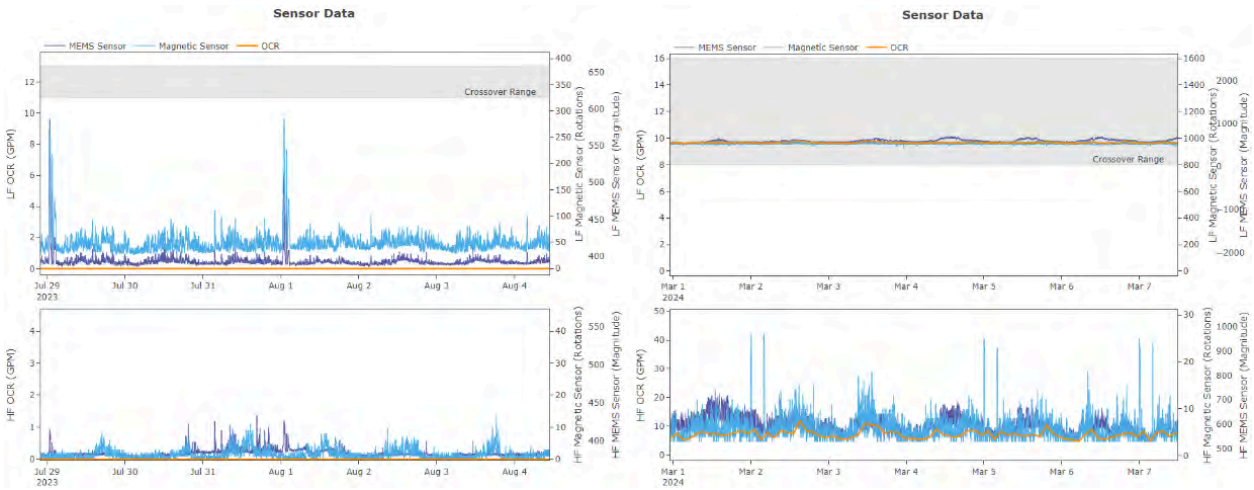

Figure 36 - Pre and post meter repair comparison

- This Badger compound meter (Figure 35), previously had failed low flow and high flow registers. Fullerton City staff have completely replaced the Hershey meter with a Badger meter, and Olea's MHA technology has identified this meter as 'No Problem Found'.
- The low flow side meter is now recording approximately 10 GPM of continuous flow, and the high flow side meter is recording approximately 10 GPM of continuous flow. Previous to the meter replacement, both low and high flow side meters were recording 0 GPM of flow (Figure 36).

Post repair takeaway:

- Both registers on this meter had completely failed. A complete meter replacement by Fullerton staff solved this problem.
- Significant non revenue water has been reduced at this meter location.

Ref ID: 1000.0414
Meter: Sensus OMNI Compound C2 3.0"
Previous Meter Health Status: Error, Low flow register failure
Current Meter Health Status: No Problem Found

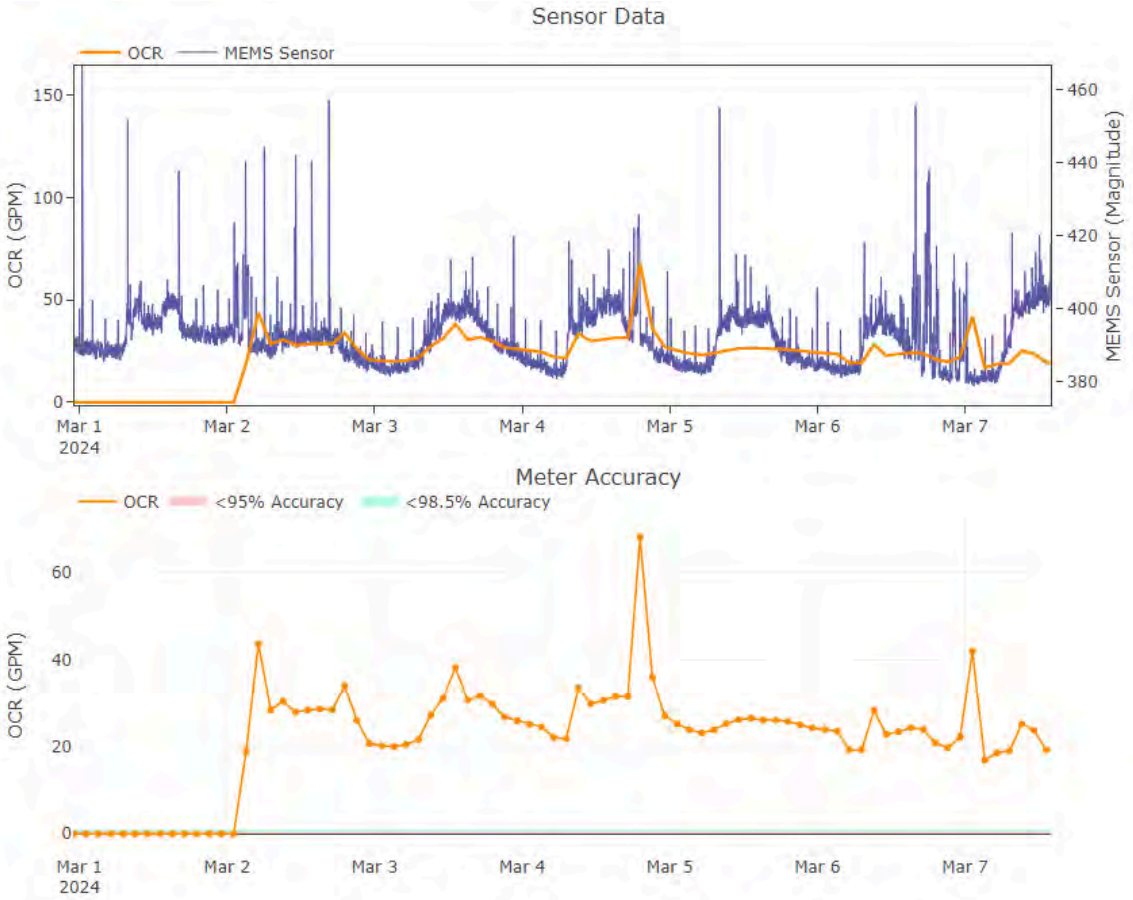

Figure 37 - Post repair ‘No Problem Found’ meter

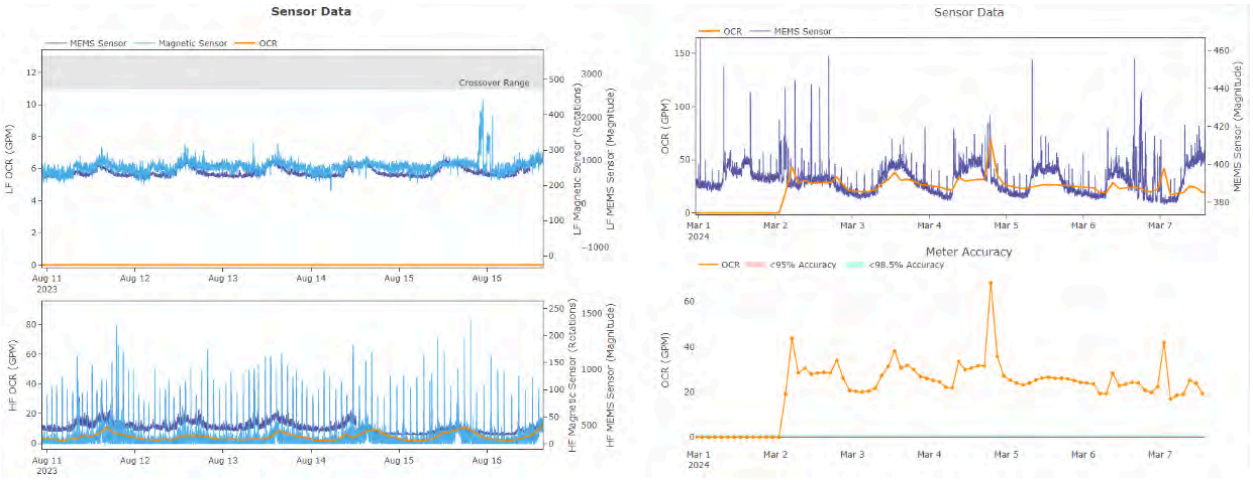

Figure 38 - Pre and post meter repair comparison

- This Sensus compound meter (Figure 37), previously had a failed low flow register. Fullerton staff have completely replaced the Hershey meter with a Sensus meter, and Olea's MHA technology has identified this meter as 'No Problem Found'.
- This new meter register is now recording up to 75 GPM of flow, compared to the previously recorded combined flow of 15 GPM (Figure 38).

Post repair takeaway:

- The low flow side register on this meter had completely failed. A complete meter replacement by Fullerton staff solved this problem.
- Significant non revenue water has been reduced at this meter location.

Ref ID: 1000.904R
Meter: Sensus OMNI Compound C2 3.0"
Previous Meter Health Status: Error, Early crossover valve malfunction
Meter Health Status: No Problem Found

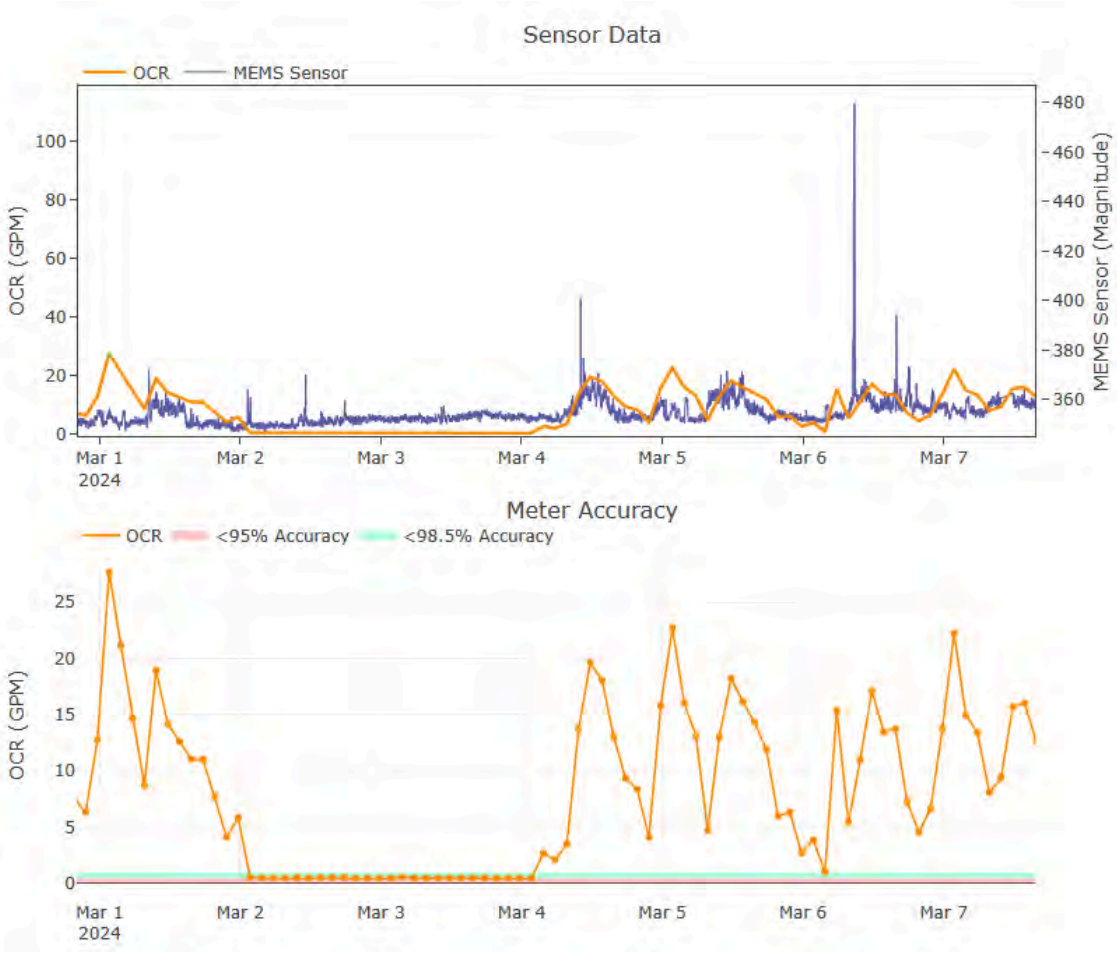

Figure 39 - Post repair 'No Problem Found' meter

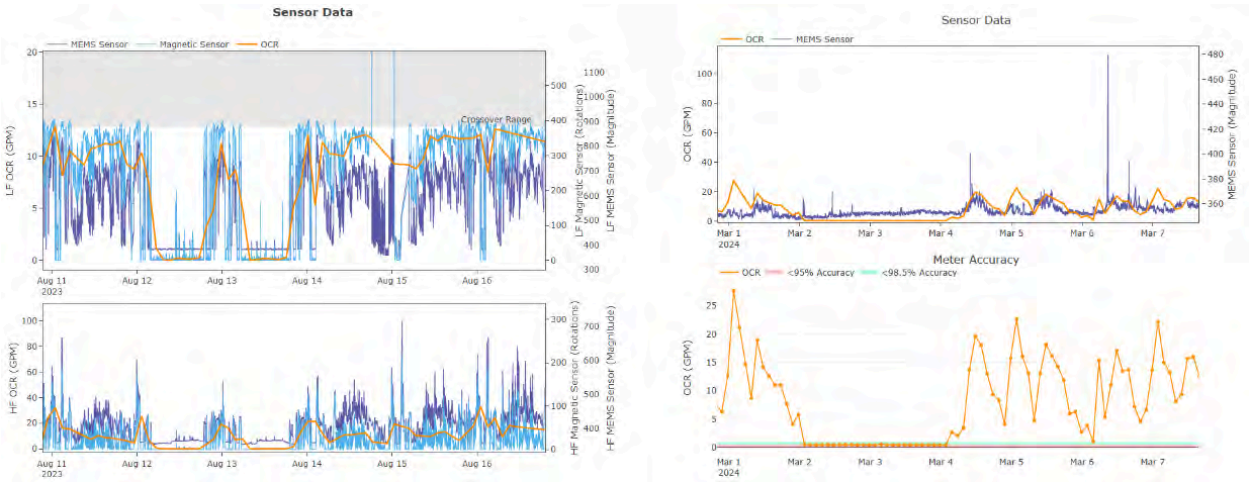

Figure 40 - Pre and post meter repair comparison

- This compound meter (Figure 39), previously had an early crossover valve malfunction error. Fullerton staff have completely replaced the Hershey meter with a Sensus meter, and Olea's MHA technology has identified this meter as 'No Problem Found'.
- This new meter is correctly sized for the flow received during the validation phase. The new meter is now recording up to 30 GPM of flow, compared to the previously recorded combined flow of 40 GPM (Figure 40).

Post repair takeaway:

- The old meter had an early crossover valve malfunction, which is a common error found in old compound meters. This is an early sign of meter failure, replacing this meter is a good strategy for preventative maintenance.
- The new meter is seeing less flow than the old meter, this may be due to the seasonal differences or changes in water use within the business.

Ref ID: 1000.03R3
Meter: Sensus OMNI Compound C2 4.0"
Previous Meter Health Status: Error, Early crossover valve malfunction
Current Meter Health Status: No Problem Found

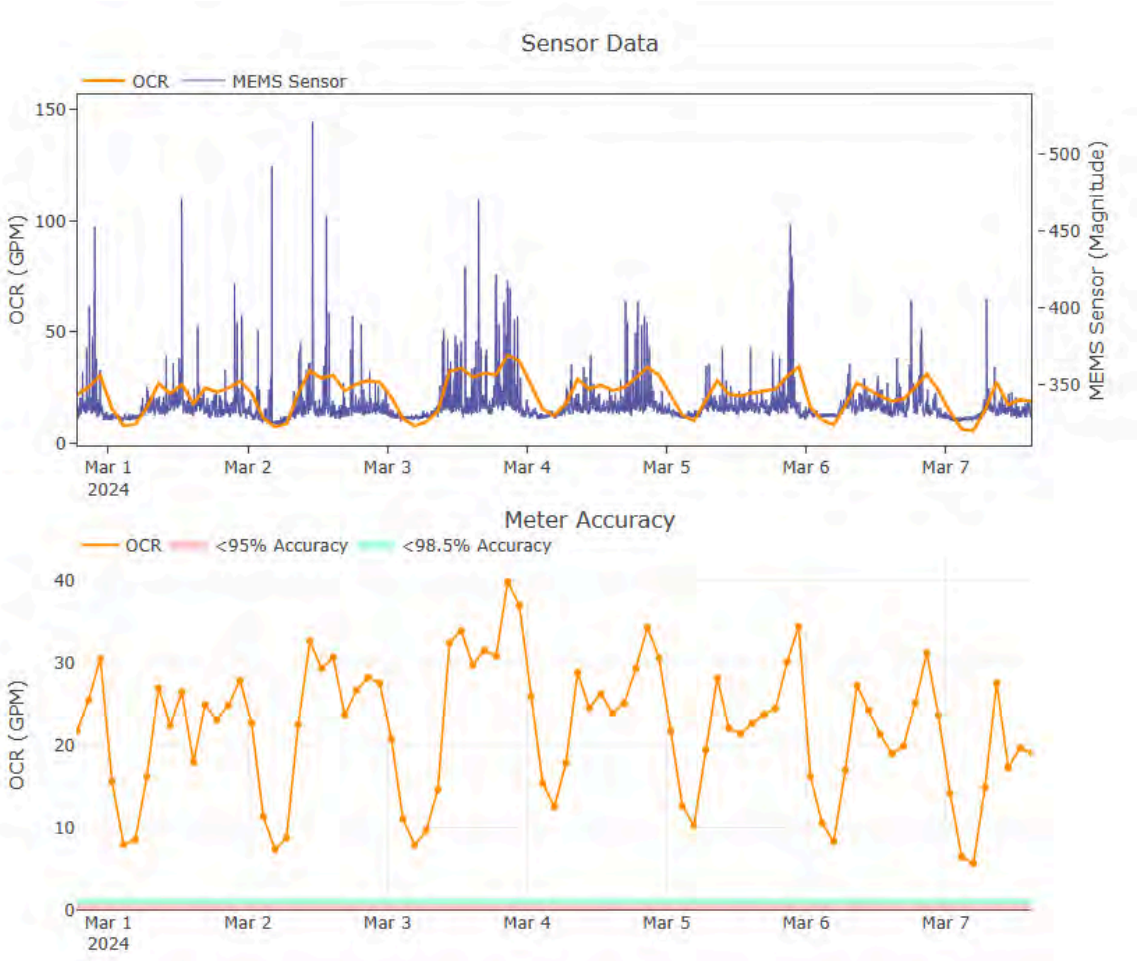

Figure 41 - Post repair 'No Problem Found' meter

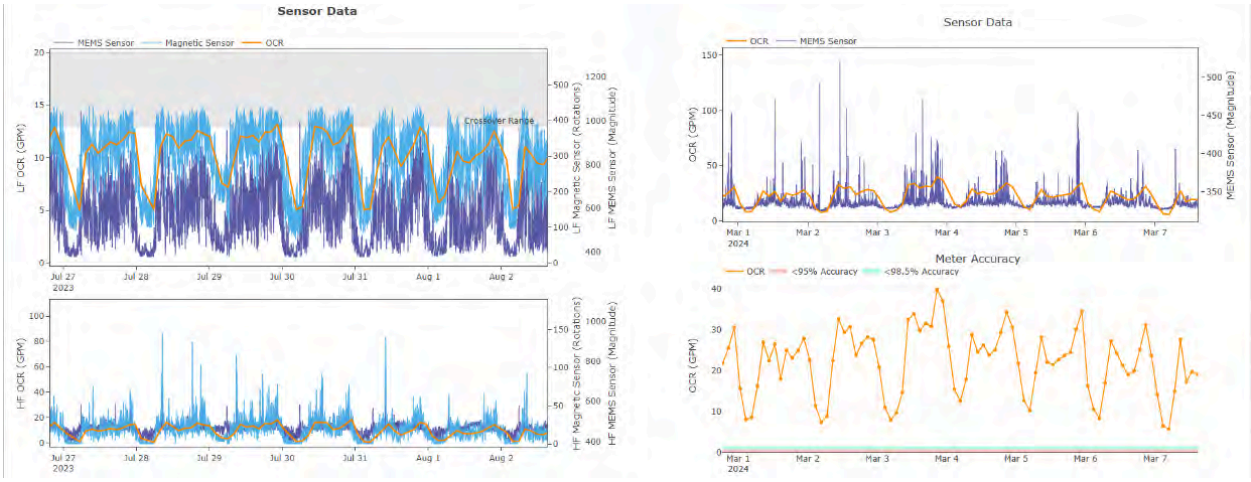

Figure 42 - Pre and post meter repair comparison

- This compound meter (Figure 41), previously had an early crossover valve malfunction error. Fullerton staff have completely replaced the Hershey meter with a Sensus meter, and Olea's MHA technology has identified this meter as 'No Problem Found'.
- This new meter is correctly sized for the flow received during the validation phase. The new meter is now recording up to 40 GPM of flow, compared to the previously recorded combined flow of 35 GPM (Figure 42).

Post repair takeaway:

- The old meter had an early crossover valve malfunction, which is a common error found in old compound meters. This is an early sign of meter failure, replacing this meter is a good strategy for preventative maintenance.

Ref ID: 1000.0712
Meter: Sensus OMNI Compound C2 4.0"
Previous Meter Health Status: Error, Damaged low flow register
Meter Health Status: No Problem Found

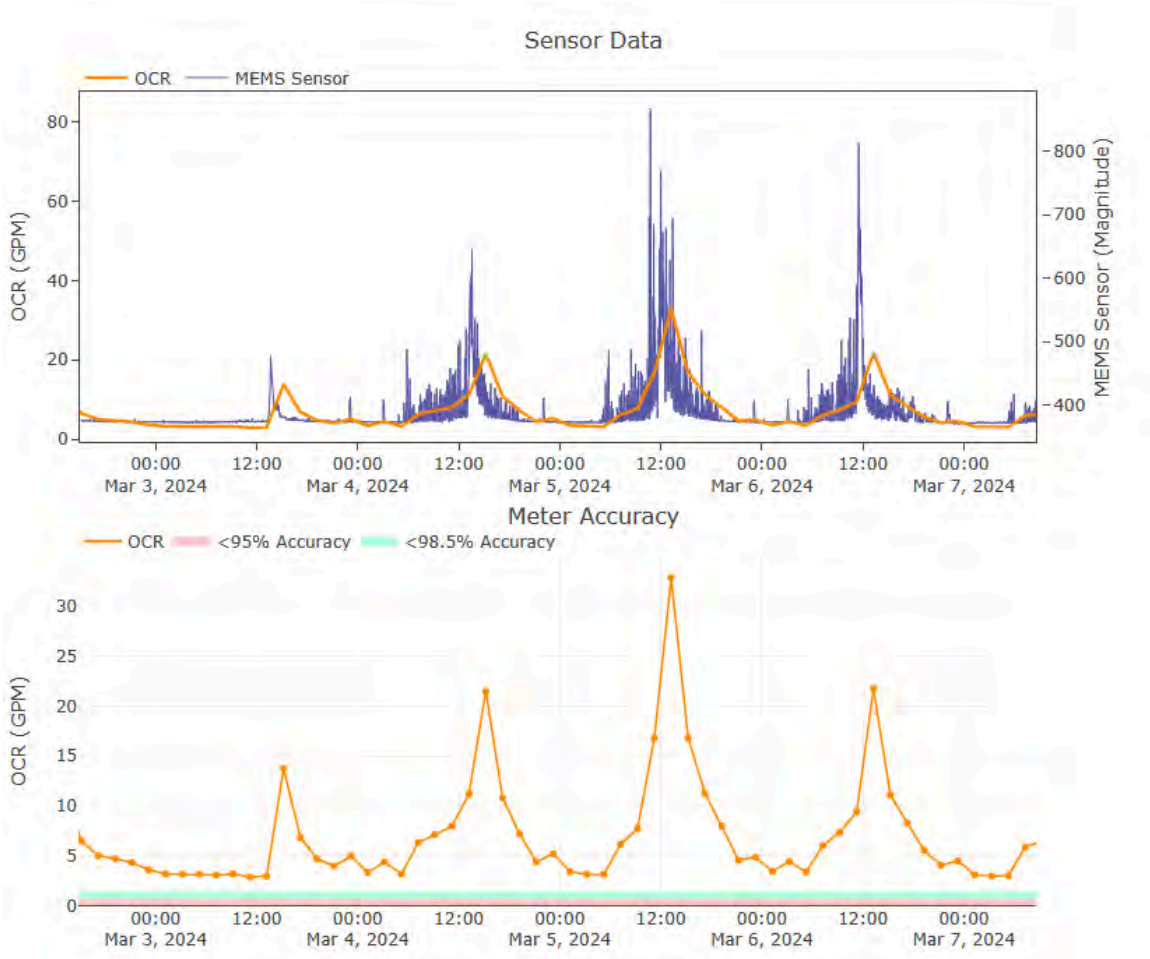

Figure 42 - Post repair ‘No Problem Found’ meter

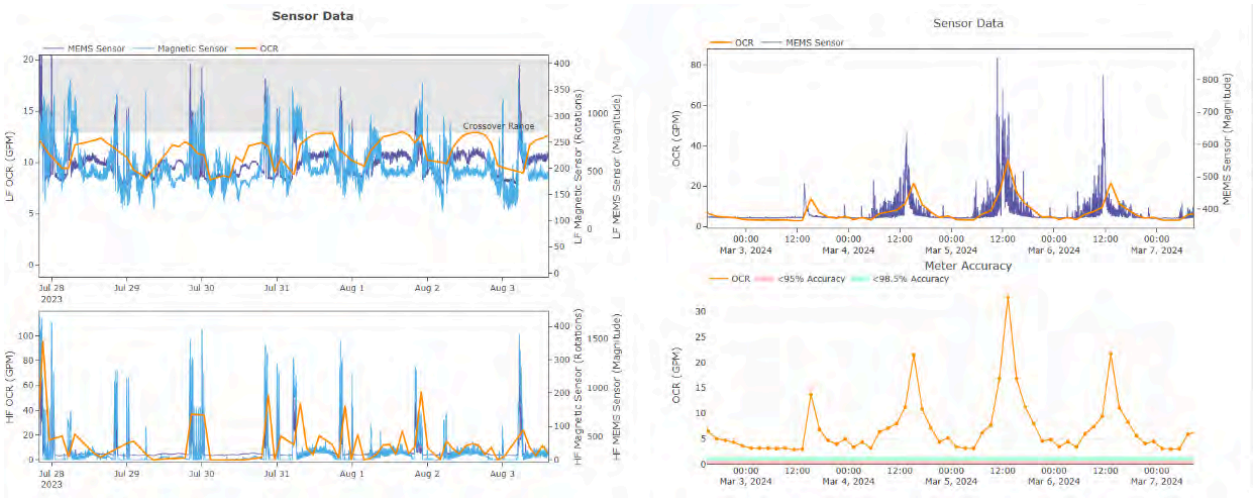

Figure 43 - Pre and post meter repair comparison

- This compound meter (Figure 42), previously had a damaged low flow register error. Fullerton staff have completely replaced the Hershey meter with a Sensus meter, and Olea's MHA technology has identified this meter as 'No Problem Found'.
- This new meter is correctly sized for the flow received during the validation phase. The new meter is now recording up to 35 GPM of flow, compared to the previously recorded combined flow of 70 GPM (Figure 42).

Post repair takeaway:

- The old meter had a damaged low flow register, which is a common error found in old meters. This is an early sign of meter failure, replacing this meter is a good strategy for preventative maintenance.
- The new meter is seeing less flow than the old meter, this may be due to the seasonal differences or changes in water use within the business.

Ref ID: 1000.K011
Meter: Sensus OMNI Compound C2 4.0"
Previous Meter Health Status: Error, Oversized meter
Current Meter Health Status: No Problem Found

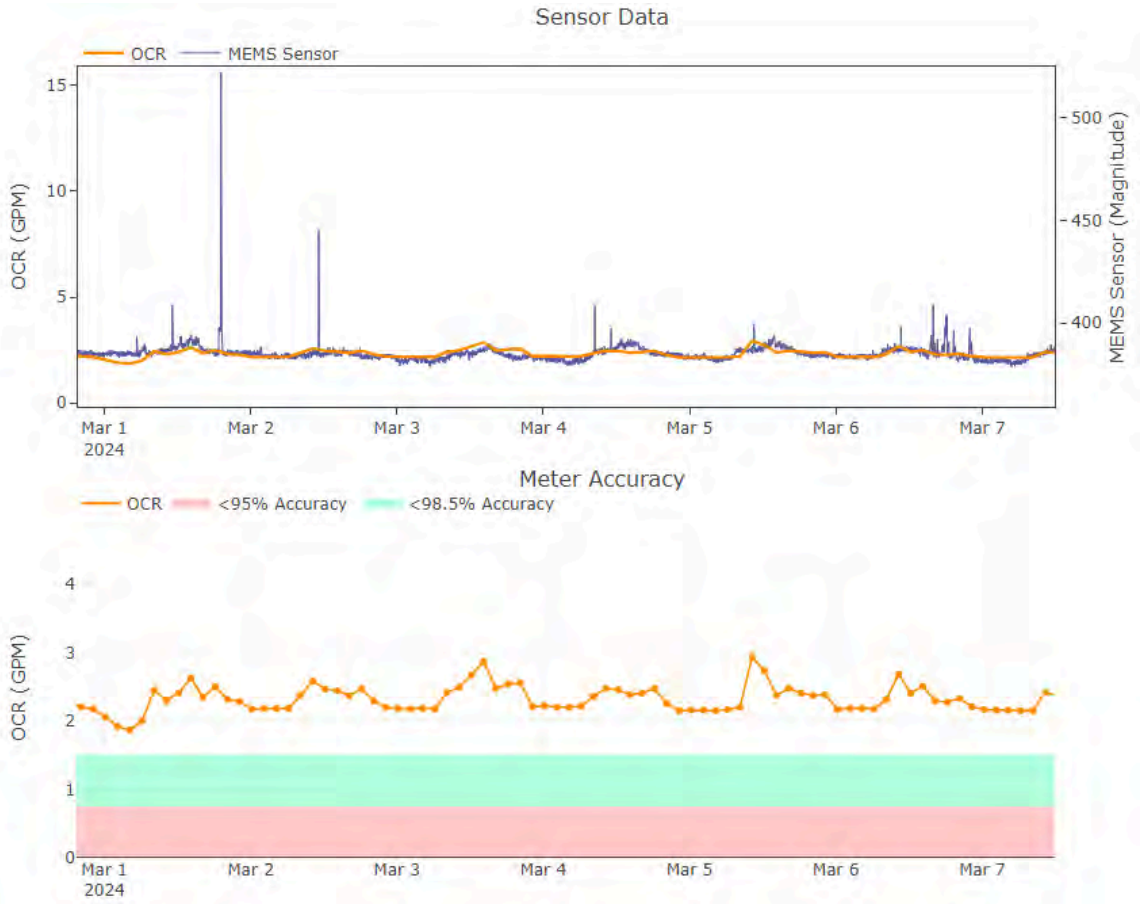

Figure 44 - Post repair ‘No Problem Found’ meter

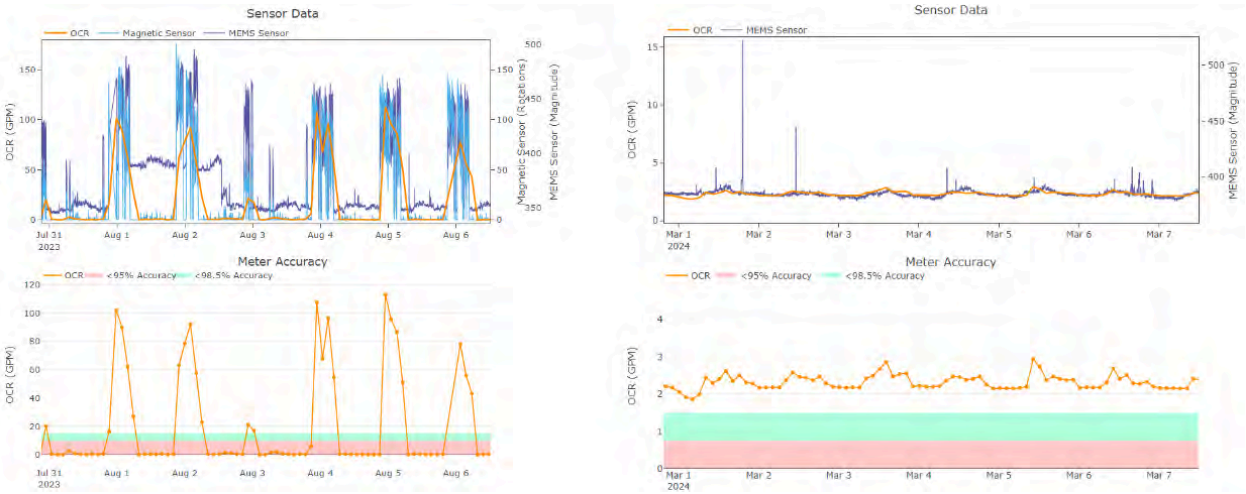

Figure - 45 - Pre and post meter repair comparison

- This compound meter (Figure 44), was previously identified as having an oversized meter error. Fullerton staff have completely replaced the Sensus meter with a new Sensus meter, and Olea's MHA technology has identified this meter as 'No Problem Found'.
- This new meter is correctly sized for the flow received during the validation phase. The new meter is now recording up to 3 GPM of flow, compared to the previously recorded combined flow of 100 GPM (Figure 45).

Post repair takeaway:

- The old meter was oversized, meaning that the low flows were under the meter manufacturers flow specifications, which is a fairly common error that occurs when business ownership changes. Oversized meters inaccurately report low flow and over time this can add up to considerable non revenue water.
- The new meter is seeing less flow than the old meter, this may be due to the seasonal differences or changes in water use within the business.

Ref ID: 1000.B019
Meter: Sensus OMNI Compound C2 3.0"
Previous Meter Health Status: Error, Oversized meter
Current Meter Health Status: No Flow - No Problem Found

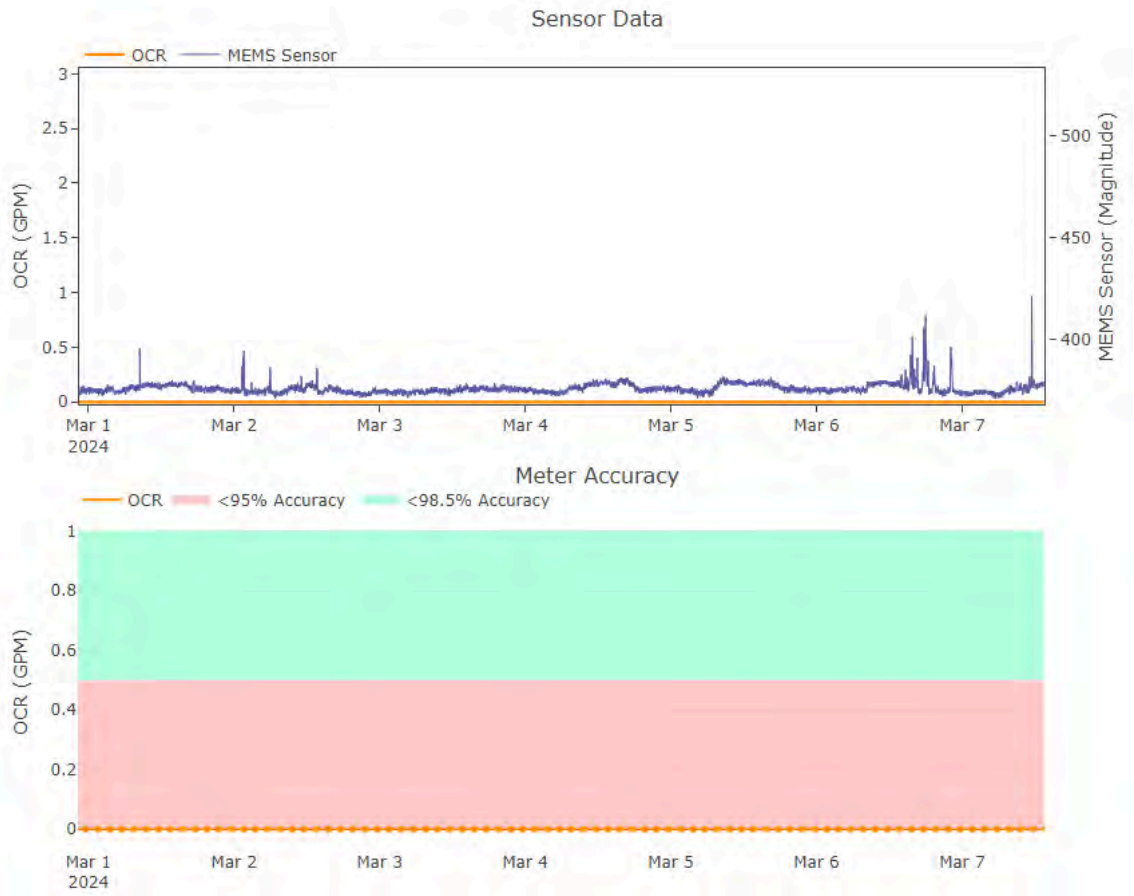

Figure 46 - Post repair ‘No Flow - No Problem Found’ meter

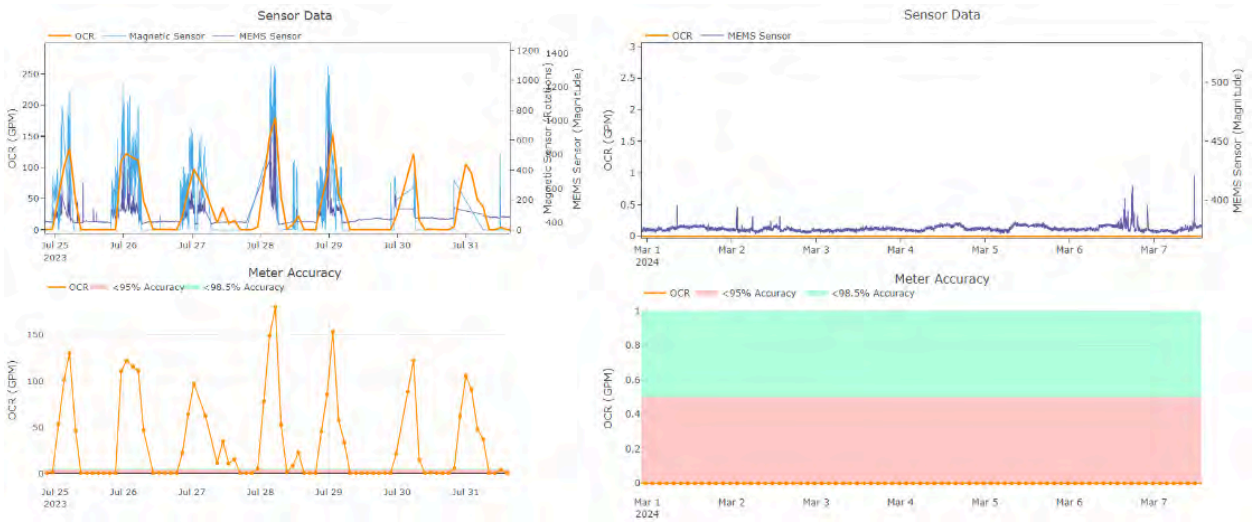

Figure - 47 - Pre and post meter repair comparison

- This compound meter (Figure 46), was previously identified as having an oversized meter error. Fullerton staff have completely replaced the Sensus meter with a new Sensus meter, and Olea's MHA technology has identified this meter as 'No Problem Found due to No Flow'.
- This new meter did not see any consumption during the March 1 to 7 Validation period. Olea captured another week of sensor data from April 2 to 8 and again no flow was recorded during this period.

Post repair takeaway:

- The old meter was oversized, meaning that the low flows were under the meter manufacturers flow specifications, which is a fairly common error that occurs when business change ownership. Oversized meters inaccurately report low flow and over time this can add up to considerable non revenue water.
- During March and April 2024 Olea's MHA did not record any consumption/flow at this meter location.

Ref ID: 1000.0K11
Meter: Sensus OMNI Compound C2 4.0"
Previous Meter Health Status: Error, Oversized meter.
Meter Health Status: Error, Oversized meter.

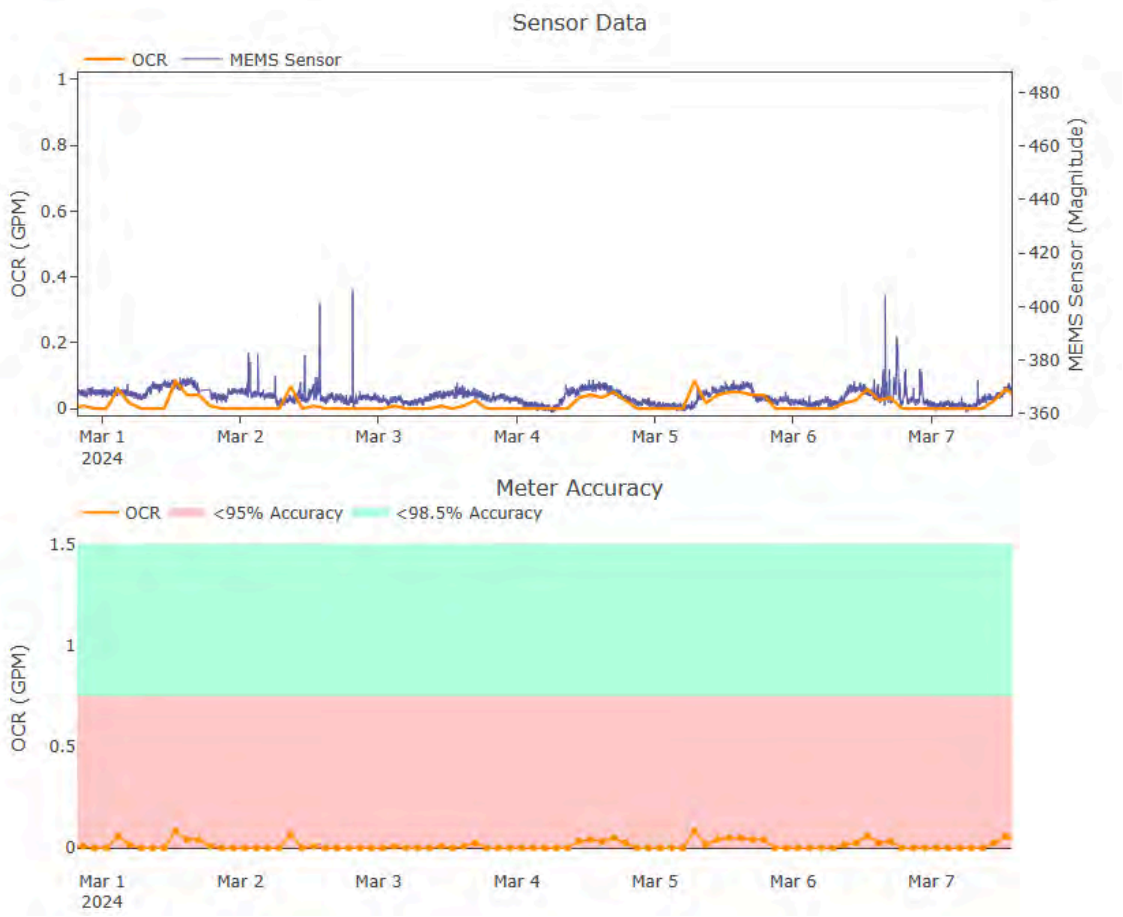

Figure 48 - Post repair ‘Oversized meter’ error

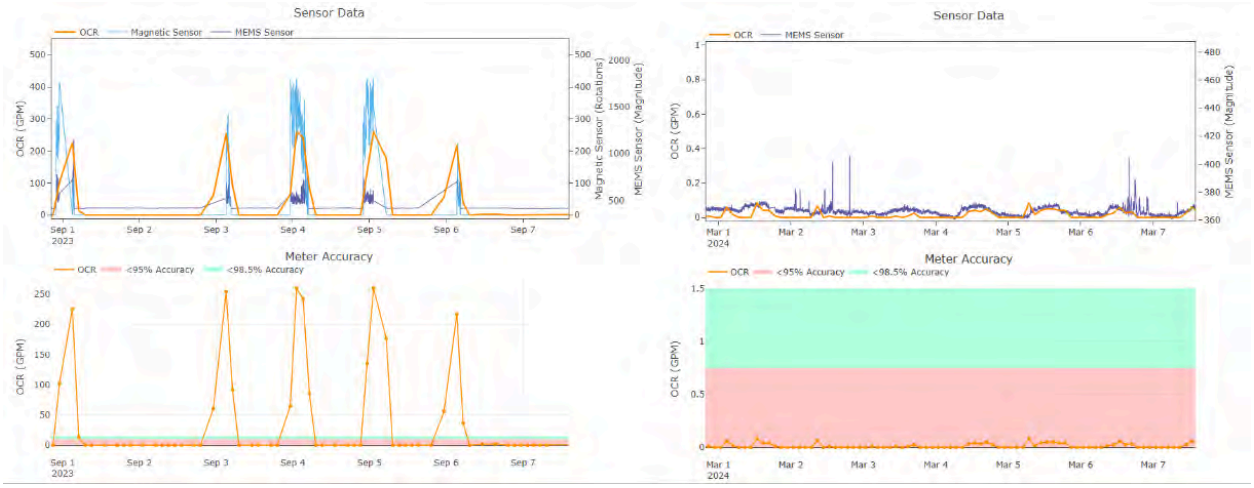

Figure - 49 - Pre and post meter repair comparison

- This compound meter (Figure 48), was previously identified as having an oversized meter error. Fullerton staff have completely replaced the Sensus W Turbo 4” meter with a new Sensus Omni C2 4” meter, and Olea’s MHA technology has identified this new meter is still identified as an ‘Oversized’ error condition.
- This new meter was analyzed in March of 2024, and the largest flow recorded was 0.1 GPM, compared with the Initial Phase which saw over 250 GPM of flow (Figure 49).

Post repair takeaway:

- The old meter was oversized, meaning that the low flows were under the meter manufacturers flow specifications, which is a fairly common error that occurs when businesses change ownership. Oversized meters inaccurately report low flow and over time this can add up to considerable non revenue water.
- The new meter is one that can handle much lower flows than the old meter. With that being said there was almost no flow during the Validation phase, so this meter is still identified as ‘Oversized’.
- Olea recommends that this meters consumption be monitored for continued very low flow.

Ref ID: 1000.8039
Meter: Sensus OMNI Compound C2 4.0"
Previous Meter Health Status: Error, Oversized meter & potential customer side leak
Meter Health Status: Error, Potential Customer Side Leak

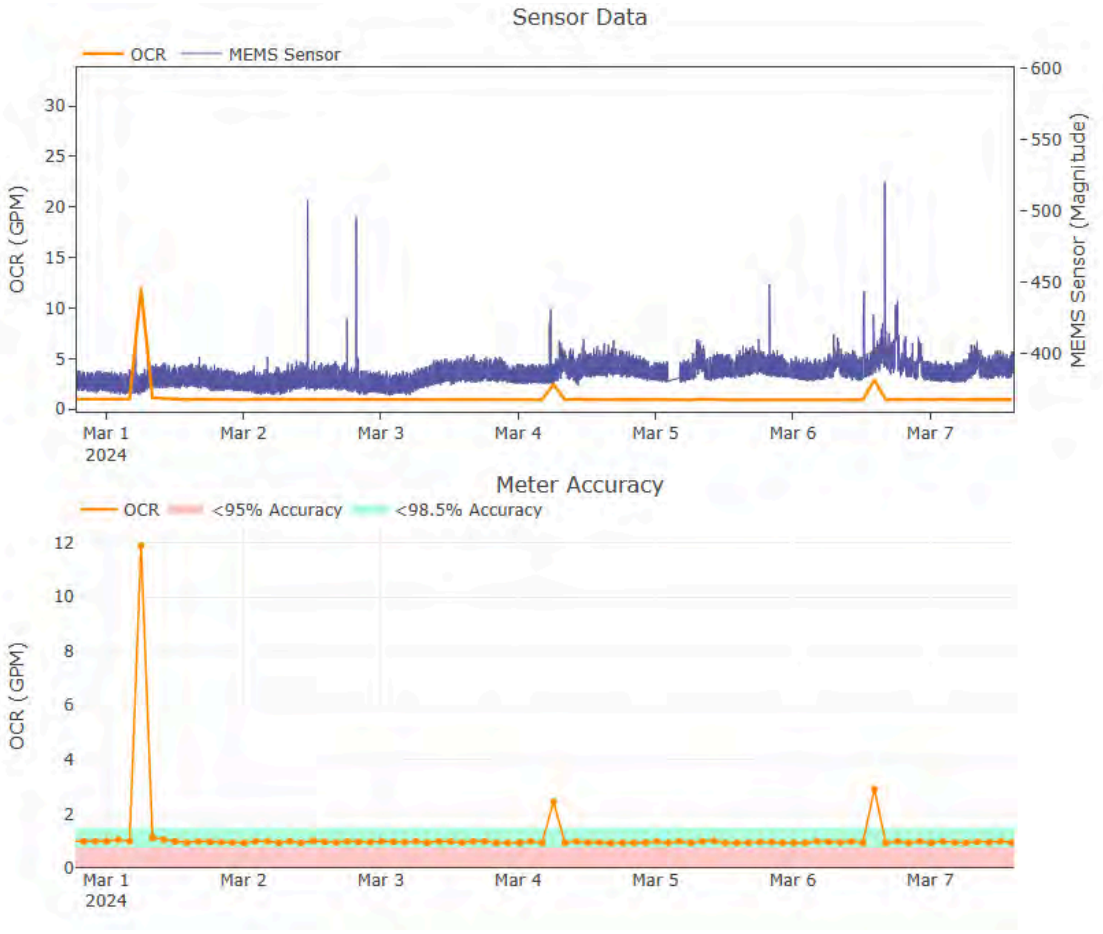

Figure 50 - Post repair ‘Potential customer side leak’ error condition

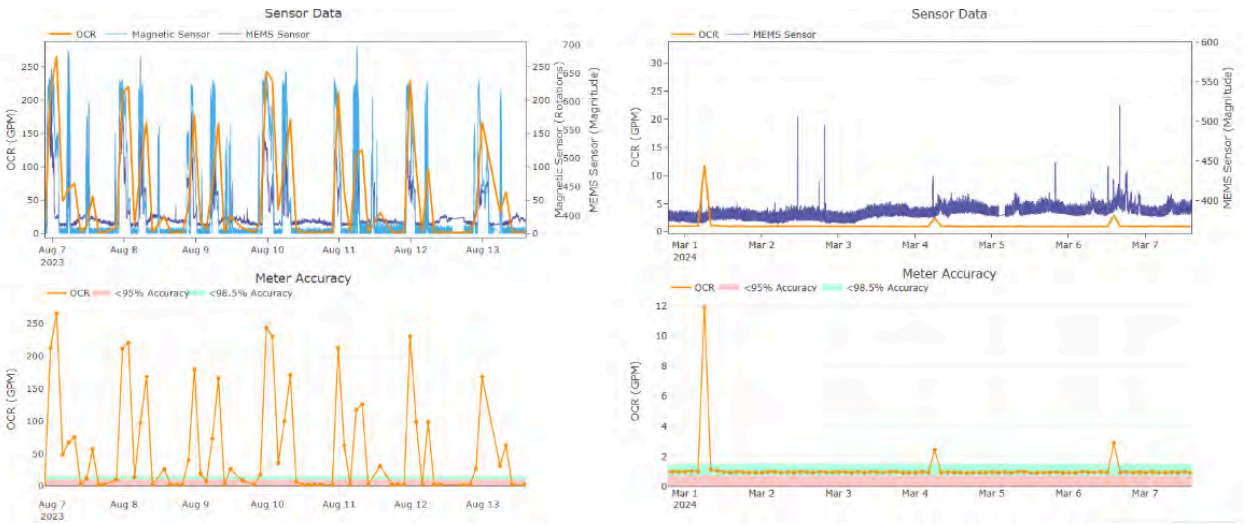

Figure - 51 - Pre and post meter repair comparison

- This compound meter (Figure 50), was previously identified as having an ‘oversized’ meter error as well as a ‘potential customer side leak’. Fullerton staff have completely replaced the Sensus W Turbo 4” meter with a new Sensus Omni C2 4” meter, and Olea’s MHA technology has identified this new meter is no longer oversized, but the potential customer side leak remains (Figure 51).

Post repair takeaway:

- The old meter was oversized, meaning that the low flows were under the meter manufacturers flow specifications, which is a fairly common error that occurs when businesses change ownership. Oversized meters inaccurately report low flow and over time this can add up to considerable non revenue water. The new meter is one that can handle much lower flows than the old meter. This low flow is now within the acceptable manufacturers flow range, and this meter is no longer oversized.
- The old meter was also identified as having a ‘potential customer side leak’. This is where the flow never reaches 0 GPM, but consistently reaches a small <2 GPM flow. The new meter still shows signs of having a potential customer side leak, where the low flow is consistently stopping at 1 GPM.
- Olea recommends that the City of Fullerton reach out to this customer to find out if they are consuming water 24/7, if they are not then they should investigate a potential leak.

Conclusion:

The pilot project with the City of Fullerton successfully demonstrated the effectiveness of Olea's Meter Health Analytics (MHA) solution in improving water meter asset management. The project's two-phase approach provided quantifiable results that highlighted significant improvements in identifying and addressing water meter inaccuracies, leading to better revenue assurance and reduced non-revenue water losses.

Quantifiable Outcomes:

1) Initial Meter Health Check Phase:
    - Total Meters Analyzed: 50
    - Meters with Error Conditions: 15 (30%)
    - Meters without Issues: 35 (70%)
    - High Priority Errors: 3 meters
    - Medium Priority Errors: 6 meters
    - Low Priority Errors: 6 meters
2) Validation Phase:
    - Total Repaired/Replaced Meters: 10
    - Meters without Errors Post-Repair: 7 (70%)
    - Meters with Low Priority Errors Post-Repair: 3 (30%)

The initial phase identified that 15 out of 50 meters (30%) were contributing to non-revenue water losses. By targeting these error-prone meters for repair or replacement, the City of Fullerton can significantly reduce apparent losses.

Post-repair, 70% of the initially faulty meters were validated as healthy and accurate, ensuring accurate billing and reducing the potential for future revenue loss. This highlights the efficiency of the MHA solution in rapidly identifying and rectifying meter issues, thus enhancing overall revenue assurance.

Operational Efficiency:

The MHA solution's automated and continuous monitoring capabilities provide several operational benefits:

- **Reduction in Manual Labor**: Traditional meter testing requires substantial manual labor, which is resource-intensive. The MHA solution automates data collection and analysis, significantly reducing the need for manual intervention.
- **Timely Identification and Repair**: The ability to continuously monitor meter performance and receive real-time alerts allows for quicker identification and rectification of issues, minimizing the duration of inaccuracies and the associated revenue losses.

- **Enhanced Resource Allocation**: By categorizing errors into high, medium, and low priority, the MHA solution helps utility staff prioritize repairs effectively, ensuring that resources are allocated to the most critical issues first.

Technological Advantages:

- **Comprehensive Error Detection**: The MHA technology can identify up to 46 different error conditions within a mechanical water meter, providing a thorough analysis of meter health.
- **Turnkey Service Offering**: The turnkey nature of the MHA solution means that utilities do not have to invest in and maintain the monitoring infrastructure. Olea handles the installation, data collection, analysis, and reporting, allowing utility staff to focus on maintenance and repairs.
- **Off-Grid Capability**: The MHA units are powered by battery or solar, and data transmission is handled via a cellular agnostic antenna, making it ideal for remote or isolated locations without the need for a connection to the electrical grid.

Future Implications:

The success of this pilot project suggests that broader implementation of the MHA solution could lead to substantial improvements in water meter management across the City of Fullerton. By ensuring accurate meter readings and timely repairs, the city can significantly reduce non-revenue water losses and improve overall financial health.

Additionally, the insights gained from continuous data monitoring and AI-driven analysis can help the City develop more proactive maintenance strategies, further enhancing operational efficiency and sustainability.

Overall, the pilot project underscores the value of innovative technologies like Olea's Meter Health Analytics in transforming water utility management, providing both immediate and long-term benefits in terms of accuracy, efficiency, and financial performance.