Beverly Hills Reverse Osmosis Treatment Plant – Review of Operation Systems and Processes

Technical Memo 1 – Baseline Review (Draft)

Revised Draft Submitted

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Executive Summary

The intention of this report is to provide a baseline review of operating systems and processes at the City of Beverly Hills Water Utility. It is focused on the management of the RO water treatment plant, as well as management of downstream water quality.

In the development of this report, we have interviewed plant staff, reviewed operational documentation and processes and reviewed operational performance. Our intent is to provide assistance to the city in minimizing risk to personnel, minimizing risk of breach of permit requirement and assisting in the construction of operational systems and processes that will result in optimized plant performance.

This review is focused in the main on plant systems and processes, however where we have seen them, we have highlighted process issues that we believe need to be addressed, particularly ensuring that this is managed in the long term with effective monitoring and reporting. It is recognized that a plant upgrade is under way with another consultant.

Overall, the plant has some significant operational issues both in terms of operational systems and processes as well as plant performance. While the current state of the plant has not compromised the safety of water supplied to the community, there are some major shortcomings that put the utility at risk of non-compliance to plant permits, risk of asset damage and degradation, and risk to safety of plant staff. But these challenges are not insurmountable, we believe that the plant staff are dedicated, enthusiastic and committed to a successful operation, and with some assistance will be able to return the plant to a high level of performance in all areas.

We stand ready to assist the city to achieve this.

Our major findings are as follows:

- **Plant Performance Targets should be clearly defined**. Targets for operations staff in terms of production, quality, safety and other regulatory requirements are not clearly defined. We recommend this so that staff can compare performance against targets.

- **Operating Performance is not sufficiently analyzed and trended**. There is a vast amount of information recorded on the HMI/SCADA and operating log sheets, however it is not presented or reviewed adequately to gauge plant performance. We recommend that trending of important parameters be set up and regularly reviewed to measure performance against overall plant and process unit specific targets. This is important for water quality targets and internal process performance targets.

- **Water Quality Management and Monitoring has shown great improvement.** This area in particular is advancing well, with robust procedures and a sampling plan being developed. We recommend using this work as a basis for a comprehensive water

quality management plan for the facility (which could be incorporated into a revised OMMP).

- **The Reverse Osmosis (RO) system data is not analyzed correctly**. The RO system performance data is not normalized, and consequently performance has not been reviewed adequately, leading to a substantial worsening of condition.

- **The RO system membranes (first stage in particular) are in very poor condition, leading to increased salinity in the treated water**. These membranes are leaking salt an order of magnitude above what is anticipated for membranes in this operation. The overall cause for poor condition must be investigated and resolved, followed by the installation of new membranes.

- **The RO Unit is not operating correctly, and requires a concentrate valve to be replaced as a matter of urgency**. This is critical for controlling RO recovery, which is itself critical for successful unit operation.

- **A concentrate reduction strategy should be considered**, with a review of current RO feed water chemistry, membrane selection and antiscalant to determine an optimum RO unit recovery. A higher recovery, if possible, can reduce brine production from unit and increase overall treated water yield from the plant.

- **Provide options for lower RO unit throughput, based on lower well yields.** This review (combined with the concentrate reduction strategy) may provide operating cost savings in terms of membrane costs, pumping energy costs and chemical dosing) as well as provide more suitable system hydraulic operating conditions.

- **Final Treated Water blend may be corrosive to concrete**. We recommend a review of water chemistry and blending along with monitoring of water stability indices to ensure protection of plant concrete infrastructure such as cement lined pipes and the concrete clear well

- **Arsenic Management Plan, a regulatory requirement outlined in the OMMP, does not appear to be followed**. This is a requirement of the permit, and included in the OMMP, however does not appear to be entirely operational. We recommend this plan is checked for compliance.

- **The Operations Maintenance and Monitoring Manual (OMMP) is not known to operators and is not in use. We recommend creating a revised, updated OMMP**. This is a major risk of non-compliance to the plant operating permit and in itself may constitute a non-compliance. We recommend as a matter of urgency that the city confirm with the State Regional Water Quality Control Board (formerly CDPH) if the version found during our visit is the current lodged with the regulator. Further, we

recommend that this form the basis of a thorough revision to include important shortcomings as well as updates to reflect existing operation.

- **Plant Weekly Operator Logs are Unwieldy and Unhelpful.** We have recommended a revised log sheet, as the current log contains a lot of data recorded but the key trends are not reviewed to determine plant performance or identify operational risks. It is data rich, but knowledge poor.

- **A non-conformance/corrective action process is recommended.** In order to capture learnings from problems or incidents, we recommend a non-conformance and corrective action system. This will involve reporting incidents, managing incidents and effectively taking from lessons learned to improve operations into the future.

- **A Safety and Emergency Management Plan is recommended.** We could not find a comprehensive safety plan on site covering the multiple safety issues that are encountered at an operational facility. We recommend that a plan be developed, to ensure safety hazards are effectively managed.

- **An Operator Training Program is recommended as a matter of urgency.** Operators are currently not sufficiently familiar with water chemistry, RO unit operation and other plant processes. We recommend a training program be developed to encompass process, operational procedures, safety and other necessary operational elements to ensure operators are well equipped to manage the plant.

- **Development for Standard Operating Procedures is recommended.** Leveraging from work already begun by the city, we recommend developing a number of robust operating procedures, developed with and by the operators themselves, to cover operation of all aspects of the plant. There are currently few procedures in use, and much operation is performed by memory and word of mouth. We additionally recommend a document change management system be established to keep track of version control and ensure changes to plant, process and operations are captured in the procedures.

- **More use of trending from the HMI should be adopted to keep track of process and water quality performance**. There is an abundance of data reported, however trends are more useful for performance analysis, diagnostics and decision making. We recommend that a set of standard trends be developed.

- **Develop a high level plant Dashboard Report, to define key performance requirements at a glance. This will be helpful to track performance against targets.**

- **Conduct a criticality and condition assessment** to determine appropriate spares and maintenance strategy to meet a desired plant availability.

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Introduction

The purpose of this report is to provide a baseline review of the operating systems and processes at the City of Beverly Hills Water Utility, focusing specifically on the management of the reverse osmosis water treatment facility, and including downstream water quality management within the distribution system.

Our aim is to support the City to enhance and reinforce an operational framework to ensure the production of safe reliable water supply.

This report provides a baseline review of operations at the facility, to better understand where we are starting from. We have reviewed existing systems and processes, risks and bottlenecks to performance, opportunities for improvement and identified gaps that need to be addressed. This includes:

- A review of current plant targets and performance against those targets (focusing on production, water quality, and regulatory reporting).
- A review of plant process performance.
- A review of current documented systems and processes.
- Interviews with operations staff and operations management.
- A review of communication practices and protocols.
- A review of operator knowledge/training gaps.

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Background to the Plant

Plant Description

The City of Beverly Hills currently receive the majority of their water supply from the Metropolitan Water District (MWD) of Southern California. Through an agreement with MWD the City developed a supplemental groundwater supply. The water treatment plant was built as part of a design/build/operate (DBO) contract with the first water purchased by the City in 2003. IN 2008 the City purchased the plant from the DBO contractor and have been responsible for its operation since that time.

The water treatment plant sources water from four wells, located along Santa Monica Boulevard and are connected via a common water main and transmitted to the water plant. At the water plant, approximately 60% of the feed water is directed to a 2 stage reverse osmosis (RO) treatment train, with the remaining 40% bypassing that train. The bypass provides a blended final treated water that contains sufficient calcium hardness and alkalinity to maintain a stable final water quality.

The water directed to the RO is dosed with sulfuric acid to reduce pH to both minimize scaling in the RO unit itself, and also to provide optimum conditions for a downstream hydrogen sulfide stripping process. It is then also dosed with antiscalant as an additional mitigation of scaling risk. Following dosing, the water is passed through 1 micron cartridge filtration prior to delivery to the RO high pressure feed pumps.

The RO system consists of 2 stages with 20 pressure vessels in the first stage, and 10 in the second stage, with each vessel containing 7 RO membrane elements each. It is physically arranged in three parallel banks of 10 vessels. The water is fed to the first 20 elements (arranged in two banks) where approximately half of the water is produced as a high quality permeate. The concentrate waste from the first stage is further directed to the second stage where additional permeate is produced. Permeate from both stages is blended together to produce a final RO permeate stream. Approximately 78% of the feed water becomes treated permeate, with the remaining 22% concentrate stream diverted as waste to sewer.

Pressure from the RO concentrate stream is converted to mechanical energy using a hydraulic turbocharger. The concentrate drives a turbine which in turn delivers energy to an impeller providing a boost in pressure to the second RO stage. This provides both a reduction in RO unit energy consumption and also assists in the hydraulic balancing of the system ensuring the correct amount of flow across all the membranes in operation.

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Figure 1 - View of Reverse Osmosis Unit

The RO permeate is then directed to a stripping tower, where water is cascaded through a tower of plastic packing with a counter current flow of air which acts to remove both hydrogen sulfide (H_2S) and dissolved carbon dioxide from the water. The RO unit is operated in such that the RO permeate pH is at or below a 6.0 for optimum removal of H_2S.

The bypass stream is also treated to remove hydrogen sulfide through a stripping tower. In this case, the pH is adjusted by sulfuric acid to achieve the required pH for this process to operate efficiently. Air from both stripping towers is then treated in a scrubber to remove H_2S prior to release to the atmosphere.

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Figure 2 View of stripping towers.

The combined RO permeate and treated bypass water are then blended in a clearwell, where sodium hypochlorite is added to provide a free chlorine CT (concentration x time) in the clearwell.

Upon leaving the clearwell, the water is dosed with ammonium hydroxide which combines with the free chlorine already present in the water to form a residual of chloramine, to provide water consistent with the MWD supply (approximately 2 mg/L as Cl_2). Following this dose, hydrofluorosilic acid (H_2SiF_6) is dosed to provide a fluoride level in the final treated water of between 0.8 to 1.1 mg/L, again consistent with MWD supplies.

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Plant and Distribution Operations Management

The City organizes the management of water systems into two streams, for the treatment plant and for distribution.

The plant is staffed 24 hours per day 7 days per week with a staff of 5 operators (Water Worker class III), operating on a three shift per day basis with oversight provided by a Water Systems/Production Operations supervisor. Until recently, water workers from the distribution system (class I and II) had been rotating through as operators at the plant to gain experience.

The distribution network is managed by a Field Supervisor with a team of 11 water workers (class I and II) along with a Field Service Rep and a Water Technician. The focus of this report, with the exception of distribution network sampling, analysis and nitrification management does not focus on the operations of the distribution system.

A water quality specialist oversees all water quality sampling, analysis and reporting for the City. This is overseen by a plant supervisor. The city is currently in a transition phase due to the departure of the long term plant supervisor, and the position is currently managed on a temporary basis while a supervisor is being sought.

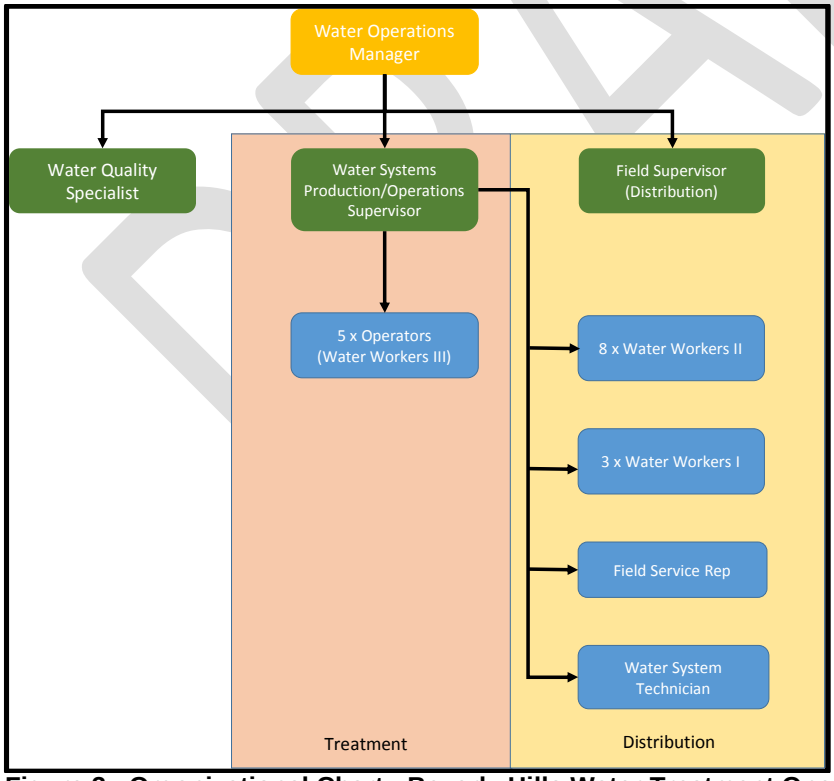

Figure 3 - Organizational Chart - Beverly Hills Water Treatment Operations

Plant Performance Targets

This section summarizes the key plant performance requirements, and in some cases reference to that requirement.

Water Production Targets

The production of the RO treatment facility is mentioned in several documents, however does not appear to have a regulated target. In the California Department of Public Health (CDPH) Engineering Report, Permit Amendment No 1910156PA-003 (page 9) the plant production is nominated as a "capacity of approximately 1880 gpm".

A version of the Operations, Maintenance and Monitoring Manual (Section 1 Page 1-51) (assumed completed in 2009 – no date found on the document) includes a set of different treated water production rates at which the plant will run, governed by different operating condition envelopes under which the plant may run. This is impacted by the level of total dissolved solids in the feed water or the requirement for additional system throughput.

Parameter	**Normal**	**Normal + 15% TDS**	**Normal + 10% Flow**	**Normal + 15% Flow**
	gpm	gpm	gpm	gpm
Total Feed	1874	1896	2060	2084
RO Feed	1098	1200	1207	1315
Permeate	856	936	942	1026
Blend Bypass	776	696	853	769
Reject (Concentrate)	242	264	265	289
Total Blended Product	1632	1632	1795	1795

Figure 4 - Treatment Process Operations Under Different Operating Conditions – (from OMMP).

This reflects the original design basis of the RO system, which acknowledges the different performance that will be achieved at these different conditions, and can provide guidance to operations on how to operate the plant under these different conditions. (Further detail on the design basis underpinning these operating settings is shown on in the OMMP on pages 1-49 and 1-50).

Actual Performance – Throughput

At the time of most plant visits during this review, the plant was not operational. The plant in recent months has had significant down time due to various maintenance issues.

Overall, the plant production is operating at approximately 20% to 30% below the design production rate when the plant has been in operation from 2013 to the present. We note that there have been significant periods with the plant off line in 2013 and also during this year.

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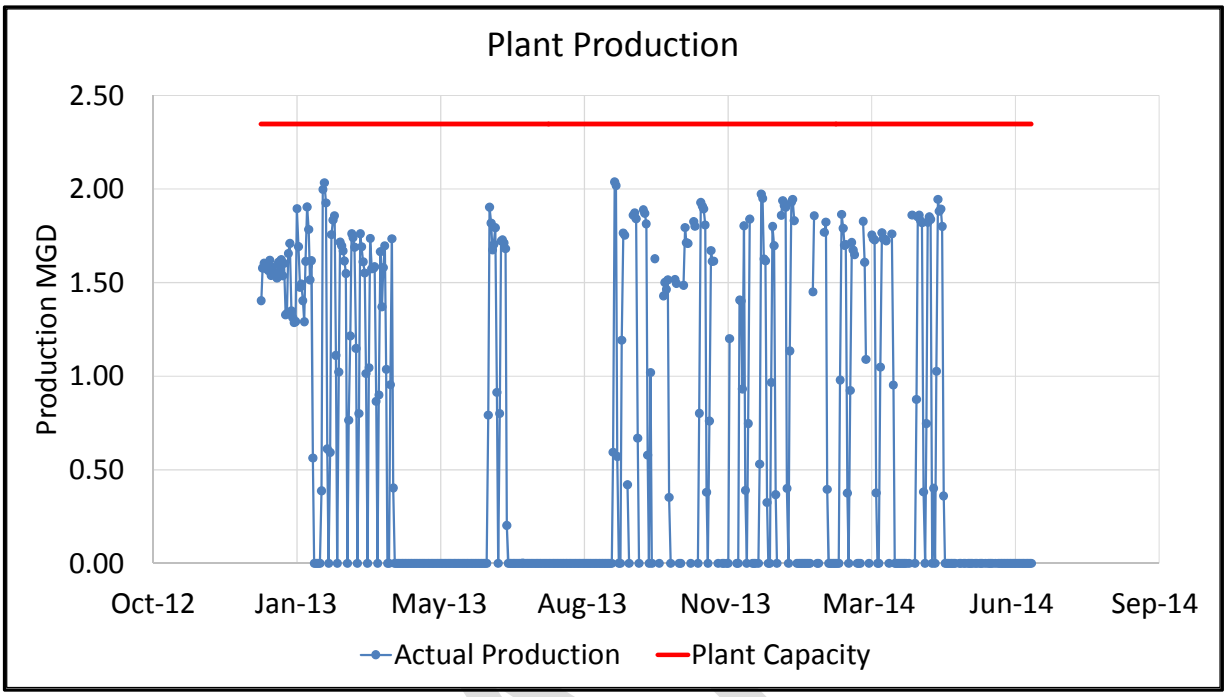

Figure 5 - Plant Production 2013 to Present (from flow meter logs)

The log sheets above provide daily production readings, and do not include any commentary of any plant shutdown events during that day. (Note that these data are taken manually, and some outliers may represent incorrect transcription).

On closer inspection from daily operator log sheets, we can see the instantaneous production rate is approximately 20% below design (taken from data during June 2014).

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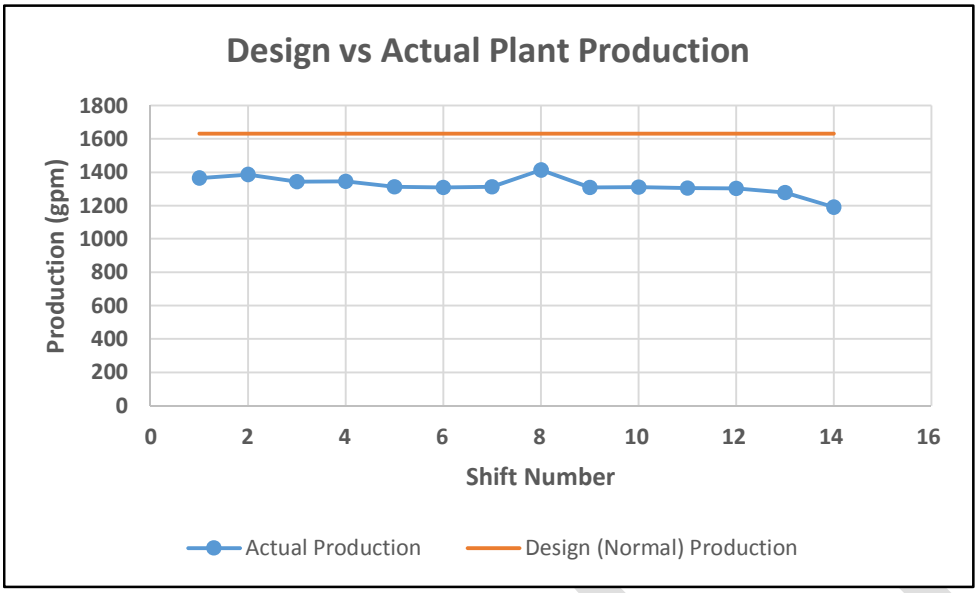

Figure 6 - Design vs Actual Plant Production - taken June 17 to June 21 2014.

The shortfall of plant production is the result of two things:

- A shortfall of plant feed water and
- The RO operating at a lower than design recovery

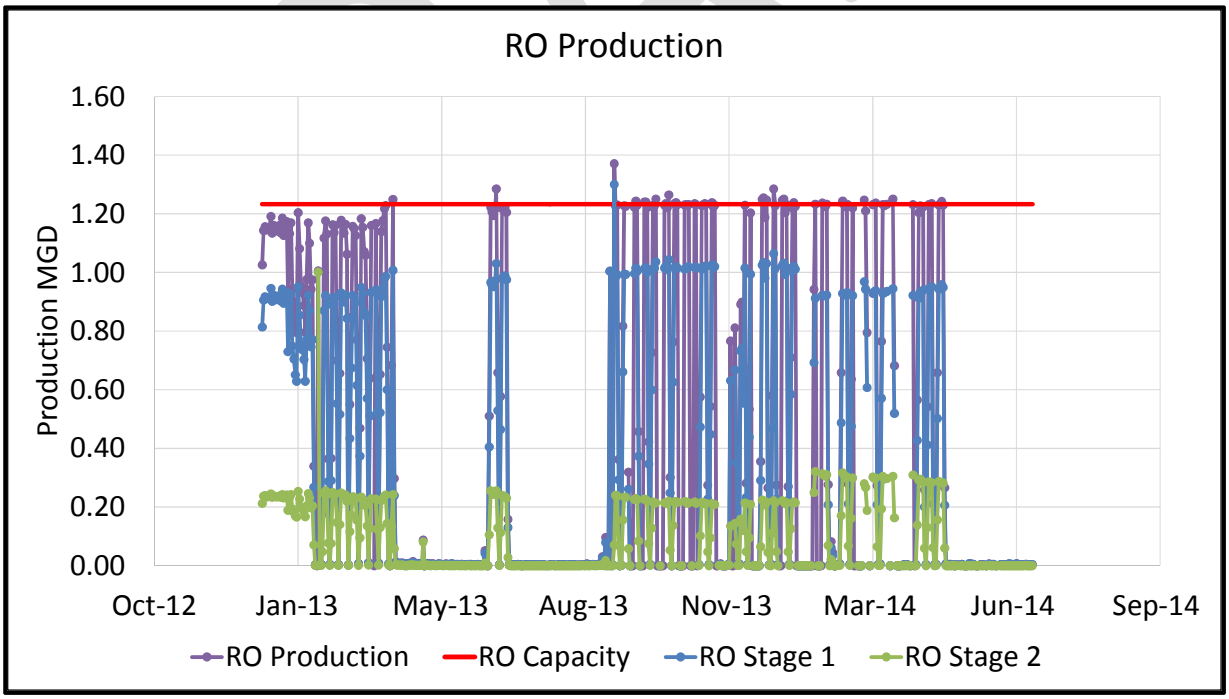

Figure 7 - RO Production 2013 - 2014

The RO unit itself, has been maintaining production consistent with the original design, as can be seen from both the daily flow logs, and weekly operator log sheets.

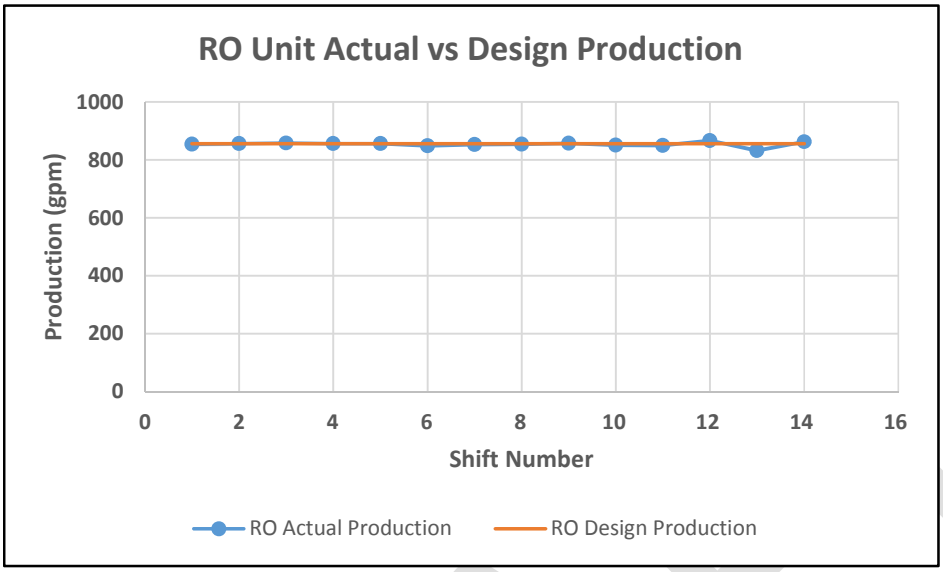

Figure 8 - RO Unit Production Design vs Actual taken June 17 to June 21 2014.

However, the RO unit is operating at a lower overall recovery (that is ratio of permeate flow to RO feed flow) than design (70% down from 78%), and as a result requires a greater portion of feed water from the wells than anticipated in the design (in this case an additional 120 gpm) in order to produce the same amount of RO permeate. Additionally, this results in 120 gpm of additional waste from concentrate to sewer. This presents increased operating costs both in terms of increased waste disposal, in addition to increased pumping energy costs as that additional flow of water must be pressurized through the RO unit. Based on the original design flow, this will result in an additional 15% energy consumption for the pump at a cost approaching $10,000 per year at continuous plant production.

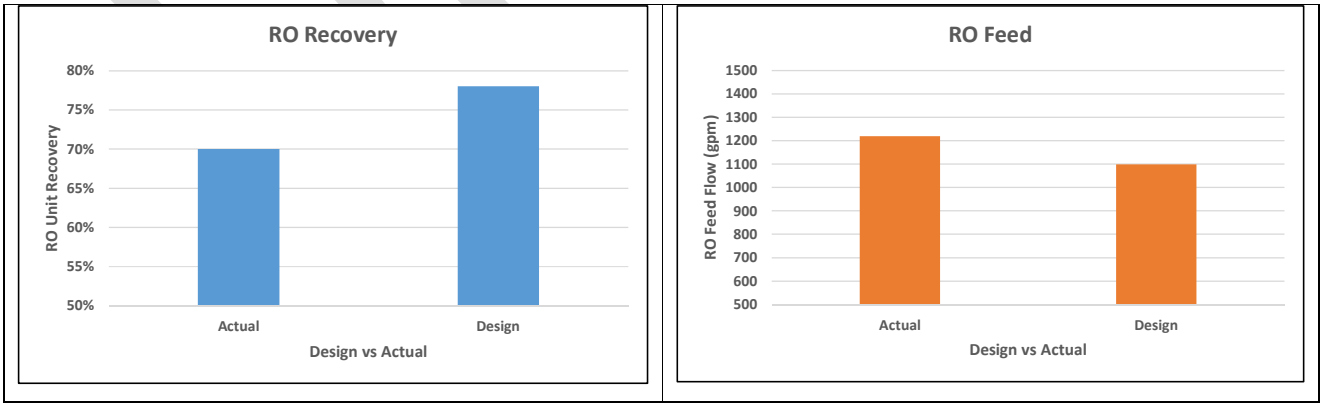

Figure 9 - RO Unit Recovery and Feed Flow Design v Actual

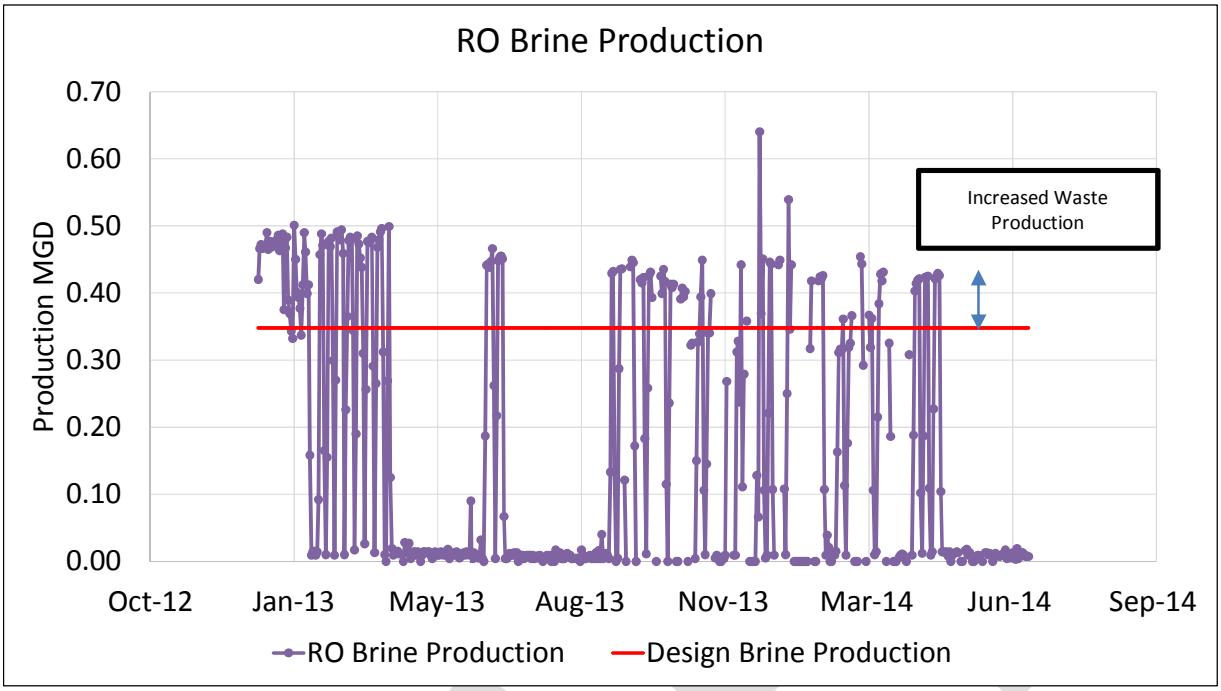

Figure 10 - Plant Brine Waste Production

We have noted that the RO recovery was lowered at some point prior to 2013. We are unsure of the reasoning, however it may have been done on the basis of a concern of scaling of the RO membranes. We recommend that this be further investigated. We additionally note, on our visit to site, that the RO concentrate valve, which is typically automated, is currently not connected to the unit, and rather the concentrate is throttled with a small diameter pipe restriction (acting as an orifice plate). The restriction and lack of control limits RO recovery.

Recommendation: We recommend an overall brine reduction strategy, with a review of RO unit recovery based on actual current feed water chemistry and options of antiscalant selection. We will work to provide options for improvement with the current infrastructure.

As well as additional feed water required for the RO unit, there is a lower rate of feed water being delivered from the wells themselves. It was noted in the project kick off meeting that this lower feed flow is limited by current well capacity constraints. This can be seen clearly in both the flow logs and weekly operator log data.

This lower well yield may limit the production capability of the RO unit. An RO is designed as a relatively constant flow device, and does not operate well at design flows significantly below its original design point.

Recommendation: We therefore recommend a review of options for reduced RO system overall throughput to allow for this reduction in well yield. We recommend a review of options for reduced RO system throughput, including items such as taking pressure vessels off line, and a review of hydraulic impacts.

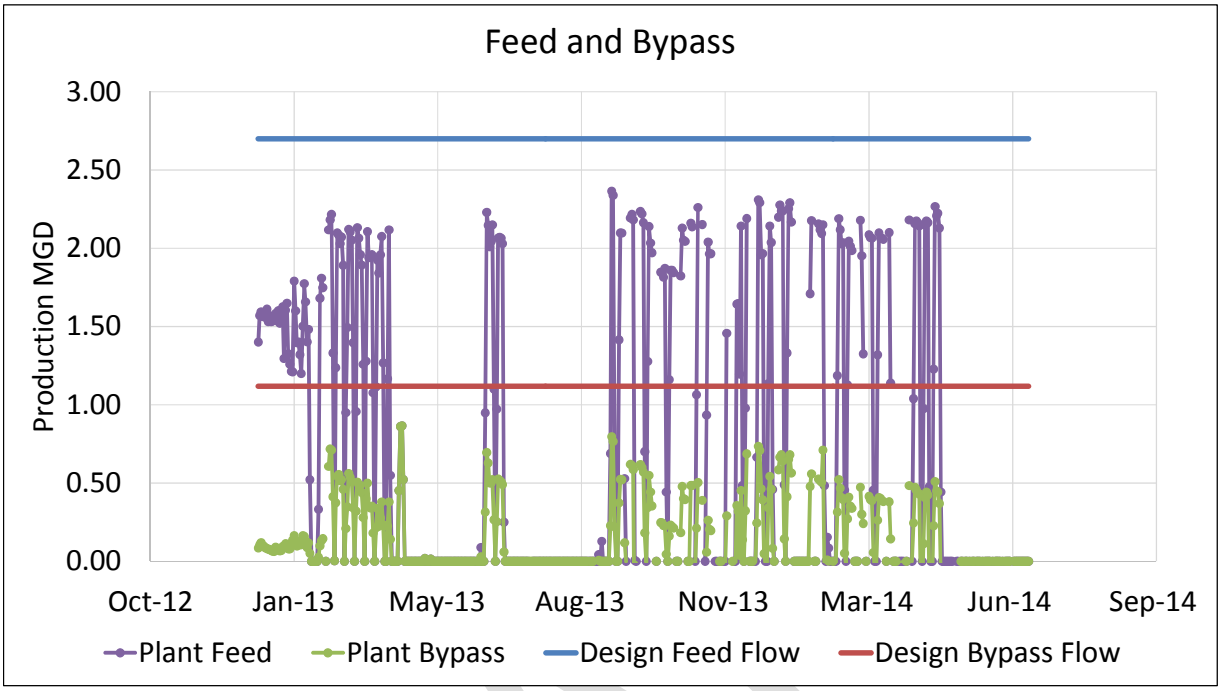

Figure 11 – Actual Feed Water Flow and Bypass Flow Production from Flow Reports

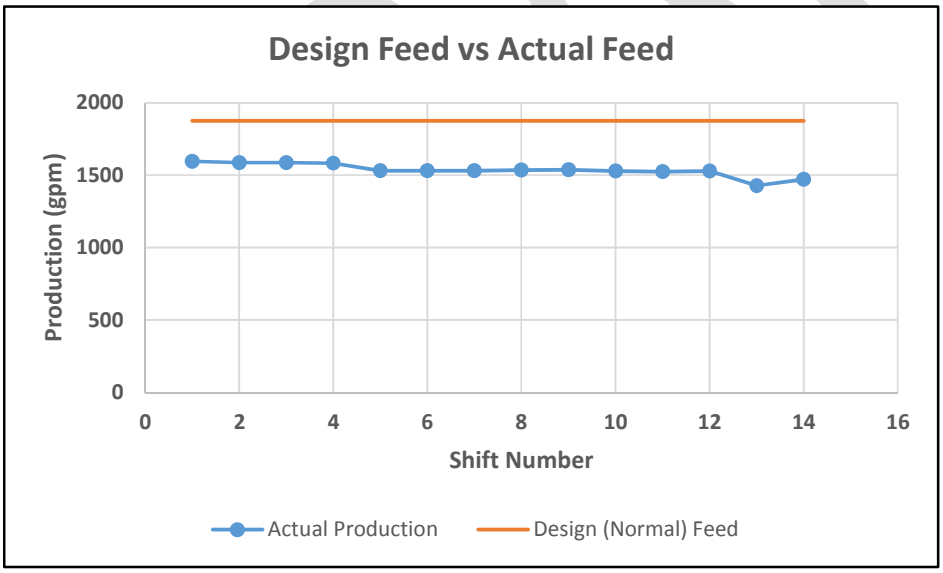

Figure 12 - Feed Flow from Weekly Operator Logs

This lack of feed water not only limits plant capacity, but also acts to impact treated water quality. The original blend design was set such that the final treated water blend would contain sufficient hardness and alkalinity to provide a non-corrosive, stable product water. With a much lower proportion of bypass water now in the final blend, careful attention should be paid

to the stability management of the final product water, as unstable water may corrode concrete infrastructure such as the Clearwater well.

Also, a loss of one well will change the overall feed water blend, and consequently the feed water quality to the RO unit and bypass streams. This may impact the risk of scaling to the RO and as a result the possible system recovery (which impacts both the amount of treated water that can be produced and concentrate waste generated).

Recommendation: Repair and replace RO concentrate valve, and work to confirm possible recovery based on feed water quality (this is discussed further later in the report).

Recommendation: Review capacity constraints on wells and review the impact of differing feed water blends and lower feed availability on plant and RO operation including impact of RO system recovery and throughput.
Recommendation: Review RO Feed Water Quality and current pH and antiscalant regime to determine sustainable RO recovery rate and minimize brine production

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Treated Water Quality Targets

The water quality targets for the plant are governed under requirements of both Federal and State water regulation. The specific requirements for the plant are articulated through the Permit No 04-15-03P-003 and subsequent amendments 1910156PA-001, 002 and 003 (2003, 03/2010, 11/2010 and 01/2011 respectively).

This permit incorporates additional federal and state requirements for the plant which include:

- EPA Groundwater Rule.
- EPA Stage 2 Disinfection Byproduct Rule
- California Title 22 COR Chapter 15 Domestic Water Quality and Monitoring Regulations

Specifically, the permit requires (Amended permit, condition 6) that all water shall "meet all Maximum Contaminant Levels (MCLs) established by the department".

Additionally, the permit specifically requires:

- A fluoride level leaving the plant of between 0.8 and 1.1 mg/L.
- 4 log virus inactivation treatment, which was a requirement subsequent to positive coliform results from the RO system.
- A total chlorine residual of 2.0 mg/L (in the form of chloramine) in the distribution system (note this is not strictly required of the permit, but noted as the city target).

There are some additional water quality targets noted in documentation at the plant. In particular, a version of the Operations Monitoring and Maintenance Plan (OMMP) refers to some additional non-regulatory parameters, which we assume are from the original plant operations manual. These include:

Parameter	**Product Concentration**
Hydrogen Sulfide	< 0.3 ppm 90% removal with inlet pH = 6.0 (also noted as <0.01 in another section of the OMMP)
Total Hardness	< 150 mg/L as $CaCO_3$
T.D.S (180 deg C)	< 400 mg/L
LSI (Langlier Saturation Index)	Non-corrosivity

Recommendations:

While many of the water quality targets are listed in the permit and associated documents, we recommend that there is a clear set of targets listed in one place, so that the overall water quality requirements of the plant are clear.

- We recommend that all requirements be clearly articulated in one document, so that they are clear for operations. (This exercise has begun with the development of a Sampling Manual and we recommend it be completed, which could be later included in the OMMP).

- We recommend that some of the non-regulatory but operationally important parameters (water stability and total dissolved solids be included in this list).

- We specifically recommend a stability index (calcium carbonate precipitation potential, or LSI) target be defined and be regularly monitored at the clear well inlet and plant effluent to ensure water stability.

Treated Water Quality Performance

There is no regular updated report of overall treated water quality performance for the plant, but rather there is a limited combination of on-line trending, and regular regulatory reporting. On line trending reviews pH, turbidity and chlorine (free and total) only. Additionally, fluoride concentration is trended leaving the plant.

The remainder of performance parameters are measured as per regulatory requirements on discrete monthly reports. There is currently a very limited amount of data that is trended and reviewed, and as a result changes in performance and opportunities to take correction early may not be identified.

We have not included an exhaustive review of treated water quality performance in this report, but rather highlighted some important trends and aspects of treated water quality that merit further investigation. The Water Quality Monitoring and Reporting section below discussed the planning, sampling and reporting of water quality and provides recommendations in more detail.

Final Effluent Quality

The water quality data below is provided from regulatory reporting between January 2013 and July 2014. Of the set of data regularly reported, we have included Total Dissolved Solids, Fluoride, Arsenic and Manganese.

In reviewing all of this data, it is important to recognize that the quality is a function of the RO unit performance, the ratio of water that bypasses the RO unit and the feed water quality from the wells.

- **Total Dissolved Solids (TDS)** – we note that for all but one result, the level is below the secondary MCL of 500 mg/L, however it is above an originally desired level of 400 mg/L as noted in a section of the OMMP. Further, we can detect a significant trend of

increasing TDS with time. This can be due to an increase in the water bypassing the RO, an increase in feed water TDS, changing operating conditions of the RO or an increase in salt passing through the membranes. A closer inspection of membrane performance and blending rates (later in this report) suggests that it is most likely due to a worsening in membrane condition allowing the passage of more salt. This is a very high rate of increase, and suggest a major problem with the membranes themselves or the membrane seals.

- **Arsenic** – arsenic is of particular interest due to high arsenic levels being present in one of the four wells feeding the plant (well 4) and subsequent arsenic management planning that has been implemented. While arsenic levels remain below the MCL of 10 ug/L, we note that it has been within 75% of this level on occasion. This may suggest a high proportion of high arsenic in the feed water. Close attention must be paid to the current arsenic management plan to ensure compliance.

- **Manganese** – manganese remains below the secondary MCL of 50 ug/L, however we note peaks that coincide with arsenic peaks. This may similarly suggest high arsenic in the feed water.

- **Fluoride** – fluoride is a controlled dose, however there is fluoride in the feed water for all wells. Depending on the fluoride levels in the wells, and the blend of wells used, the level of fluoride in treated water does fluctuate.

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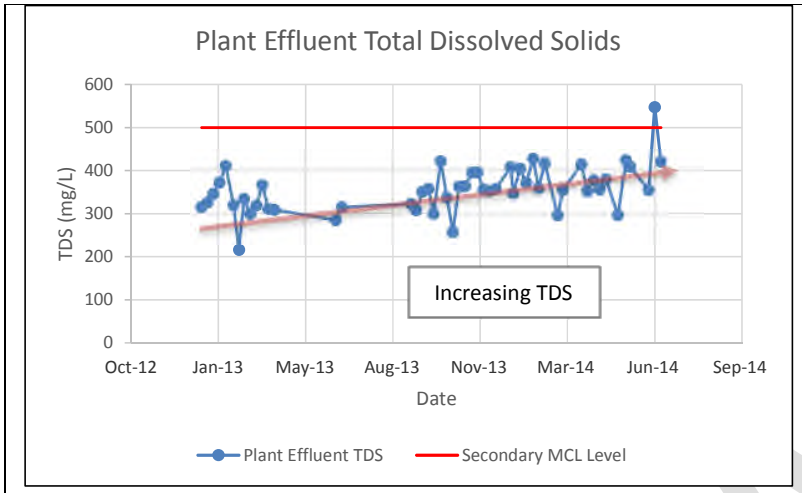
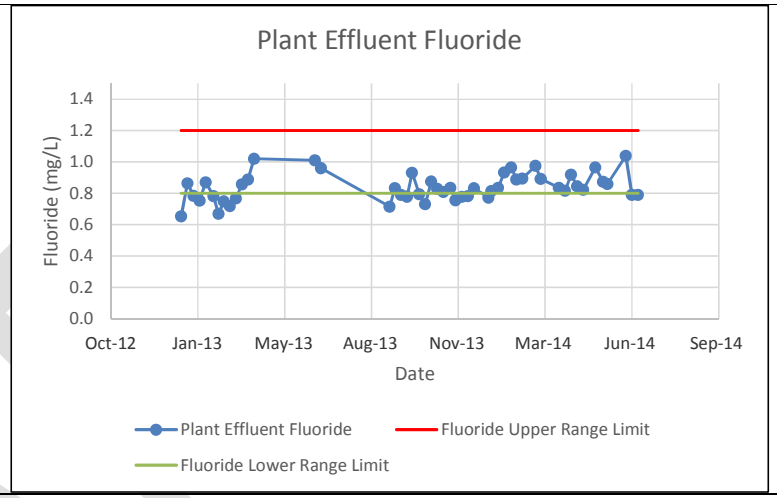
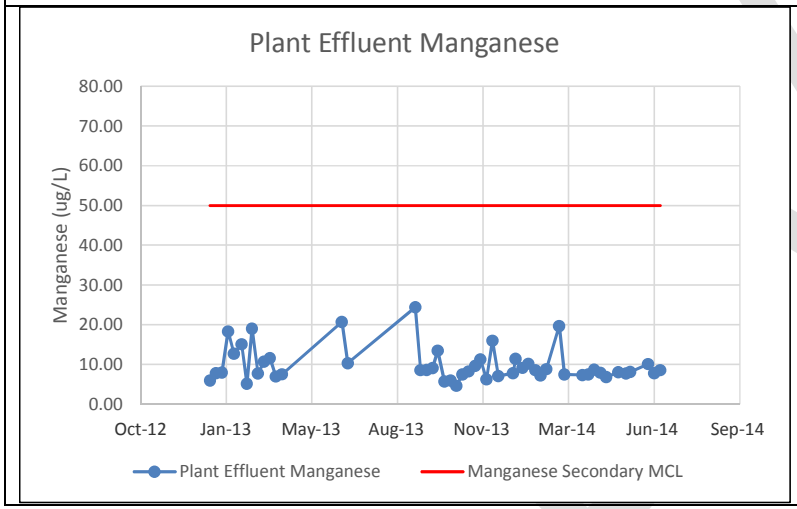
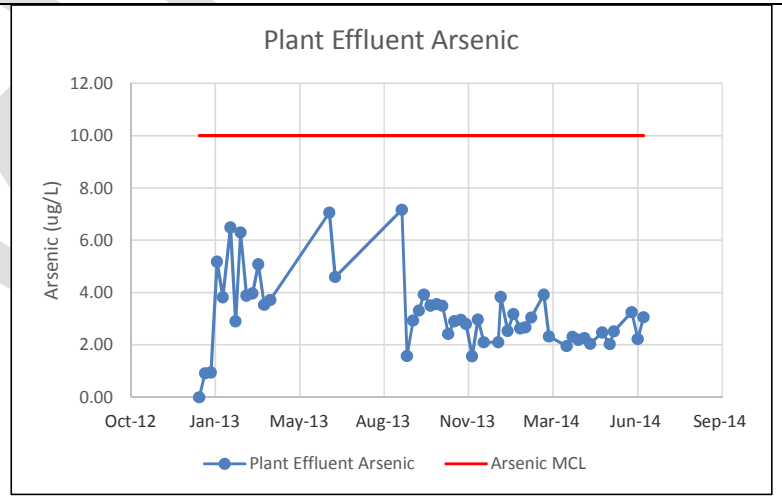
Table 1 - Plant Effluent Water Quality (from Monthly Regulatory Reports









Chlorine and turbidity data is both trended at the SCADA and logged by plant operators. We have not extracted significant trends from the SCADA for review, however we recommend that this be done and reported on a regular basis, again to identify trends in performance and to confirm compliance.

Daily logs checking both turbidity (reported from an on line analyzer) and chloramine (from a site test kit) provide some operational data. Data from shift logs the week of June 16 are shown below. We note that the turbidity level appears to have had an excursion beyond the desired 0.3 NTU, however it would need to be confirmed if this is an accurate result or reflects cleaning maintenance required at the instrument.

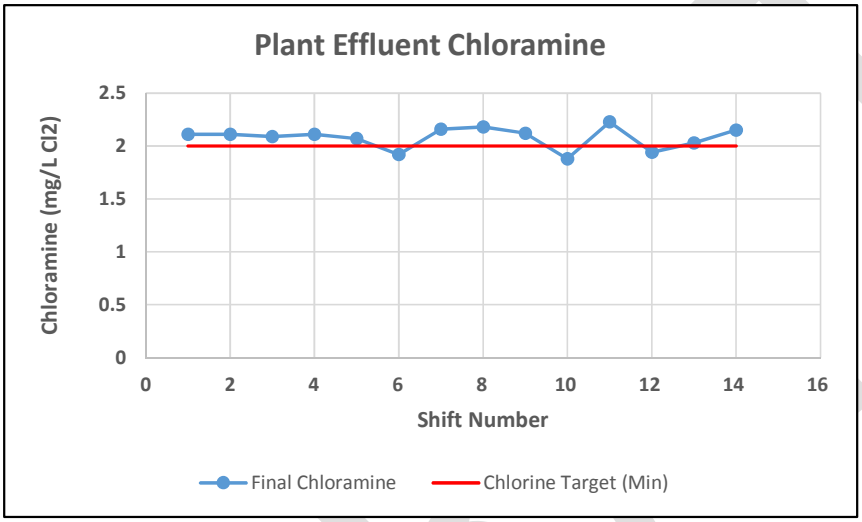


Figure 13 - Plant Effluent Chloramine - from operator logs

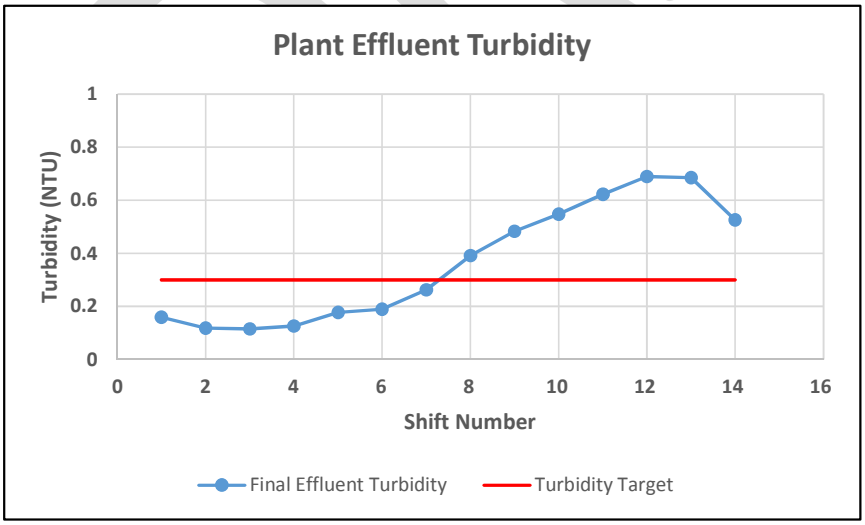


Figure 14 - Plant Effluent Turbidity from Operator Logs

Recommendation: Develop regular and trended water quality reporting, similar to those shown above, to provide an ongoing review of plant performance, and provide an opportunity to identify problems early and optimize performance.

Operating Systems and Processes

The long term success of any operating facility relies on a well-documented, up to date and functioning set of operating systems and processes. Operating systems and processes are systems by which infrastructure can be operated to function consistently and reliably. It is important that there is enough documentation to define the how, when, why and by whom for operations so that responsibilities are clear, tasks are repeated in a consistent timely fashion and a functioning history of performance is maintained.

Ideally, systems and processes are contributed to by staff, and act to empower them to make good operating and maintenance decisions.

This section reviews some of the system documentation that was identified at the plant during recent plant visits, and provides some recommendations on actions to improve or enhance the existing systems.

Overall, there appear to be a limited set of functioning, documented systems and processes in use at the facility. The working documents are limited to some operating log sheets, simple task planning schedules and operator log books. Notably, significant work has been done to further improve documentation of water quality requirements in development of a water quality Sampling Manual.

Of particular concern, much of the knowledge of plant operation appears to have been gained through verbal instruction, site experience and trial and error.

Operations Maintenance and Monitoring Manual

Existing Documents

The Operations, Maintenance and Monitoring Manual (OMMP) is a key requirement for the operations of the facility, and is an explicit permit requirement. The most recent permit amendment (Amendment 1910156PA-003, Jan 2011), condition 17 requires the city to update the OMMP within 120 days of that amendment being received, to update for change in plant ownership and the inclusion of a start-up monitoring procedure.

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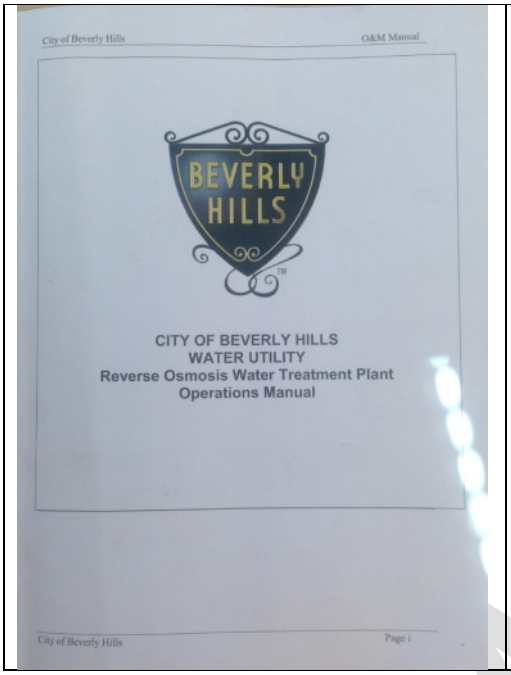
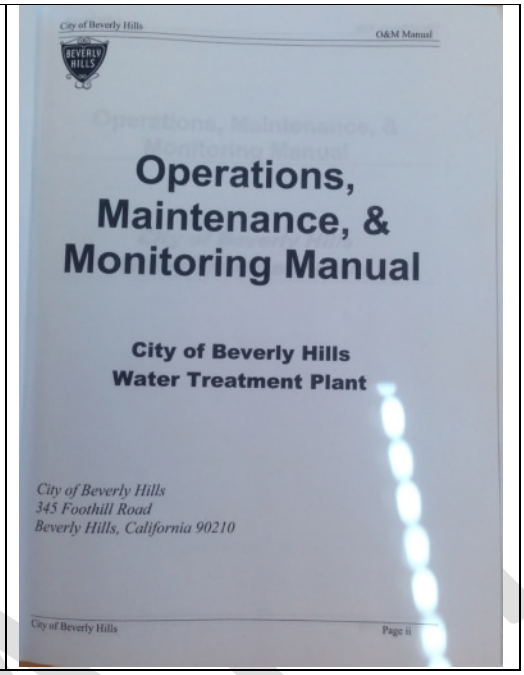
Table 2 - More Recent Operations Maintenance and Monitoring Manual sighted during plant review.





During this review, we have been able to located two versions of an OMMP for the plant.

The first version had been developed by the previous DBO contractor, and was not currently up to date. While much of the plant technical information is correct, it refers to previous management systems and plant management personnel within the DBO contractor's structure. Additionally it does not include a number of recent modifications to plant operation that have taken place including addition of fluoridation, the operation of free chlorine CT in the clearwell and current monitoring practices. This document appeared to be known to plant operators, and occasionally referenced for technical information. It is not in regular use.

The second version was uncovered in the previous Plant Supervisor's Office. This version of the document appears to be more up to date, and has removed most references to the previous DBO contractor. This document appears to have been revised to meet the requirements of the most recent permit amendment, as this permit amendment is specifically referenced in section 6, however there is no date of publication or revision on the document. The document appears as it may still be a draft, as there are numerous formatting errors within it and many areas appear that they have not been entirely updated to reflect current operation. Notwithstanding these problems, however, there is valuable information within the document that should be used in the updating of final documentation for the plant.

Most importantly, this version of the document appeared unknown to operations staff until it was uncovered in this review.

The second of the two OMMPs is divided into 10 sections:

- Section 1 – Introduction and System Description
- Section 2 – Process Flow (Process Description)
- Section 3 – System Safety
- Section 4 – Process Controls
- Section 5 – System Operations
- Section 6 – Operating Permits
- Section 7 – Monitoring and Sampling
- Section 8 – Chemical Storage and Handling
- Section 9 – Troubleshooting Procedures
- Section 10 – Drawings

Additionally, at the back of the manual is a draft Arsenic Blending and Treatment Plan. A Fluoride OM&M plan (explicitly required in the permit) is not explicitly included in the document, although fluoride operational information is incorporated into Section 8 of the report.

OMMP Section 1 – Introduction

This section provides an overview of main equipment at the plant and the equipment function for all equipment within the water treatment plant. It provides a great deal of detailed information including:

- Basic operating description of major plant components.
- A list of instruments including location, range and equipment part number.
- RO membrane specifications including membrane models at the time of writing.
- List of electrically operated valves including material information and valve function.
- Sample valve listing.
- RO performance design basis, including a list of operating scenarios, flows and treated water quality expectations.
- Plant overall flow balance.
- Chemical system details including chemical used, concentration, approximate doses and consumption.

Much of this section is very useful information, and important to be documented. We recommend that this information be used, and updated to reflect current plant equipment and operational information. Some of the more detailed information (such as equipment part numbers) could be recorded in a subsequent section or kept in a future asset register, however the main body of information is important.

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This section does not provide a clear set of plant targets, specifically target treated flow and water quality. We recommend these be included at the front of any future OMMP document.

Recommendation: This section contains good information that will be useful in plant operation. We recommend that the system be updated to include the current plant configuration. This may be best completed following the upgrade of the plant which is currently under way. We further recommend that some detail items (such as equipment part numbers) be removed from this section and included either in an appendix or in equipment asset registers.

OMMP Section 2 – Process Description

This section provides a brief process description for operation of the plant. This provides a broad process overview and some knowledge particularly of RO system and H2S stripping and scrubbing information. Additionally information detailing the operation of the clearwell to meet CT requirements for 4.0 log virus inactivation is included.

A flow diagram is noted, but not included, in the document.

Recommendation: A process description with a process flow diagram is a useful inclusion to the OMMP. We recommend that this information be updated.

OMMP Section 3 – System Safety Precautions

This is a relatively short section of the document which includes general safety requirements for the plant. It provides a very high overview of requirements, but provides very few specific details on safety. For example, a lock-out tag-out procedure is recommended for electrical devices, however there is no reference to what the procedure is or where it can be found.

PPE is referred to, however there is no specific list of what PPE is required, where it is located and how it is managed.

Chemical safety is discussed briefly however no specific procedures are referred to either later in this document or elsewhere. MSDS documents are referred to as located in the document, but they are not included.

Recommendation: We recommend that this section be entirely re-written to provide a more specific, and detailed safety plan for the site. This should include as a minimum:

- Safety training requirements for staff.
- Hazardous chemicals.
- PPE requirements for site including what is required in specific plant locations, and where PPE is kept.

- Emergency procedures (unless included in a separate plan)
- MSDS sheets for current chemicals.
- Safety incident management.
- Lock/out tag out procedures
- Working with contractors on site.
- First aid

We further recommend that this be consistent with City wide safety management systems.

OMMP Section 4 – Process Controls

This section provides an overview of controls system architecture, control philosophy and a detailed review of plant SCADA screens and functionality.

This information is critical for the operation of the plant, however the material documented within the OMMP does not appear to be consistent with the existing SCADA system. This may be due to a SCADA upgrade that has occurred since the original writing of the document. As this is the only document sighted that details SCADA operation screens – which are at the heart of plant operation – we recommend that this section be extensively re-written to correctly provide operating guidance.

Recommendation: We recommend a significant re-write of this section to reflect the currently configured SCADA controls system.

OMMP Section 5 – System Operations

This section provides both system start up procedures and some limited operating procedures for the RO system only. It refers to other equipment system documents that have not been sighted (for example Volume 2 Equipment Data Sheet and Vendor Manuals) and to sections which may refer to a previous manual.

In general, the procedures to not provide sufficient detail for operation, and do not include significant portions of the plant equipment and process.

Recommendation: We recommend that these procedures be re-written, perhaps stand-alone from the OMMP, and include more specific detail to ensure they can be adequately followed by plant operators. The procedures should include:

- Version and revision dates to ensure they are current.
- A regular date of review.
- Specific valve, equipment and instrument numbers where these are referred to.
- Photographs of equipment, to assist operators identify equipment.

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OMMP Section 6 – Operating Permits

This section provides a list of operating permits for the plant. It is a useful summary, and we recommend that this simply be updated regularly to ensure that it is current.

Recommendation: Provide regular update to ensure this is current.

OMMP Section 7 – Monitoring and Sampling

The monitoring and sampling section provides a series of monitoring log sheets and operating schedules for the plant. There are two operating log sheets included:

- A daily log sheet

  The first log sheet is focused entirely on the reverse osmosis unit, with daily logs required of specific analyzers, with some specific samples to be taken also A facility operating log

- Facility Operating Log

  This contains more overall performance measures, however still focuses largely on the reverse osmosis unit. Prior to this log sheet, the OMMP refers to a process monitoring software (OpsWin™) which is to be used to provide operational performance reporting and process optimization.

It appears that these log sheets and the discussion of optimization software may be a remnant of the original DBO operations manual. The log sheets have both been superseded with the current weekly operating log (discussed in section Plant Performance Monitoring and Reporting). To the knowledge of the writer, there is no optimization software currently in use at the facility.

Recommendation: These operating logs be replaced with the updated operating logs based on current operations and modifications based on recommendations. It is important that we are reviewing all aspects of the plant, not only the RO system.

- Process Monitoring Analyzers

  Additional to the log sheets is a list of online process monitoring analyzers. This identifies the analyzer, instrument tag number (important for SCADA identification), manufacturer, model number and importantly calibration frequency. The table provides a useful list of analyzers and identification to allow collection of trends from the HMI computer. The calibration information is a useful list, however many of the frequencies do not appear to be correct for those particular instruments.

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Recommendation: We recommend that a separate calibration schedule be developed for on line analyzers, and reviewed against manufacturer's recommendation and experience of other like facilities. Additionally, calibration records should be developed and retained as evidence of calibration.

- Process Daily, Weekly and Monthly Monitoring

  Two tables show a daily and weekly internal process monitoring schedule for on-site water quality analysis. This includes a number of parameters in the influent, RO permeate, RO concentrate and final effluent streams. This is non-regulatory monitoring, and to our knowledge few of the listed items are currently being monitored or reported. On review we believe that some would be helpful, while others may be redundant as they are already adequately managed by on line monitoring.

Recommendation: A revised on site laboratory monitoring document be developed to include important and useful parameters for analysis. This may be considered as part of the overall Water Quality Management Review

- Regulatory Sampling and Analysis

  There are four log sheets covering regulatory sampling requirements. It appears that this list may be somewhat out of date, and does not include all of the regulatory sampling and analysis required.

Recommendation: Revert to the work currently being completed as part of the Sampling Manual (and possible future Water Quality Plan) for regulatory water quality sampling and reporting. This may be integrated at a later stage in the OMMP.

- Contractual Reporting

The final part of this section includes a list of contractual reporting requirements. It would appear that these are a remnant from the original DBO operations contract which specified some regulatory, but also some contractual water quality requirement. Some no longer have contractual relevance, and many are already requirements mirrored in existing regulatory requirements. There are, however, some parameters that are important for managing plant infrastructure (such as water stability indices) which we will recommend are added to current water quality monitoring.

Additionally, a single, clear location that outlines water quality targets is very helpful for plant operation. These recommendations are outlined in the discussion on water quality management.

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Finally in this section, schematics of regulatory sampling locations, daily plant flow meter logs and a monthly monitoring report are shown as sub-headings, but those schematics and logs do not appear in the report. (The daily plant flow report has been sighted as a spreadsheet in use).

OMMP Section 8 – Chemical Storage and Handling

This section provides a set of standard operating procedures for each of the chemicals used on site. These procedures are provided in a reasonable format, with the majority of important information including safety information contained in each. These procedures are originally from the DBO contract, although have been updated as per 2011 and have a revision included in the document.

It is important to note that the current dosing pump arrangements have been modified since the original design and consequently some of the information contained in these procedures will be incorrect or out of date.

A Fluoride procedure has been included along with this list, in order to meet the requirements of the most recent permit amendment. This appears to be more of a comprehensive manual than a simple procedure, and perhaps consideration could be given to this as a stand-alone section.

MSDS documents are referred to throughout, along with references to other chemical industry training and documentation resources. We recommend that where possible, documents or a document location be provided as a part of this procedure. For external industry information, web addresses and phone numbers are very helpful.

Recommendation: Update and revise standard procedures for chemical handling to reflect current equipment and chemical usage. Ensure that all external information referred to is available in a known location (e.g. MSDS).

OMMP Section 9 – Troubleshooting

This section provides a limited discussion of plant troubleshooting, primarily focused on the RO system. Much of the information is helpful, and can be incorporated along with other troubleshooting material that should be developed for other plant processes. It is general, rather than prescriptive, and can be a useful addition to other training material that should be developed.

OMMP Section 10 – Drawings

Drawings are not included in the OMMP.

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Arsenic Blending and Treatment Plan

The final section of the report is an arsenic blending and treatment plan. This plan outlines both sampling and analysis and blending strategies to ensure that the plant final water is compliant with the arsenic MCL of 10 ug/L. It sets out requirements for regular well sampling, including field test kits. Additionally, it refers to an arsenic blending and treatment formula, which could not be found in the document.

During visits to site, we did not see any evidence of records of arsenic test kits in the field (although it is sampled by laboratories). Additionally, other than regulatory sampling we have not seen any reporting along the lines of this plan.

Recommendation: We recommend further review be conducted with a check of compliance against the current arsenic plan. Given that arsenic remains a risk due to levels in Well 4the plan should be in place.

Overall Recommendation OMMP Recommendation

The OMMP is a critically important document for operations, and should contain the key documented elements to operate the plant safely, reliably to meet production, water quality and other regulatory targets. The OMMP is an explicit requirement of the plant permit, and it must be kept current as a compliance requirement.

The current OMMP appears to not be up to date, incomplete in some sections and not in regular use. We anticipate that the version uncovered is the most recent lodged with California SWRCB, however we recommend that this be confirmed.

We recommend that the OMMP be used as the master document for operations, and that the framework within be upgraded and updated to reflect current (and improved) operations of the plant. This is best done in conjunction with the coming plant upgrade.

In its development, we need to strike a balance providing sufficient level of detail to satisfy regulatory requirements in the one document, and developing additional material that may be referenced by the OMMP, but not included with it. For example, some standard operating procedures, sample planning documents and other items may be referenced by the OMMP, but not included specifically within it. This provides flexibility on minor operational system changes that can be captured, but will not require a change to the master OMMP document itself.

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Water Quality Monitoring and Reporting

The plant monitors treated water quality both internally to track operations performance, and also specifically for regulatory requirements. There are several sources of water quality information and a number of different reports.

Internal reporting

The internal reporting of treated water quality data at the plant comes from three sources:

- The Weekly Operating Log sheet.
- HMI Reports
- HMI pre-canned trends.

Weekly Operating Log Sheet

The Weekly Operating Log sheet is a comprehensive log sheet that is filled out at each shift. This log sheet contains data covering water quality and other general operational parameters throughout the plant. (More detail on the log sheet overall is discussed in section Plant Performance Monitoring and Reporting). There are approximately 5 on-line water quality analyzers that are regularly logged. (Note that the terminology for final treated water quality used at the plant is typically "Final Effluent"). These include:

- Final plant effluent pH.
- Final plant effluent turbidity (NTU).
- Final total blended product conductivity (uS/cm)
- Plant effluent chlorine residual (mg/L).
- Fluoride analyzer (mg/l)

This data does not appear to be graphed or reported elsewhere from these log sheets, but rather act as a confirmation that operators are conducting routine checks. In addition, there are on site laboratory tests conducted at the plant for:

- chlorine,
- ammonia and
- chloramine

which are conducted for both the clearwell (to check on free chlorine CT) and in the final effluent to confirm chloramine dosing targets and chlorine to ammonia ratios. These latter measures provide a verification of on line instruments.

HMI Reports

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There is a HMI report entitled “Effluent Water Quality Report”. This report contains final plant effluent pH, turbidity, free and total chlorine and fluoride – taken from on line analyzer data. It provides a daily maximum, minimum and average value.

Additionally, there is a Plant Effluent Chlorine 5 min average report, which provides 5 min average data for total chlorine leaving the plant.

These reports are used for regular reporting, and in particular reporting for free chlorine CT, as part of the 4 log removal requirements noted in the most recent permit amendment (see details below in regulatory reporting).

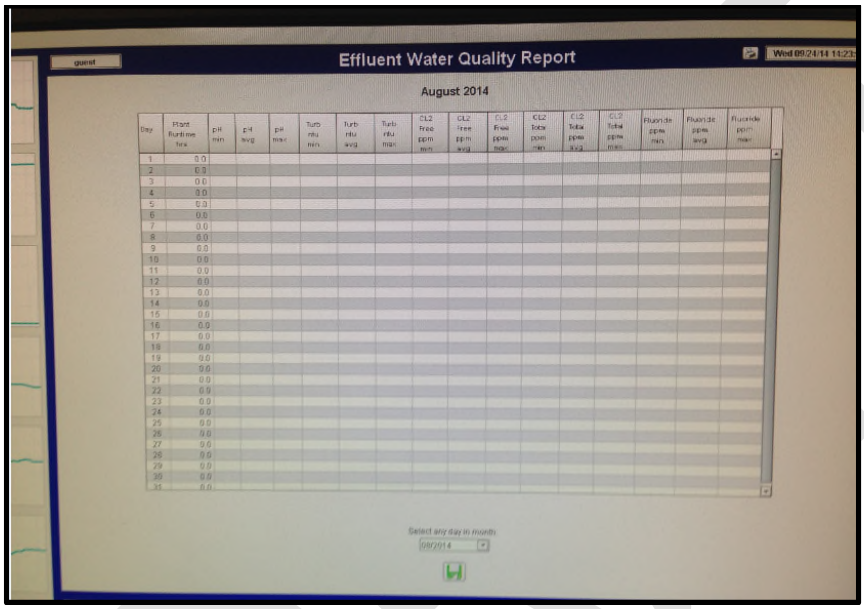

Figure 15 - Effluent Quality HMI Report

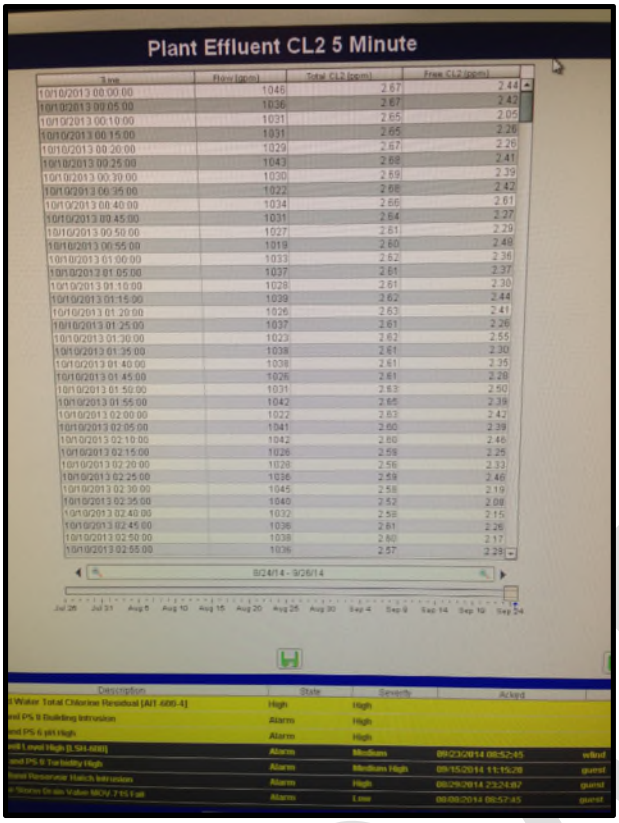

Figure 16 - Plant Effluent Chlorine 5 min Average Report

HMI Pre-canned Trends

There are a set of pre-canned trends that have been developed for final effluent water quality. These include trends of pH, turbidity, conductivity, chlorine and fluoride.

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Figure 17 - Pre-canned treated water quality trends.

This data is used by operators for review of performance, but to our knowledge is not included in any other reporting.

HMI Custom Trends

It is possible to generate additional custom trends on the HMI for any of the on line analyzers that provide data in to the SCADA system. On option, regularly used by operators, is a trend that is available when mouse clicking on the analyzer to provide an up to date recent trend. It is typically used for short term operational review or operational troubleshooting.

A second option is the extraction of data via customized trends. It was not clear how this could be extracted from the HMI, although data was provided by the plant SCADA contractor to Hazen and Sawyer to provide membrane system performance trends. It is a typical function of all HMI systems, and may be located at a higher security level than is typically set during plant operation.

Recommendation: Customized trending is a very important diagnostic tool, and we recommend that this feature be enabled and operations staff trained in its use.

Regulatory Water Quality Monitoring

Water quality regulatory requirements for the plant can be complex to navigate, being based on numerous regulatory requirements which are not always documented by agencies in a format that is convenient to navigate. As a part of our review, we worked to cross check that all of the water quality regulatory requirements were being met, and were clearly documented.

In our search, we noticed that there were several internal sources of information that documented the requirements of water quality regulatory reporting. Commendably, the Water Quality Specialist had already begun tackling this issue, and has developed a Water Quality Sampling Manual, to capture all of the required regulatory sampling, monitoring and reporting. This is a work in progress, and we have included a cross-check in the tables below outlining the water quality requirements, and where these are documented, including if this is currently documented in the Sampling Manual.

As discussed previously in this report, we also noted some regulatory reporting requirements noted in the OMMP, although these appeared to be out of date.

In addition to treated water quality, there is also regulatory water quality monitoring required at each of the feed wells, within the water treatment plant, and also within the distribution system. Working with the Water Quality Specialist, we put together the tables below, which document what needs to be reported, how often, for which agency, and where this is currently documented in Beverly Hill's document system.

We have not provided in this section a comprehensive review of water quality performance, but rather focused on ensuring that reporting requirements are captured, and clear. The tables below detail our review of regulatory sampling, analysis and reporting for the water treatment plant, groundwater wells and distribution system. They list:

- What needs to be measured/reported?
- How often does it need to be measured/reported?
- Which agency/regulatory authority requires it, and in what permit/regulation?
- Where is this currently documented in the City's system?
- Is it listed in the new sampling manual?
- Did we sight the corresponding report delivered to the regulatory/permitting authority?

Recommendation – We recommend that the tables below be incorporated into a Water Quality Management Plan or Sampling plan as a checklist of all regulatory requirements.

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Water Quality Regulatory Sampling Requirements

Water Treatment Plant Requirements.

Water Treatment Plant	Parameters Measured	Frequency of Sampling (and reporting)	Agency and location.	Where in Beverly Hills Documentation	Listed in Sampling Manual	Report to SWRCB Sighted?
RO Effluent (Prior to Blending) PS Code 1910156-016	TDS (Total Dissolved Solids) HPC (Heterotrophic Plate Count) Total Coliform Sulfate Manganese Chloride Fluoride Arsenic	Weekly (Reported Monthly)	State Water Resources Control Board (formerly CDPH). Permit 04-15-03P-003 Table 6. Fluoride Permit Amendment 1910156PA-003 Table 6.	Listed in OMMP Page 7-14 for all but Fluoride and Arsenic. Arsenic - covered by Arsenic Blending and Treatment Plan part V Monitoring and Reporting. Fluoride listed in OMMP.	No	Yes
Plant Effluent combined treatment plant effluent after disinfection. PS Code 1910156-017	TDS (Total Dissolved Solids) HPC (Heterotrophic Plate Counts) Total Coliform Sulfate Manganese Chloride Fluoride Arsenic	Weekly (Reported Monthly)	State Water Resources Control Board (formerly CDPH). Permit 04-15-03P-003 Table 6. Fluoride Permit Amendment 1910156PA-003 Table 6.	Listed in OMMP Page 7-14 for all but Fluoride and Arsenic. Arsenic - covered by Arsenic Blending and Treatment Plan part V Monitoring and Reporting. Fluoride listed in OMMP.	No	Yes

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Water Treatment Plant	Parameters Measured	Frequency of Sampling (and reporting)	Agency and location.	Where in Beverly Hills Documentation	Listed in Sampling Manual	Report to SWRCB Sighted?
Plant Influent - combined raw water prior to RO treatment process PS Code 1910156-018	Arsenic Fluoride H_2S	Requirements not clear	Fluoride Permit Amendment 1910156PA-003 Table 6.	OMMP covers arsenic. Fluoride in revised permit. H_2S is by choice of the plant.	No	Yes
4-Log Virus Inactivation	Minimum free chlorine residual by on line analyzer.	Monthly	Permit Amendment 1910156PA-003 Condition 24	There is a CT spreadsheet used for calculation and reporting SWRCB. This is not documented in any procedures to our knowledge. (Note, we uncovered some minor errors in the spreadsheet which we have alerted to the Water Quality Specialist).	No	Yes

Recommendation – we note that HPC and coliforms are currently reported in the RO effluent. An RO unit's prime role in the plant is TDS/hardness reduction, and not microbiological removal. Given the fact that a portion of flow bypasses the RO in any case, and that there is now a CT managed in the clearwell to ensure 4 log virus inactivation, we recommend that the SWRCB be approached to remove this regulatory requirement. It is not uncommon for bacteria to be present in RO systems even in groundwater applications, especially as these usually do not have a continuous disinfection process. As many disinfectants (particularly chlorine) are not compatible with RO membrane materials, it is not practical to manage disinfection across the RO unit. Biological activity at the RO unit should be reviewed instead in the context of membrane fouling.

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Well Monitoring.

In addition to the water quality sampling within the plant, the wells are also monitored in line with permit requirements. The table below summarizes the regulatory reporting requirements for the wells, and again cross checks these with current documentation.

Well Monitoring	Parameters Measured	Frequency of Sampling and Reporting	Agency and location.	Where in Beverly Hills Documentation	Listed in Sampling Manual	Report to SWRCB Sighted?
Monthly requirement	TDS (Total Dissolved Solids) HPC (Heterotrophic Plate Counts) Total Coliform Sulfate Manganese Chloride Arsenic Fluoride Dissolved H_2S	Monthly	CDPH Amendment 1910156PA-003 Condition 7 (This refers to Title 22, Chapter 15, CCR and Vulnerability Assessment and Monitoring Frequency Guidelines).	Sampling Plan OMMP Arsenic blending plan (attached to OMMP)	Yes.	Yes

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Well Monitoring	Parameters Measured	Frequency of Sampling and Reporting	Agency and location.	Where in Beverly Hills Documentation	Listed in Sampling Manual	Report to SWRCB Sighted?
Annual Requirement	Benzene Carbon Tetrachloride 1,2-Dichlorobenzene 1,4-Dichlorobenzene 1,1-Dichloroethane 1,2-Dichloroethane 1,1-Dichloroethylene cis-1,2-Dichloroethylenetrans trans-1,2-Dichloroethylene Dichloromethane 1,2-Dichloropropane 1,3-Dichloropropane Ethylbenzene Methyl-tert-butyl ether (MTBE) Monochlorobenzene Styrene 1,1,2,2-Tetrachloroethane Tetrachloroethylene Toluene 1,2,4-Trichlorobenzene 1,1,1-Trichloroethane 1,1,2-Trichloroethane Trichlorofluoromethane 1,1,2-Trichloro-1,2,2-trifluoroethane Trichloroethylene Vinyl chloride Xylenes Nitrates	Annually (Monthly if detected above MCL, quarterly if detected).	CDPH Amendment 1910156PA-003 Condition 7This refers to Title 22, Chapter 15, CCR and Vulnerability Assessment and Monitoring Frequency Guidelines. (Need to confirm most up to date monitoring guidelines. Appendix H in Permit is shown valid until 2004 – with no subsequent permit changes). Recommend regular review prior to each sampling run that	Sampling Manual OMMP	Yes	No

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Distribution Monitoring.

Regular distribution modelling is also required. This is probably the highest burden for operators given the number and frequency of sampling, and has been the result of regulatory reporting non-compliance in the past. The table below outlines the routine sampling requirement, the Stage 2 DBP Rule requirements and lead and copper requirements.

The routine sampling in particular is well documented in the new Sampling Manual.

Distribution System	Parameters Measured	Frequency of Sampling and Reporting	Agency and location.	Where in Beverly Hills Documentation	Listed in Sampling Manual	Report to SWRCB Sighted?
Routine Sampling The City is required to collect a minimum of twenty one (21) Bac-T samples, seven (7) general physical, seven (7) fluoride and ten (10) nitrite samples each week. DHS has approved a sampling plan that insures at least one sample from each pressure zone is recovered each month.	Bac T at 21 locations.	Weekly (Tuesdays)	2.6.3.4 original permit Permit (original) 12 weekly samples among 19 locations. Now at all 21 locations by choice.	Sampling Manual. Not noted in the OMMP.	Yes	Yes
	General Physical 5 locations in distribution system and additionally 2 MW connections.	Weekly (Tuesdays)	2.6.3.4 Original permit. Requires 4 locations in the distribution system. Includes temperature, color, odor and turbidity.	Sampling Manual.	Yes	Yes
	Fluoride	Weekly Split sample (Tuesday) Daily (one of the four locations)	Condition 33, amended permit	Sampling Manual (to be updated for daily).	Yes	Yes
	Nitrite	Weekly (Tuesdays)	Original permit.	Sampling manual.	Yes	Yes

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Stage 2 DBP Rule Samples recovered to insure compliance with the Surface Water Treatment Rule as it applies to the stage II Disinfection/Disinfectants By-Products Rule D/DBPR. Samples are recovered at the same locations as the general physical samples with at least four samples representing water with the maximum residence time in the distribution system.	TTHM, HAA5	Quarterly (taken on third week of the month)	Stage 2 DBPR and letter from CDPH noting that plant is at stage 2.	Sampling manual.	Yes	No
Lead and Copper	Lead, Copper. Based on a certain number of customers	3 years	EPA	Not captured.	No	No

Brine Waste Monitoring.

Brine discharge to the sanitary sewer is sampled quarterly and reported to LA County Sanitation District. Requirements are shown below.

LACSD	**Parameters Measured**	**Frequency of Sampling and Reporting**	**Agency and location.**	**Where in Beverly Hills Documentation**	**Listed in Sampling Manual**	**Report to LACSD Sighted**
LACSD (Brine)	pH Oil & Grease Total Dissolved Solids Total Cyanide Amenable Cyanide Arsenic* Lead* Nickel* Copper* Cadmium* Silver* Zinc*	Quarterly Annual summary report.	Self-monitoring for LACSD.	Sampling Plan	Yes.	No

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	Total Chromium* *Composite Sample					

National Pollutant Discharge Elimination System (NPDES) Reporting

NDPES sampling is required on a quarterly basis from the wells, and monthly if there is a spill to storm water from wells during that month. This is documented in the Sample Manual.

NPDES	Parameters Measured	Frequency of Sampling and Reporting	Agency and location.	Where in Beverly Hills Documentation	Listed in Sampling Manual	Report to NPDES Sighted
NPDES (Wells)	pH TDS (Total Suspended Solids) Turbidity BOD (Biological Oxygen Demand) Settable Solids Oil & Grease Total Sulfides Total Phenols MBAS Copper Residual Chlorine Total Total flow to the storm water collection system in Million Gallons (MG)	Monthly (if discharge occurs). Quarterly	NDPES Permit # CI-8509 RO Water Treatment Plant	Sampling Manual Not mentioned in OMMP	Yes	No
	Acute Toxicity (EPA 600/4-90/027)	Annually	NDPES Permit # CI-8509 RO Water Treatment Plant	Sampling Manual Not mentioned in OMMP	Yes	No

In addition to the wells, samples are taken monthly, quarterly and annually from the parking structure on N Crescent Drive from the storm water collection system. Requirements are listed below.

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NPDES	Parameters Measured	Frequency of Sampling and Reporting	Agency and location.	Where in Beverly Hills Documentation	Listed in Sampling Manual	Report to NPDES Sighted
NPDES (Site A South Storage Area)	pH TDS (Total Suspended Solids) Turbidity Oil and Grease BOD (Biological Oxygen Demand) Residual Chlorine Selenium Temperature Total Flow to the storm water collection system in Gallons per Day (GPD)	Monthly	NDPES Permit CI-6684	Sampling Manual	Yes	No
	pH TDS (Total Suspended Solids) Turbidity Oil and Grease BOD (Biological Oxygen Demand) Settable Solids Sulfides Phenols MBAS Residual Chlorine Selenium Temperature Total Flow to the storm water collection system in Gallons per Day (GPD)	Quarterly	NDPES Permit CI-6684	Sampling Manual	Yes	No
	Turbidity Total Suspended Solids	Annually	NDPES Permit CI-6684	Sampling Plan	Yes	No

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	Oil and Grease BOD Settable Solids Total Sulfides Total Phenols Chlorine Residual MBAS Selenium pH Acute Toxicity EPA 600/4-90/027					

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Internal Plant Process Water Quality Monitoring

In addition to regulatory water quality requirements, there are important additional internal water quality sampling and analysis requirements both in well feed water and internal to the process plant that are important to ensure that the systems are operating optimally, and to manage risk to those items.

A number of these are recorded on the weekly operating log sheet, and are available to view as trends on the HMI system (although most are not configured as pre-canned trends). However, there is no regular reporting of these parameters to provide a longer term review of how the plant and systems are operating.

We recommend that the following performance data be recorded and trended over time to monitor ongoing performance of specific plant areas/parameters.

Plant Area/Process	Specific Parameter	Frequency	Importance
Wells	Full Plant feed analysis [(1)] including cations/anions, suspended solids and pH.	Quarterly	It is important to regularly review a full cation and anion balance of the water to compare water quality against initial design considerations, as well as providing a check for potential RO performance risks (such as risk to treated water quality, and risk of scaling).
RO Feed	Full Plant feed analysis[(1)] including cations/anions, suspended solids and pH.	Quarterly	As above. Note that a change in well blend ratios will alter feed chemistry to the RO, and hence we need to review the range of possible chemistries that may impact the RO. While this water quality could be estimated based on a mass/flow balance of the operating wells, we recommend that an actual RO feed sample be taken as a confirmation.
RO Feed	Silt Density Index	Daily	This is currently conducted, however is not performed following the standard method [(2)].
RO Feed	pH	Daily	Important to check to minimize scaling risk and necessary for downstream pH target.
RO Permeate	pH, Alkalinity, H_2S	Daily	Useful as a check in performance of the stripping towers.

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Bypass Stripping Tower Feed	pH, Alkalinity, H_2S	Daily	Useful as a check in performance of the stripping towers.
RO Permeate Stripper Sump	pH, Alkalinity, H_2S	Daily	To ensure performance of H_2S stripping – taste and odor.
Bypass Stripper Sump	pH, Alkalinity, H_2S	Daily	To ensure performance of H_2S stripping – taste and odor.
Scrubber	Hardness	Weekly	Ensure softeners are maintaining sufficiently low hardness to prevent scaling in the scrubber unit.
Plant Effluent	Calcium hardness, alkalinity, pH, TDS	Weekly	Used to calculate water stability index (LSI or CCCP) to ensure risk of concrete erosion is minimized.
Clearwell Effluent	Calcium hardness, alkalinity, pH, TDS	Weekly	Used to calculate water stability index (LSI or CCCP) to ensure risk of concrete erosion is minimized.

(1) Recommended Water Quality Plant Feed Analysis

Cations		**Anions**	
Sodium	mg/L	Chloride	mg/L
Potassium	mg/L	Sulfate	mg/L
Calcium	mg/L	Bicarbonate	mg/L
Magnesium	mg/L	Nitrate	mg/L
Iron	mg/L	Fluoride	mg/L
Manganese	ug/L	Silica	mg/L
Barium	mg/L	Phosphate	mg/L
Strontium	mg/L	TOC (Total Organic Carbon)	mg/L
Aluminum	mg/L	pH	
Arsenic	ug/L	Suspended Solids	mg/L
Boron	mg/L	Sulfides	mg/L

(2) Silt Density Index

The silt density index is a standard measure that has been developed to assess the plugging rate of a filter. It is used as a guide to determine the likelihood of fouling of the RO membranes from particulate matter. The test operates using a supply of RO feed water delivered at 30 psi across a 0.45 micron filter. A very simple test, water is run through the filter for 15 minutes. At the start of the test, the time required to fill a 500 mL measuring cylinder is recorded. At the end of 15 minutes, the time required to fill a 500 mL measuring cylinder is again recorded. Note that this is a recognized standard, and hence the pressures and volumes described here must be adhered to.

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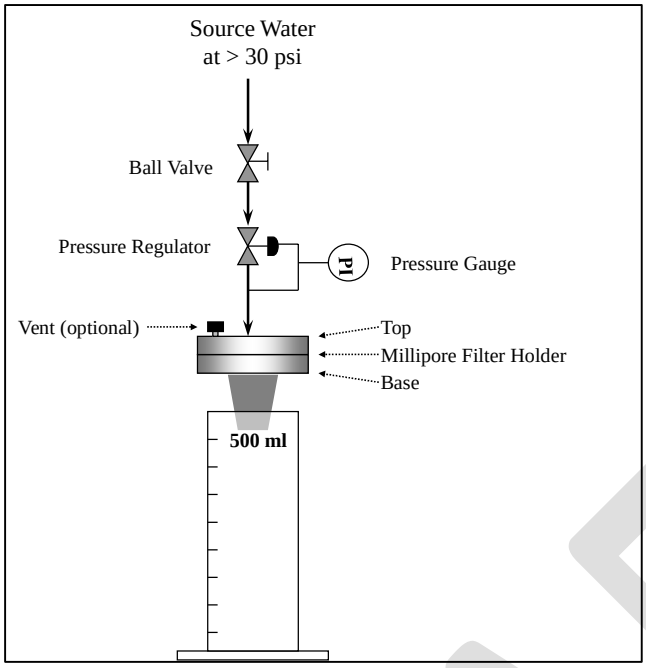

The SDI is calculated from the following formula:

$$SDI_{15} = \frac{100\,(1 - T_1/T_2)}{15}$$

Where T1 = the time to fill the cylinder at time zero and T2 is the time to fill the cylinder at time 15 minutes.

The RO membrane warranty will usually specify that RO feed water remains below a specific SDI value, which is typically between 3.0 and 5.0 depending on the water source and warranty provisions.

Figure 18 - Plant SDI Apparatus

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Analyzer Calibration and Verification

Highly automated plants such as this RO plant rely heavily on the accuracy and reliability of water quality analyzers. It is very important, therefore, to be confident that the analyzers are reading correctly. Therefore, it is important that there is regular calibration of the instruments (where the analyzer is reset against a known standard) and regular verification (where the analyzer is regularly checked against a probe or on site laboratory test).

As previously discussed, a list of calibration frequencies have been listed in the OMMP.

Recommendation: We recommend that a calibration and verification schedule be established for analyzers, based on vendor recommendation and operational experience. This should include both a schedule of calibration and verification, and check sheets for each analyzer which can be kept as a record.

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Water Quality Reporting

There is a great deal of water quality information that is reported both on the weekly operating log, from on line analyzers at the HMI, and in regulatory reports – mentioned above.

However, the data is not easily available, and is not regularly trended (except for the limited data at the HMI). We recommend that important water quality data be produced in trended reports to allow identification of any potential issues, and assistance for troubleshooting and optimization.

Well Water Quality

Water quality from each of the wells is analyzed monthly as described previously. We recommend that this data be regularly trended, to allow identification of some of the main water quality risks to performance, and to contrast water quality against original from plant design assumptions.

The data below shows trended feed water quality from each of the four operating wells. This is particularly useful, for example we can see significant fluctuation in the level of arsenic in well 4, which is vitally important as a part of the plant's arsenic management strategy. By presenting the data in a graphical format, it is easier to identify any trends and understand the extent of possible fluctuations.

On each chart, a black line provides an estimated theoretical blended value, calculated from a simple mass balance based on the flow contribution from each well. This provides estimated concentrations for plant feed water, and will be helpful where this is not already measured.

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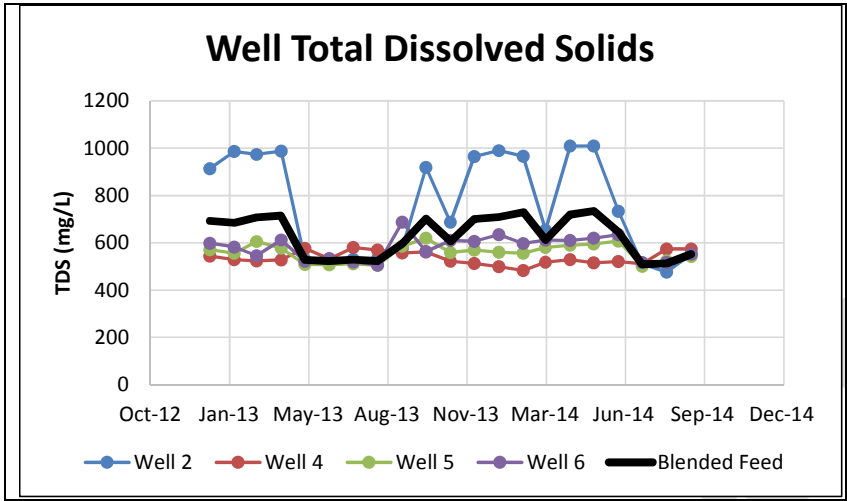
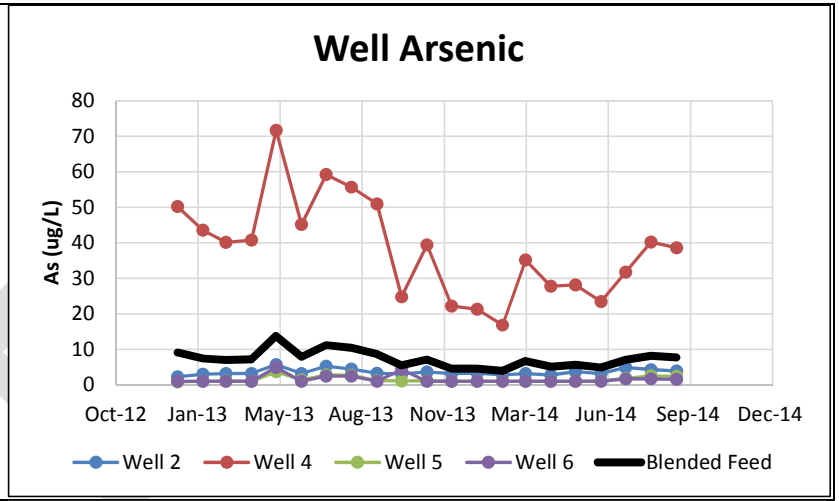
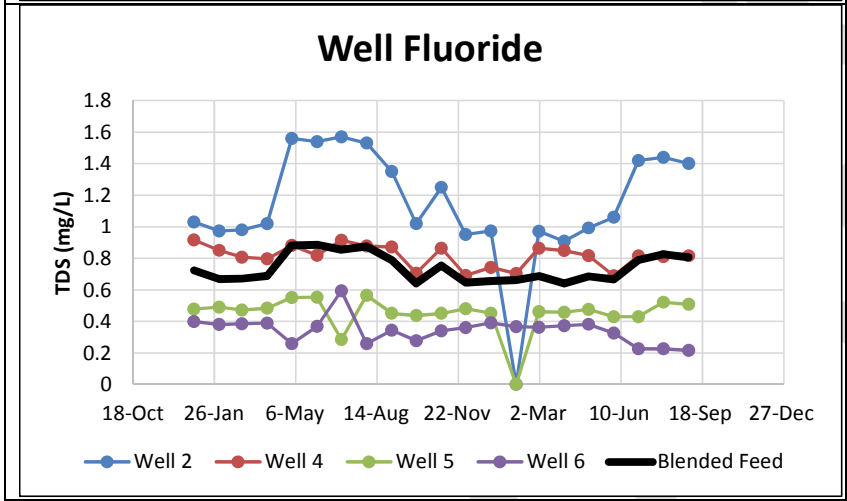
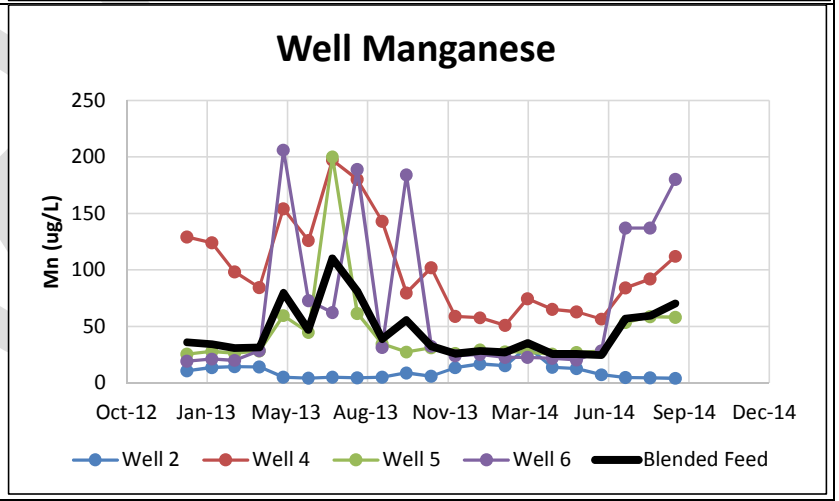

Well Total Dissolved Solids
TDS (mg/L)
1200
1000
800
600
400
200
0
Oct-12
Jan-13
May-13
Aug-13
Nov-13
Mar-14
Jun-14
Sep-14
Dec-14
Well 2
Well 4
Well 5
Well 6
Blended Feed


Well Arsenic
As (ug/L)
80
70
60
50
40
30
20
10
0
Oct-12
Jan-13
May-13
Aug-13
Nov-13
Mar-14
Jun-14
Sep-14
Dec-14
Well 2
Well 4
Well 5
Well 6
Blended Feed


Well Fluoride
TDS (mg/L)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
18-Oct
26-Jan
6-May
14-Aug
22-Nov
2-Mar
10-Jun
18-Sep
27-Dec
Well 2
Well 4
Well 5
Well 6
Blended Feed


Well Manganese
Mn (ug/L)
250
200
150
100
50
0
Oct-12
Jan-13
May-13
Aug-13
Nov-13
Mar-14
Jun-14
Sep-14
Dec-14
Well 2
Well 4
Well 5
Well 6
Blended Feed

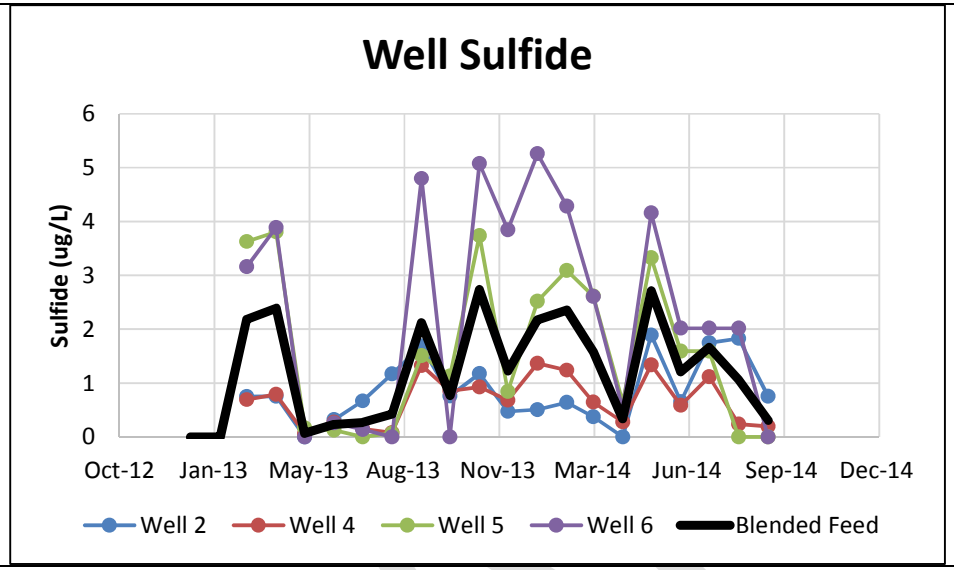


Figure 19 Well Water Quality 2013 – 2014

Plant Influent Quality

Plant influent quality is also measured weekly for arsenic, fluoride and sulfide. We additionally recommend that these data are regularly trended also to provide an indication of water quality into the plant. Trends for 2013 to 2014 are shown below.

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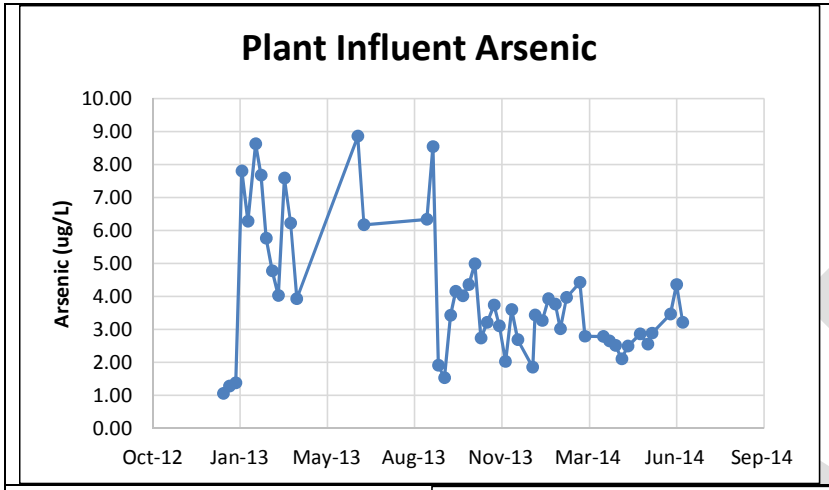
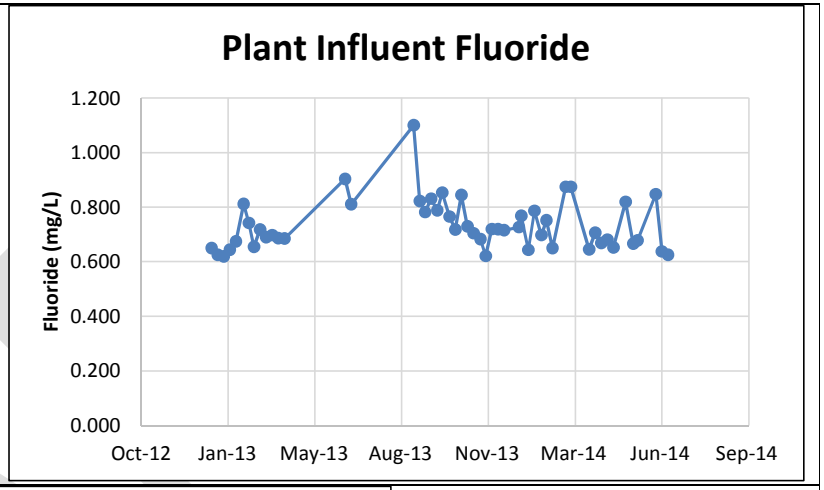
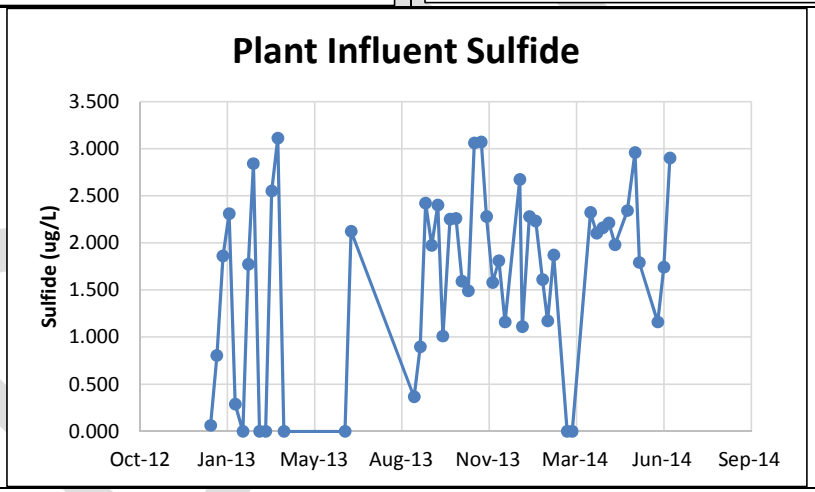
Table 3 - Plant Influent Water Quality 2013 - 2014





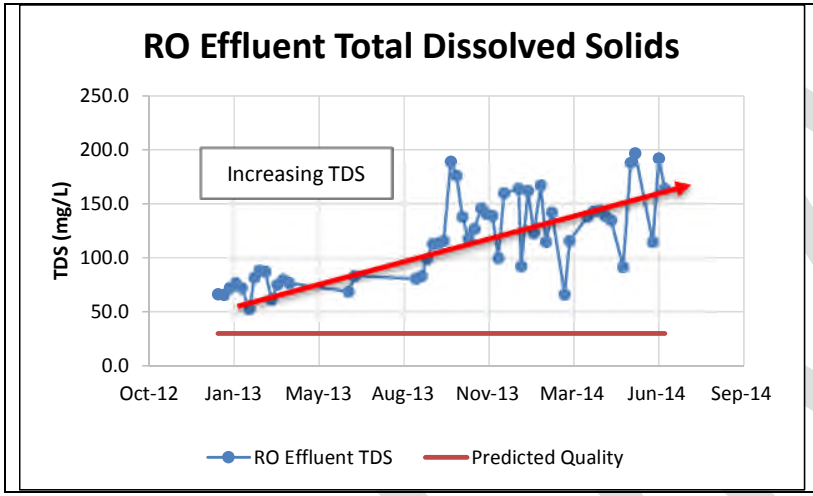


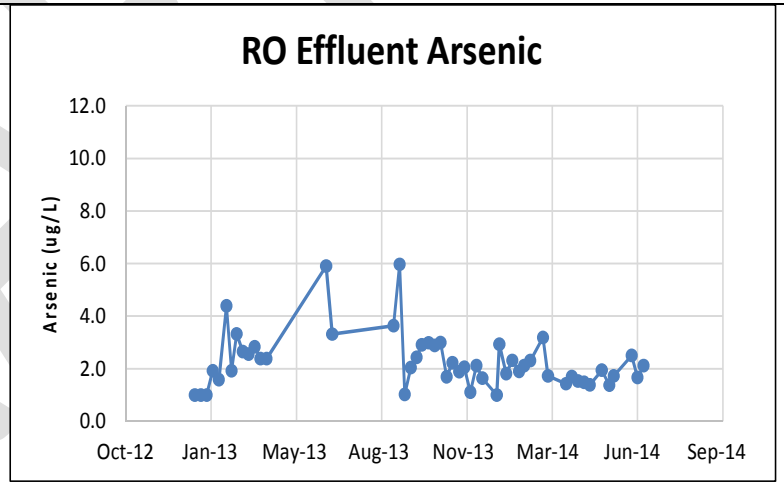
RO Effluent Quality

RO effluent quality is also monitored weekly for a number of parameters as described earlier. As for plant influent and plant final effluent, we strongly recommend the trending of these parameters. They show quite clearly a substantial increase in RO permeate TDS, a result of worsening of performance of the RO membranes over the course of 2013 – 2014.

We have compared the RO Effluent total dissolved solids (TDS) actual results against the result anticipated from RO system projection software. The measured TDS has been measured up to 3-4 times higher than anticipated. This is a very poor result for membrane performance, and may be a result of significant membrane damage. We understand that some membranes are currently being autopsied which may provide some indication of what may have occurred.

Similar trends in performance for other parameters, which is increasing the likelihood of a failure of overall treated water quality.





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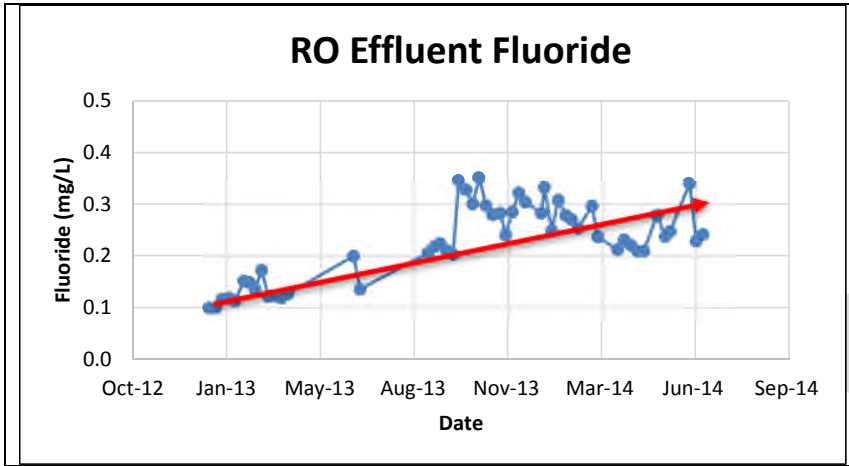
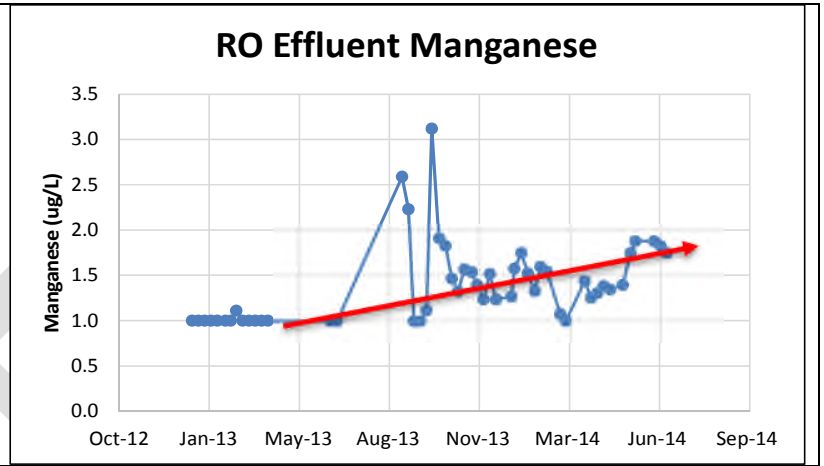
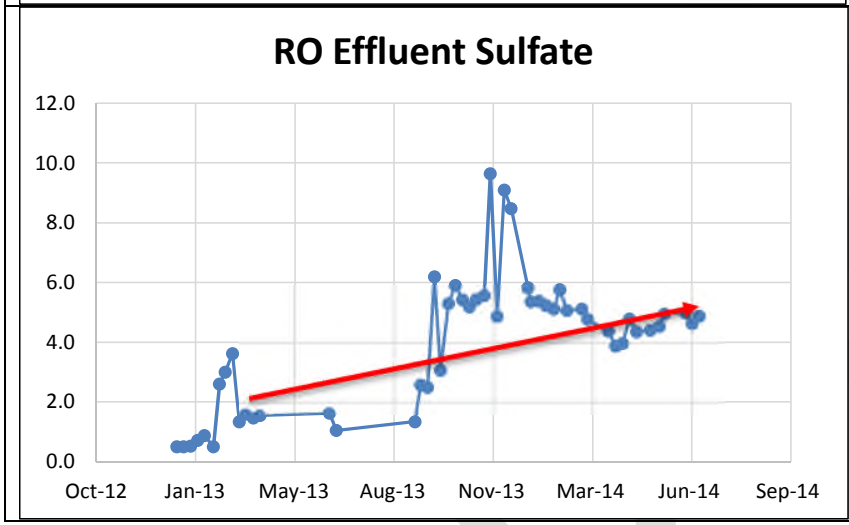
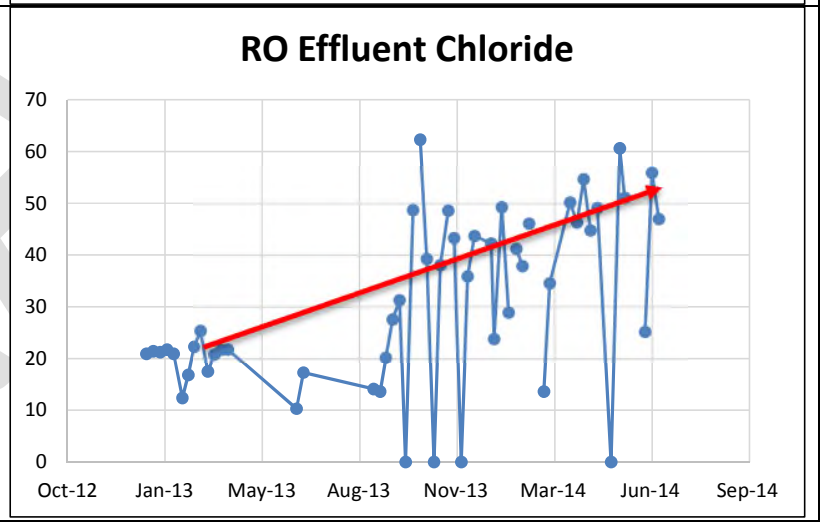








Final Effluent Quality

Details of final effluent quality have been provided in the Plant Performance Targets section above.

Water Quality Management Documentation

Water quality management documentation consists of the Sampling Manual (being developed by the water quality specialist), several specific sampling and analysis standard procedures, a sampling schedule, and the regulatory reports themselves (described above).

Additionally, the OMMP provides details of both internal and regulatory sampling and analysis (discussed previously), however some of these are out of date and don't reflect current practice.

Sampling Schedule

A sampling schedule is included in the overall Water Distribution/System Team schedule (see below). This notifies what sampling is to be conducted for each shift, and acts as a checklist for regulatory sampling.

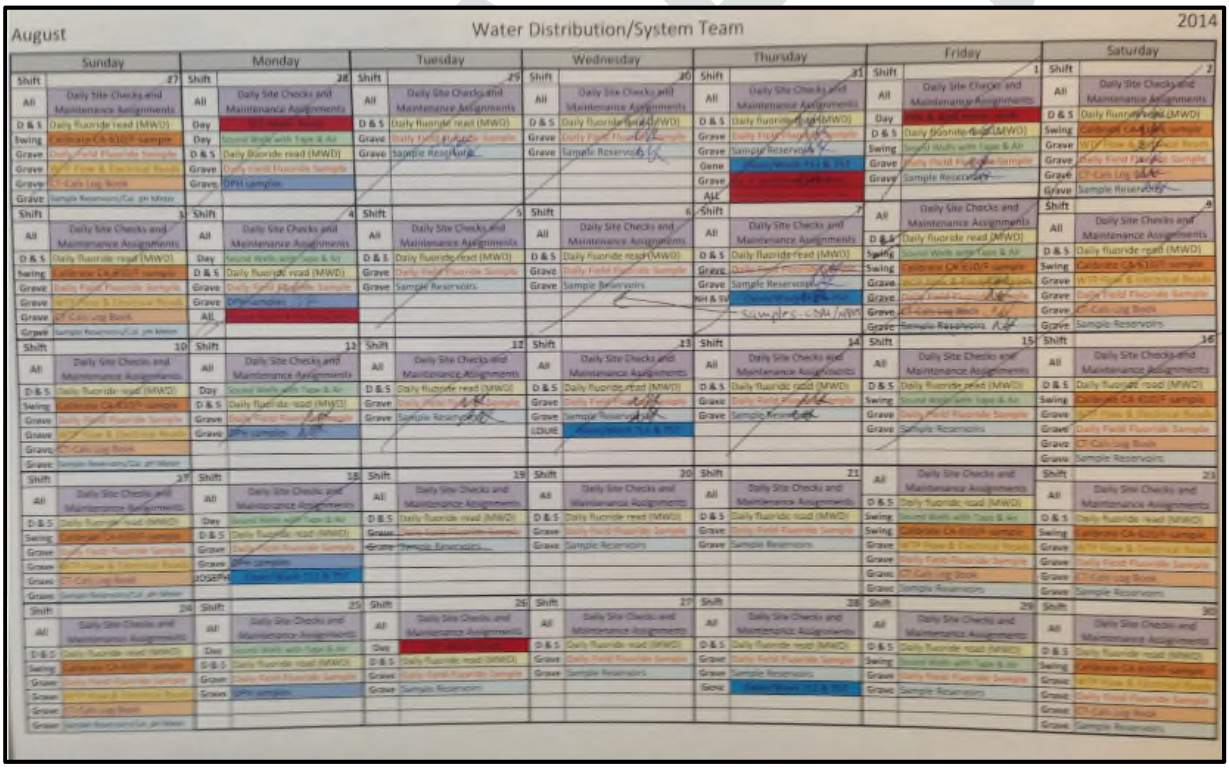


Figure 20 - Water Distribution/System Team Schedule identifies sampling requirements per shift.

This document is a helpful guide for operations staff. This advises what is required for operators on their particular shift. A further recommendation is to provide a "handshake" system whereby there is a confirmation provided of the sampling event having occurred. This can be in the form of a daily or weekly check list with a confirmation provided by the operator

when the sample has been taken and correctly stored or analyzed. Once the sample is taken, the chain of custody documentation will follow the sample through to completion.

Chains of Custody

The City has implemented chain of custody documentation for all external sampling and analysis requirements. This appears to work well and is used effectively in handling samples from site to the external laboratories. Several of these were sighted during the plant review and appear to be working well.

Recommendation: To provide greater surety that samples have been taken when required on a specific shift, we recommend that a "handshake" system be adopted to ensure sampling has occurred when required. This could take the form of a sampling check or shift log checklist which is completed by operators and communicated to the plant supervisor and/or water quality specialist.

Recommendations on Water Quality Management

The work that has been done in developing the Sample Manual, sample schedules and Chains of Custody documentation has been helpful in ensuring that samples are taken correctly, handled correctly, taken at the correct time.

The next step in ensuring effective water quality management is to bring all of this information together into one overall plan.

Recommendation: We recommend that the City develop a Water Quality Management Plan (WQMP) to incorporate all of the requirements of water quality management in the one document. This could be a stand-alone document, or it could be incorporated into the OMMP. It may be useful to develop a stand-alone document initially to enable the staff to "road-test" it, prior to incorporation into a regulatory reviewed document.

Items that would be included in the WQMP should be:

- Clear definition of water quality targets including both regulatory and plant performance targets.
- Important water quality targets within the process.
- Current Chains of custody documentation.
- Sampling procedures for all sample points including details of sample bottles, labelling, preservation, storage and any duplicate testing.
- Types of Samples. e.g. Grab, composite
- Proper sampling technique
- Labeling requirements
- Chain-of-Custody requirements/procedures

- Sample locations
- Sample frequency
- Sample schedules.
- Reporting templates.
- Operator knowledge requirements.
- Roles and responsibilities for sampling and analysis.
- Correct type of sample for each constituent of interest
- Process vs Regulatory sampling/testing

An important aspect of managing this document will be the introduction of effective version control, to ensure that any old documents are effectively superseded and updates to operation, sampling and reporting are effectively communicated.

Recommendation: We recommend that water quality reports be developed for effective internal communication of performance to operations staff and management. This should be for both regulatory requirements, but also importantly plant operational performance requirements. This is often effectively communicated in a dashboard type report, with simple indication of water quality acceptance or non-conformance, and provides an indication to operations staff if requirements are on target and being met.

Plant Performance Monitoring and Reporting

Overall, a great deal of data is monitored and recorded at the plant, both at the HMI system, but also via operator log sheets, water quality sampling and analysis, flow logs, energy logs and operator log books.

While a great deal of data is available, there do not appear to be many reviews of performance trends in the medium to longer term. Without a method of reviewing operational information in this way, the operations team can become data rich, but knowledge poor. Data is useful when it can be communicated for effective decision making. One of the overall recommendations on review of the plant operations, is that plant monitoring be greatly developed to ensure that operations are able to notice trends of performance, identify potential issues and importantly identify options for optimization.

Plant Dashboard Reports

An effective way at providing useful important data at a glance is the development of dashboard reports. The intent of these reports is to provide information “at a glance” to quickly highlight key areas of operational importance, identify problem areas that need to be addressed, and review plant overall compliance.

An example dashboard, developed for a recycled water plant, is shown below. At a glance, it can provide monthly production, plant (or RO) recovery, energy consumption and water quality

compliance. These can be relatively easily configured, and will use data that is already gathered at the site.

Providing information in this way is also very empowering for operations staff, to allow them to see the targets they are aiming for, and to see improved performance demonstrated when it is achieved.

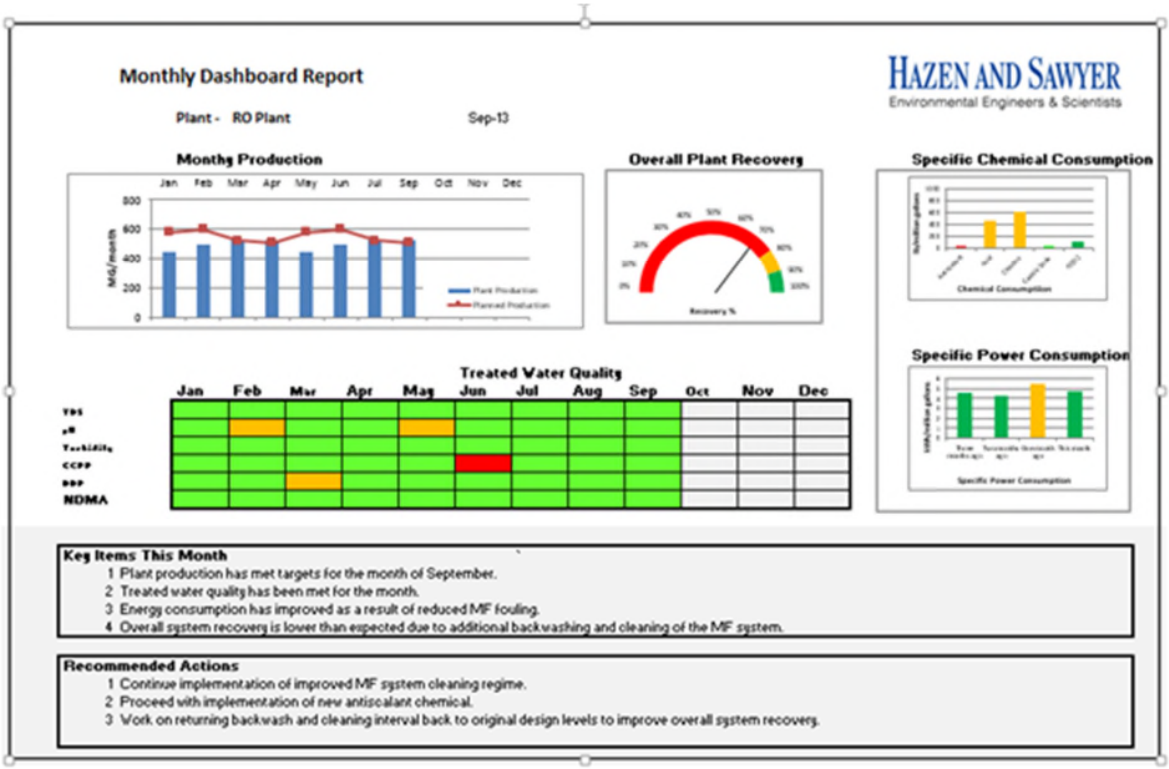


Figure 21 - Example Performance Dashboard Report

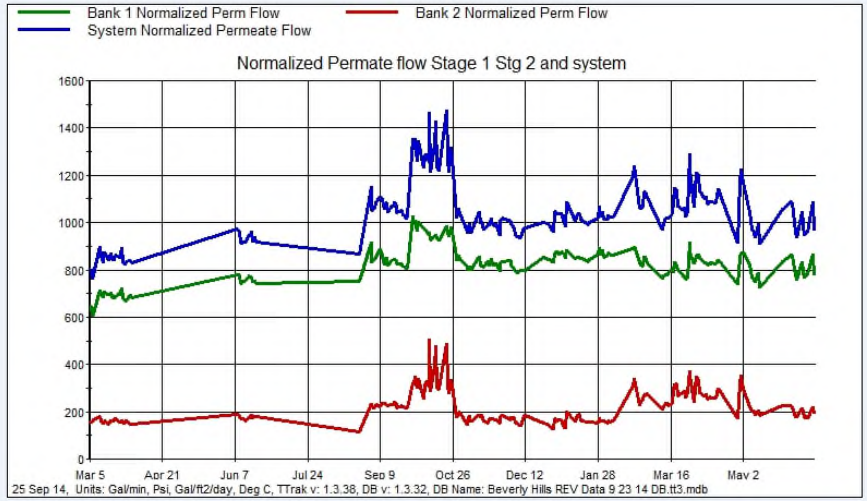
Recommendation: A series of dashboard reports be configured to allow "at a glance" review of plant performance.

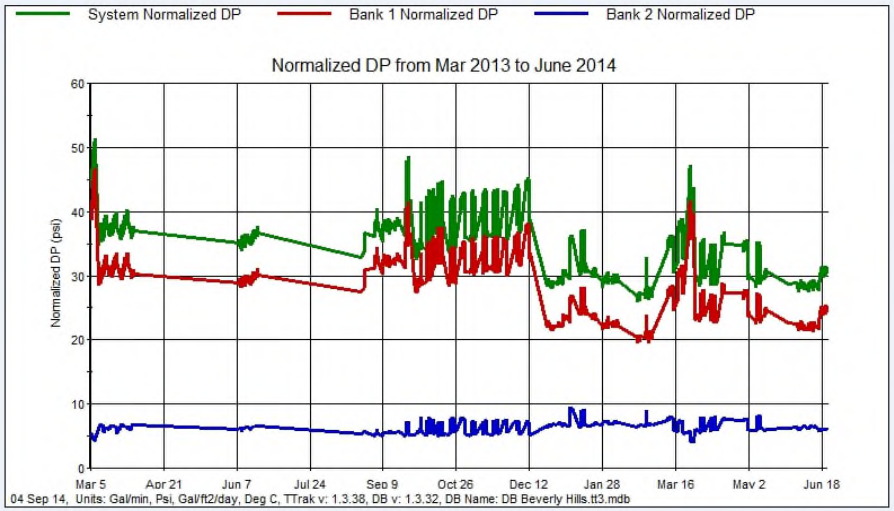
Reverse Osmosis System Normalization

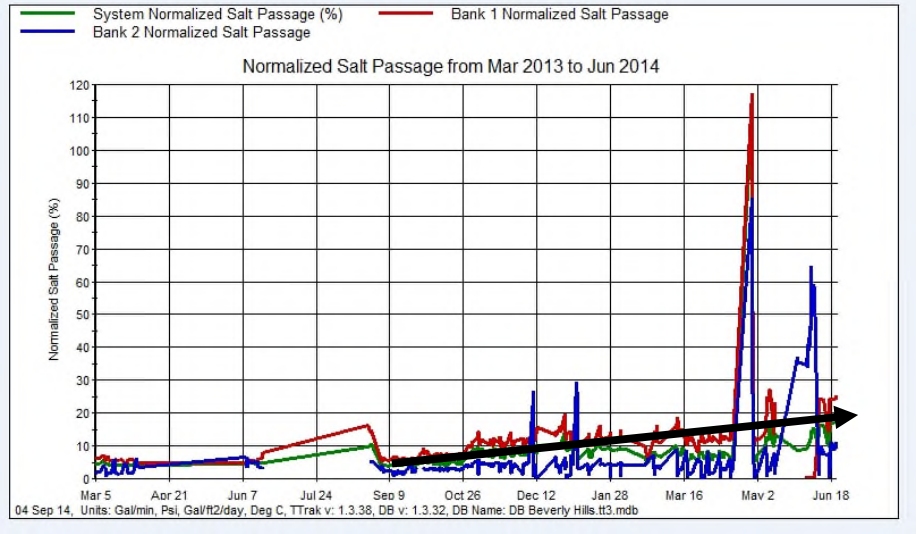
In order to accurately review the performance of the RO system, the operating data must be normalized, to take into account effects such as temperature, flow variation and TDS variation so that actual membrane condition is not masked by normal membrane operating phenomena.

Normalization provides a "correction" of operating data, filtering out these affects, and comparing performance to an original baseline condition to provide a more accurate picture of how the membranes are performing. It is very important that this data is logged and normalized, and provides the basis for the decision to clean membranes, and ultimately to replace them.

Table 4 - Normalized RO Data, Using Toraytrak Software







The three charts provided in Table 4 have been developed using data gathered from the HMI and using Toraytrak™ software from Toray Membranes. RO normalization can be performed using membrane supplier's software (usually available free on the internet) or developed independently on an excel spreadsheet. Ideally, the calculations for normalization can be included in the HMI/SCADA and trends appear here automatically.

We understand that the normalization software at site had fallen into disuse, and so Hazen and Sawyer have re-established trending using this software using historical data, installed it on a City machine, and provided a standard operating procedure for its use. The software we have used at this time is Toraytrak™, however if another model membrane is selected for membrane replacement we can work to establish normalization for that model.

The three graphs shown include:

- Normalized permeate flow – this provides a flow rate compared to the original baseline, corrected for temperature and feed salinity. It has been performed on both individual stages as well as the unit overall. Generally, a trend downwards indicates an increased resistance to flow usually from some form of fouling or scaling. In the case above, normalized flow appears variable but with no discernible reduction overall. In fact, there may have been a reduction in flow resistance over time.

  This is not typical performance, and one hypothesis is that a lower resistance to flow may be related to a loss of membrane rejection. The membrane material may have become damaged to the extent that it provides less flow impedance.

  An additional item to note is that the permeate flow from the second stage is quite low. Typically we expect a flow rate approximately 40% to 50% of the first stage permeate flow. The lower than expected flow may be due to insufficient driving pressure at the hydraulic turbocharger, that provides additional boosting pressure to the second stage membranes. The backpressure is provided by the concentrate valve, which is currently not in operation on the unit, but rather is replaced with a restricted pipe spool.

  .

- Normalized Differential Pressure – this provides an indication of any resistance to flow or blockage on the feed/brine channel of the membrane. Higher normalized DP is usually an indication of fouling.

  In this case, it appears that there has been a gradual reduction in normalized differential pressure. This usually only occurs in cases where fouling has been successfully combatted. In this case, it is unclear if this is a true reduction in fouling, or if as for normalized flow it is indicative of damage to the membrane systems – with RO

membranes providing less resistance to flow.

- Normalized Salt Passage – this provides an indication of the RO system salt rejection capability.

  In this case, there is a very large increase in salt passage through the membranes. This is most likely indicative of membrane damage, o-ring leaks or both. As noted previously with the increase in RO permeate TDS, the salt passage is 3 to 4 times higher than at the start of the logging run.

  We note that membrane autopsies are currently under way which may confirm the condition of the membranes and provide insight into what has caused the potential damage.

Recommendation: We strongly recommend that normalized data be logged regularly to provide a clear indication of RO performance. Hazen and Sawyer have provided software and a procedure for this to take place.

Weekly Operating Log Sheet

A weekly plant operating log sheet is completed by plant operators at each shift (we note that during our review on our recommendation the frequency was reduced from once per shift to once per day). The log sheet contains over 130 items that are required to be logged each day. We have previously mentioned this log sheet in our discussion on water quality monitoring.

In general, we believe that there is too much information required on this log sheet, and that while a great deal of data is gathered, there is no evidence of much analysis of the data. We do agree that a checklist of items per shift is very important, however with too much information key important areas are hidden beneath the piles of data. Additionally, much of the data that is recorded is (or should be) available at the HMI where some of the key parameters could be trended to provide an easier visual guide to performance.

The log sheet appears to be a remnant of an on line excel spreadsheet as there are a number of calculations in the sheet. These are typically not filled out currently, and display a "#DIV/0!" where a calculation would otherwise have been.

Rather than list each individual item, we have provided an updated log sheet which we believe is sufficient for operations. In it, we have recommended a reduced frequency and a reduced number of parameters. We have identified a number of parameters which can be trended on

the HMI, rather than gathered on the spreadsheet manually daily – we recommend the effort be put into reviewing trends rather than gathering numbers.

We have also removed the daily monitoring of each RO pressure vessel. This testing is typically only performed on a weekly or even monthly basis, as a follow up to normalized data observations which provide a review of overall plant performance. It is commonly used as a troubleshooting exercise to identify o-ring leaks or damaged membranes within vessels. This is time consuming, and regular testing does not provide sufficient value at the current frequency.

The proposed revised Weekly Operating Log Sheet has been included as an appendix to this report.

Recommendation: Review the recommended Weekly Operating Log Sheet provided and work to implement in lieu of the current worksheet.

Flow Meter Reading Form.

A flow meter reading form records major flow rates in and out of the plant on a daily totalized basis. This form includes:

- Plant influent Flow
- Plant effluent flow
- RO Feed Flow
- Brine Discharge
- First and Second Stage RO Permeate

These are recorded on to a master spreadsheet with monthly tabs.

Recommendation: We recommend that these totalized flows be configured on the HMI/SCADA to provide an automated flow balance record.

We further recommend that a regular trend of plant influent flow, plant effluent flow and brine discharge be recorded in trend format to provide good tracking of plant production and waste volumes.

Electrical Reads

Electrical power consumption is recorded on a daily Electrical Reads spreadsheet. This records all electrical consumption within the building, and separates the plant consumption from other

unrelated items in the building. Electrical power consumption is useful if calculated as a power per unit volume of water produced.

Recommendation – Include a calculation to produce a kWH/1000 gallons or kWh/AF for water produced to provide a useful target for power consumption.

Non Conformances and Corrective Actions

It is important that operations teams continually learn from any plant or process non-conformances, safety incidents, operational mishaps or other operational problems that may occur. It is also important in many cases to communicate the issue, and corrective actions taken, to various stakeholders including plant management, City administrators, regulators and customers.

During our visits, there did not appear to be any formal process for managing non conformances and documenting corrective actions.

Recommendation: We recommend that a system of non-conformance and corrective action processes and procedures be developed. In particular we recommend the inclusion of:

- An incident management procedure – this details how to manage the incident process for any incidents. It assists in classifying what kind of incident it is, who needs to be contacted and by when, what needs to be reported and by when, and how any follow up investigation must be conducted.

- An incident report form – this provides a format to report the incident, document immediate actions taken and record communications of the incident.

- An incident investigation procedure – outlining how we can learn from the incident, and what changes to procedure have resulted.

During one of our visits we have shared a possible incident reporting and investigation process used at another facility, which could be used as a basis for development of a process for Beverly Hills.

Safety and Emergency Management

During the site visit, we worked to identify safety and emergency management processes or information. Some facilities develop specific safety and emergency management plans, which provide details on managing various safety aspects throughout the facility.

The safety of site staff, and the general public, is always a first priority for any organization. At the RO Water Treatment Plant, and in the distribution system, there are a number of inherent safety hazards including:

- High operating pressures.
- Dangerous chemicals.
- Working in restricted, confined spaces.
- Driving, particularly to and from distribution sampling and maintenance locations.
- Trip and fall hazards.
- Lifting hazards.
- Flammable materials.
- Earthquakes.

During the site visits, there appeared to be limited safety information available and in use by operations, with no overall safety plan at the site. As discussed previously, there was a small amount of information contained within the OMMP, although this is inadequate to sufficiently cover all safety issues. Other various pieces of documentation are available at the plant, including chemical MSDS, some chemical spill management plans, and some procedures.

Recommendation: We recommend that a more comprehensive safety plan be developed for operations at the Beverly Hills facility. This could either be included as a portion of a revised OMMP, or as a stand-alone document that may be referenced by the OMMP. The intention is not to create a large and unwieldy document, but rather to make sure that operations staff understand safety hazards, understand how to manage them and are able to manage through a safety emergency. Elements may include:

- Responsibilities and accountability within the organization for safety.
- Safety policies and regulation.
- Safety behavior.
- Safety goals and target measurement.
- Job safety and hazard assessment.
- Managing visitors and external contractors on site.
- Personal Protective Equipment (PPE) requirements.
- Safety training.
- Communication and consultation.
- Management of Hazardous Chemicals.
- Emergency management (chemical spills, accident, fire, earthquake etc).

- Change management (ensuring that safety is considered in any changes to plant, infrastructure or procedures).

Safety Items Noted During the Plant Visit

There were a number of items that were identified during the site visit that we believe may present an additional safety hazard for plant staff and visitors alike. Safety is the responsibility of everyone, and we raise these items to your attention in the best interests of safety for all.

Item	Description	Suggested Remedy
1	**Chemical Storage Tank level indication is not clearly visible from outside platform during chemical loading.** The indicator for ammonium hydroxide, sodium hypochlorite and sulfuric acid storage tanks are obscured behind the storage tank and cannot be viewed without entering the containment area. This is not desirable during chemical fill. This increases the risk of tank overflow during filling.	Suggest either a relocation of the panel to be more visible, or providing a second indication that can be viewed directly by the chemical loader. Review the possibility of a high level tank alarm to sound an alarm and/or flashing light.
2	**Chemical dosing pumps are not all well supported in the containment area**. There is a risk of dosing line breakage/leaking, during maintenance. Additionally, there appear to have been significant maintenance and changes to the system over time, and it is unclear if pump capacities are matched to the existing system.	Review chemical dosing lines and supports to ensure systems are robust and do not leak. Conduct a review of each dosing pump to ensure it is correctly matched to the corresponding piping system.
3	**Cluttered storage areas**. There are trip hazards/access hazards around storage of various items within the plant (boxes of stripper packing,	We recommend that some material be reviewed to determine if it can be disposed of. We further recommend that equipment

	cleaning chemicals, softening salt etc).	that must be stored be done to minimize impedance of access to equipment and minimizes risks of trips and fall.
4	**Access to manual valves is difficult within valve trench**. We note that many valves required during the RO chemical cleaning cycle are in this trench.	Review intended operation of the valves and determine if operators must descend into the trench, or if an extension valve stem operator can be used through the grating.
5	**Temporary hoses are potential trip hazards**. These are running across the floor in a few places, and present trip hazards.	Recommend providing step over points for hoses and clear indication to alert plant staff and visitors of the hazard.

Figure 22 - The chemical storage tank level indicator is only visible from within the containment area. This is not desirable during chemical filling as a full tank cannot be identified easily by the tanker driver.

Interviews with Operators and Staff

During our visits we met with and interviewed two operators, the water systems production/operation supervisor and the water quality specialist.

In general, there were a few clear themes that emerged during these interviews:

- **Lack of knowledge sharing and training from the previous plant supervisor**. As an overall theme, most of the staff interviewed commented that there was not a great deal of training or information sharing under the previous plant manager. It appears that tasks were instructed or delegated, but without providing a good understanding or thorough knowledge behind that task. In general, there has not been sufficient capacity built for the remaining staff to fully understand plant operations as required.

  This was particularly evident when the most recent OMMP was located, but its existence was unknown to staff.

- **Knowledge of Plant Process is Weak**. In discussing plant and process with the operators and supervisor, it is clear that the plant process is not well understood. This is particularly true of the reverse osmosis system, where a few fundamental areas appear not to be understood. For example, the functions of the concentrate valve and hydraulic turbocharger did not seem well understood by operators.

  The RO membranes themselves appear to be in very poor condition. This is generally understood by staff at the plant, but not the degree of the problem nor a full understanding of what to look for. This is a pity, as lots of data has been collected in the field, however not correlated to performance in such a way that process decision making can take place.

  Additionally, there is not a thorough understanding of the impact of water chemistry through the plant, in terms of both impact to the RO condition and final treated water quality.

- **Log Sheets Takes Significant Time to Complete**. According to plant operators, it takes approximately 2 hrs to complete the Weekly Operation log for each shift. As previously noted, we have provided an alternative log sheet which we believe would improve the time required, and place greater focus on already collected on line data.

- **No good instructions for RO Cleaning**. This was a complaint by both operators interviewed, and is a very important issue. Effective cleaning of the RO is critically important, in terms of chemicals used, prevention of damage to RO membranes and cleaning effectiveness. Additionally, cleaning is a manual procedure and safety for

operators is very important.

- **Not many Standard Operating Procedures**. There are not many standard operating procedures produced for operators for any of the regular tasks that are performed. The majority of tasks are based on verbal instruction, memory and trial and error. There are some standard operating procedures within the OMMP, however these do not appear in use.

  There has been an initiative to produce a range of standard operating procedures, a list of which was provided during a site visit. This is a detailed list, and contains a number of important procedures. We note that there has been some very good progress with water quality sampling and analysis, however progress in other areas seems to be slower. We recommend that this list be reviewed, and key targets for completion agreed upon. We have further discussion below in our section on Standard Operating Procedures.

- **Water Quality Sampling and Analysis**. There appeared to be good knowledge of water quality sampling and analysis requirements by operators. This is no doubt in part due to the good work that has been done by the Water Quality Specialist in developing revised procedures and the Water Quality Sampling Plan. This area appears to have been bolstered following previous issues with regulatory sampling.

- **Inconsistency at Shift Handover**. There are different systems used by operators at shift handover. This is typically done in a combination of operator log book and email. It appears that different operators have set up a standard template, but there is not consistency across all. There is a one hour overlap between shifts and information is informally transferred with a run through operator's screens at that time.

- **Distribution System Trainees**. The plant operators discussed problems with distribution trainees coming to gain higher level accreditation by operating at the plant, but then returning to distribution once the required time has been completed. This appears to have been a significant drain on experience from the plant. We understand this practice may be discontinued.

- **Reservoir Management** – This appears to take a significant proportion of operator time at the site. During our visits to site, the RO unit was only operating at one time, and so we are unclear if the balance between plant and reservoirs is manageable. We recommend, based on the review of plant operations, to ensure the balance of plant to reservoir management is acceptable.

- **Key Plant Problem Areas**. The plant operators appear to have consistent problem areas within the plant that take time away from other duties. These include:
    - Air/gas locking of sodium hypochlorite dosing pumps.
    - Maintenance of dosing systems.
    - pH control of the bypass stream.
    - Stripping tower performance (in particular H_2S management).
    - Sand clogging cartridge filters.
    - Sand clogging RO elements.
    - Incorrect material selection at chemical dosing pumps for maintenance.

Recommendations: Overall, it is clear that significant training is required for the operations staff, in particular to properly understand the water treatment process as a whole and reverse osmosis in particular. We recommend that an operator training program be developed and executed as soon as possible. As a starting point, we recommend process training to understand the fundamentals of the treatment process – Hazen and Sawyer can provide this training in a short period of time.

Following this, we recommend a structured training of specific plant procedures, systems and processes in order to tie training to the particular requirements at the plant. During our visit, we did sight a training schedule that does include some required operator tasks. This is a good start, and building upon this document may be useful to produce a final training plan.

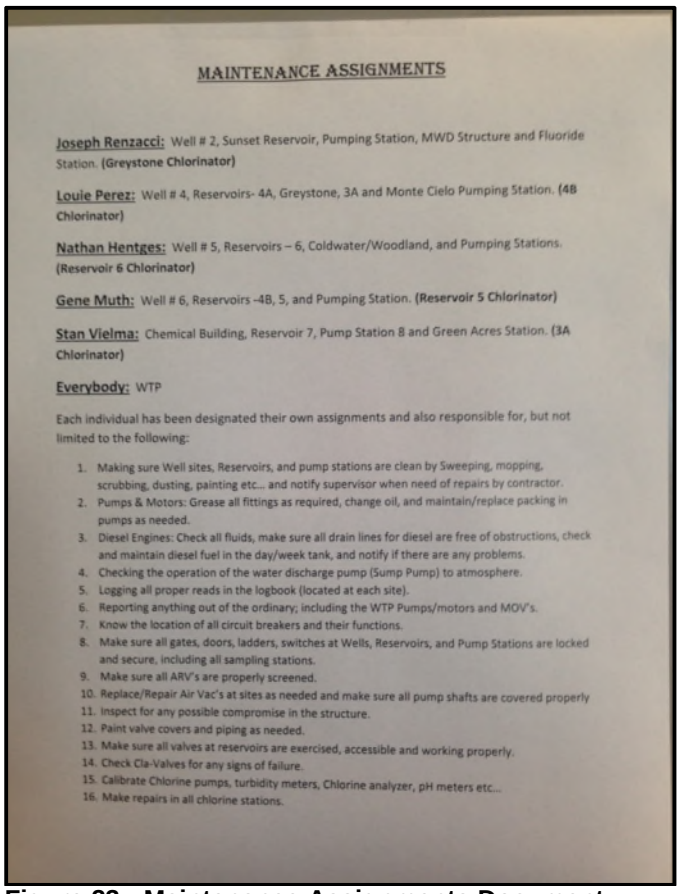
Standard Operating Procedures are clearly important, and we recommend that this be addressed urgently. We propose working with the City to identify priorities for procedures, and assist working with plant staff to complete them. We agree that the best way to gain acceptance and have ownership of these procedures is for operators to be directly involved in creating them.

Lastly, we recommend a review of communication protocols at shift change to ensure that information is consistently transferred from one shift to the next.

Maintenance Management and Asset Management

Maintenance Management

During our site visit, there did not appear to be a process for maintenance management. We found a posted list with maintenance assignments (shown below) along with items listed on a white board in the control room area.



MAINTENANCE ASSIGNMENTS

Joseph Renzacci: Well # 2, Sunset Reservoir, Pumping Station, MWD Structure and Fluoride Station. **(Greystone Chlorinator)**

Louie Perez: Well # 4, Reservoirs- 4A, Greystone, 3A and Monte Cielo Pumping Station. **(4B Chlorinator)**

Nathan Hentges: Well # 5, Reservoirs – 6, Coldwater/Woodland, and Pumping Stations. **(Reservoir 6 Chlorinator)**

Gene Muth: Well # 6, Reservoirs -4B, 5, and Pumping Station. **(Reservoir 5 Chlorinator)**

Stan Vielma: Chemical Building, Reservoir 7, Pump Station 8 and Green Acres Station. **(3A Chlorinator)**

Everybody: WTP

Each individual has been designated their own assignments and also responsible for, but not limited to the following:

1. Making sure Well sites, Reservoirs, and pump stations are clean by Sweeping, mopping, scrubbing, dusting, painting etc… and notify supervisor when need of repairs by contractor.
2. Pumps & Motors: Grease all fittings as required, change oil, and maintain/replace packing in pumps as needed.
3. Diesel Engines: Check all fluids, make sure all drain lines for diesel are free of obstructions, check and maintain diesel fuel in the day/week tank, and notify if there are any problems.
4. Checking the operation of the water discharge pump (Sump Pump) to atmosphere.
5. Logging all proper reads in the logbook (located at each site).
6. Reporting anything out of the ordinary; including the WTP Pumps/motors and MOV's.
7. Know the location of all circuit breakers and their functions.
8. Make sure all gates, doors, ladders, switches at Wells, Reservoirs, and Pump Stations are locked and secure, including all sampling stations.
9. Make sure all ARV's are properly screened.
10. Replace/Repair Air Vac's at sites as needed and make sure all pump shafts are covered properly
11. Inspect for any possible compromise in the structure.
12. Paint valve covers and piping as needed.
13. Make sure all valves at reservoirs are exercised, accessible and working properly.
14. Check Cla-Valves for any signs of failure.
15. Calibrate Chlorine pumps, turbidity meters, Chlorine analyzer, pH meters etc…
16. Make repairs in all chlorine stations.

Figure 23 - Maintenance Assignments Document

The list provides some specific and daily tasks required, however there does not appear to be a process of work order management, maintenance scheduling, maintenance prioritization or recording/follow up at the plant. We note that the distribution system is currently using Hansen work order management and that this may be employed for the plant also. We encourage that a system be developed for the plant, to ensure that maintenance is prioritized correctly, is conducted correctly and that the costs and time required to perform maintenance are tracked. A well-constructed work management system can provide very valuable information to improve maintenance performance.

One issue at site was illustrative of the problems with maintenance management. The RO concentrate valve has been out of service on the RO unit. Typically, and RO unit will not operate without this valve in service due to problems with controlling recovery effectively. It was noted at site that this valve was not in service during operation, and that there was a significant lead time on its replacement.

Secondly, chemical dosing pumps appear to have had maintenance conducted at different times in the past. There does not appear to be any record of materials used, replacement pump sizes or other information. This is critical, as it appears that dosing pumps of a different size to the original design have replaced originals, and there is no record of a check on piping and instrumentation suitability. Additionally, there may be incorrect and incompatible material used in its replacement.

Asset Condition Assessment

We recognize that GHD have currently provided or are providing an asset condition assessment for the plant. We recommend that a formal asset condition assessment be conducted on a regular basis following plant upgrades, to ensure that equipment is safe and reliable for operation. A simple assessment, with photographs and documentation can be conducted either in house, or with expert advice to both advise on safety and reliability of equipment as well as inform upcoming capital budgets.

Plant Availability/Criticality

We have noted whilst reviewing the plant, that there appears to be inconsistency in design with regard to plant availability. In some portions of the plant, there is redundancy such that the plant may either continue to operate automatically, or be available on line after a short period of equipment change over.

In other parts of the plant, however, there are process/equipment bottlenecks and “pinch points” which, in the case of failure, will shut down the entire plant.

For example, the RO unit itself has an entire standby feed pump to operate the unit if one of the pumps requires maintenance. Just slightly ahead in the process, there is only a single antiscalant dosing pump – itself a critical item which if unavailable will shut down the plant.

While this may be a deliberate decision (chemical dosing pumps can generally be procured quickly or cheaply kept as a spare on the shelf whereas a high pressure pump may require 12 – 18 weeks delivery on order) we recommend that an assessment be conducted to determine the

availability of the plant overall. This will help both set an expectation of reliability, as well as inform future capital upgrades with a basis of equipment selection and redundancy.

Recommendation: We note that there does not appear to be a current strategy to maintain a minimum plant availability in terms of spares inventory management or targeting of maintenance. We recommend that a criticality assessment be conducted to review critical components, identify critical spares and target maintenance tasks based on a targeted plant availability.

Operator Training

Effective training of operations staff is critical in the successful management of the plant and distribution system. As we have noted in our interviews with operations and staff, training particularly in process plant and operation appears to be significantly lacking. We recommend that a training program be developed as a priority both for the plant and process as well as the operations systems and processes that are being and will be developed.

An overall training program may consist of:

Topic Area	Contents
Permits and Regulations	Operating Permit. Environmental Discharge
Water Quality Sampling and Testing	Types of samples Proper sampling technique Labeling requirements Chains of custody Sample locations Sample frequency Process vs Regulatory Sampling and Testing Process Control Testing Procedures and Instrument Use
Safety	Safety (OSHA) requirements. Identify Safety Hazards Emergency Management Incident reporting and investigation City safety policies.
Instrumentation	Ability to read/record values from gauges and displays Understanding of units of measure Standardization/Calibration/Verification

Equipment and Maintenance	Ability to identify/describe components of equipment Start/Stop procedures Identify normal operation. Understanding of standard operating procedures
SCADA	Ability to navigate screens Ability to identify/acknowledge alarms Ability to select individual system components Ability to generate/select graphs and interpret results. Ability to Start/Stop a process or entire facility for planned or emergency shutdown.
Process Technology	Chemical dosing and Handling Reverse Osmosis (and pretreatment) Water chemistry and impacts to process. H_2S stripping Air scrubbing

We recommend that a training program be developed, with a training register to keep a log of which personnel have received which training.

Hazen and Sawyer are able to assist with training, and can provide process technology training rapidly for the city.

Standard Operating Procedures

As discussed, we have noted that there are not a great deal of standard operating procedures (SOPs) that are in use at the plant. These are critical, to ensure that there is consistency of operation and that systems can be passed on to new employees as other employees' transition to other roles within or outside the organization.

We recommend that the program of SOP development be continued to engage staff in the development of procedures that will incorporate all major, repeated operating tasks. We recommend a review of the current list, with a view to refining and prioritizing completion.

Importantly, we recommend that a system of document change management and revision control be adopted. This control ensures that operators and other staff are using the current

version of a document, and that any changes that have occurred are accurately captured. This is vitally important as the city launches into an upgrade of facilities.

We welcome the opportunity to assist the city in development of these procedures and a document change management process.

Other Process Items

Our report focused on operational systems and processes rather than a specific plant and process review. Nonetheless, we have identified some areas which we believe merit further review and discussion.

Reverse Osmosis Membrane Condition

As we have discussed in both Water Quality Monitoring and our RO Normalization review, the RO membranes are in a particularly degraded state. The chart below provides an indication of the severity of the condition in terms of the salt that is passing through those membranes.

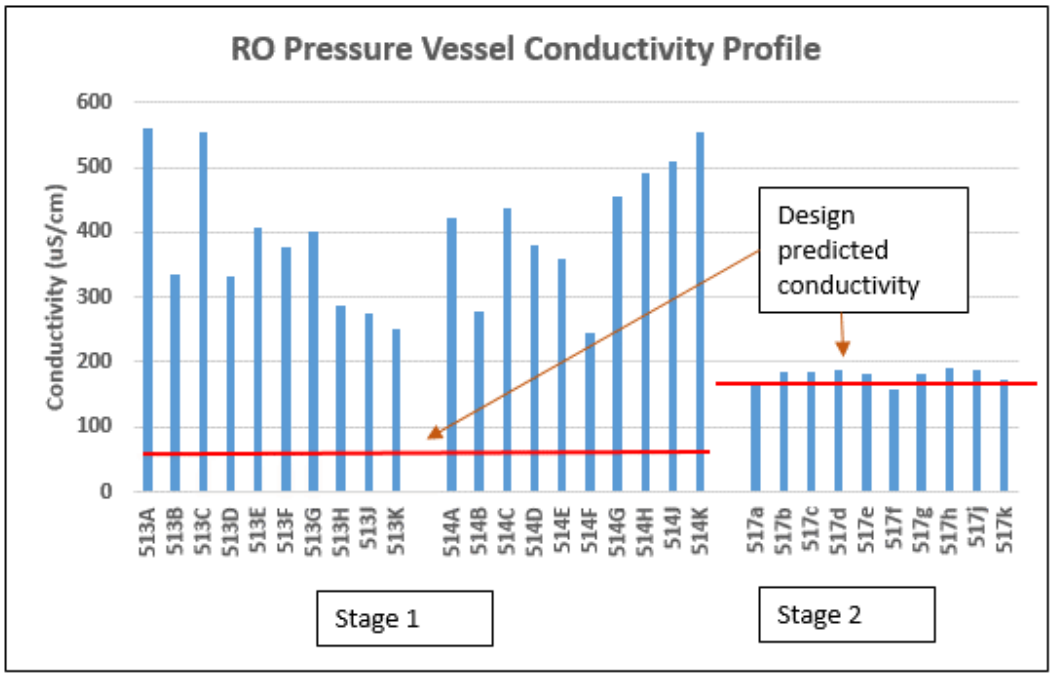


Figure 24 - Expected vs actual individual vessel conductivity

In Figure 22, we have compared individual RO vessel conductivity against what is predicted for the current feed water and membrane age. As can be seen, the first stage membranes appear to be in a very bad condition and in some cases are producing as little as 50% rejection in that stage of salt. There is significant variability between the vessels in the first stage, however all appear to be significantly worse than anticipated for membranes of that age. This may be due to membrane physical damage, membrane oxidation or chemical damage and/or leaks of membrane interconnecting o-rings. It is unusual to see membranes in this condition continuing to operate.

We note, that by contrast the second stage elements appear to be operating at close to their anticipated performance. This is consistent with the fact that second stage membranes have been replaced more recently than first stage (2 years compared to 7 years).

There are several reasons this may have occurred, and we understand that GHD are currently investigating with autopsies.

One significant concern is entrainment of sand from the wells into the vessels. The sand may have an abrasive effect, particularly on lead elements. We understand that options for sand removal from the wells prior to the cartridge filters is being conducted. Additionally, we recommend a particle size distribution of the sand particles to understand if these are passing through the cartridge filters, or are somehow bypassing.

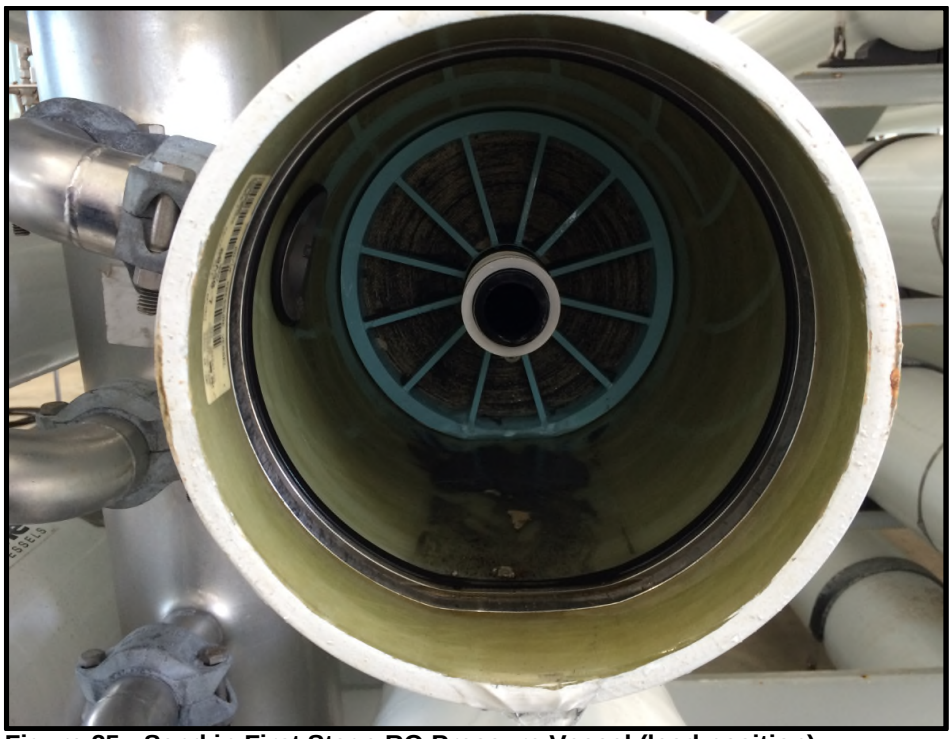


Figure 25 - Sand in First Stage RO Pressure Vessel (lead position)

Additionally, we understand that chloramine has been used on occasion to disinfect the membrane system as a result of adverse HPC and bacterial counts during sampling. While chloramine is a weaker oxidant than free chlorine, it can still oxidize membranes over time and can react with certain catalyzing agents (such as iron and manganese) in the water to have a stronger oxidant effect.

The RO Cleaning procedure is a potential area of risk to membranes. During the sequence, there is a risk of applying back pressure to the membranes that may cause a detachment of the membrane layer from the backing surface. A backpressure event is reasonably common in this situation, and if a manual valve is placed in the wrong position during this cycle backpressure can occur. We recommend strongly that the cleaning sequence is thoroughly reviewed and a solid procedure developed to ensure that this cannot occur.

One last consideration is the shimming of membrane elements. Standard membrane elements do not always exactly match the length of the pressure vessel, and as a result there can be some forwards/backwards movement of the membranes during start up and shutdown. Shims simply use small plastic annular spacers to take up any space between the membrane end connector and the vessel connector to minimize this movement. We recommend that the city ensures shimming be conducted on membrane replacement.

RO Concentrate Valve and RO Recovery Control

An RO unit is typically controlled by providing a variable frequency drive on the feed pump to produce a desired permeate flow rate, and a controlled concentrate valve to control concentrate flow (and hence RO recovery).

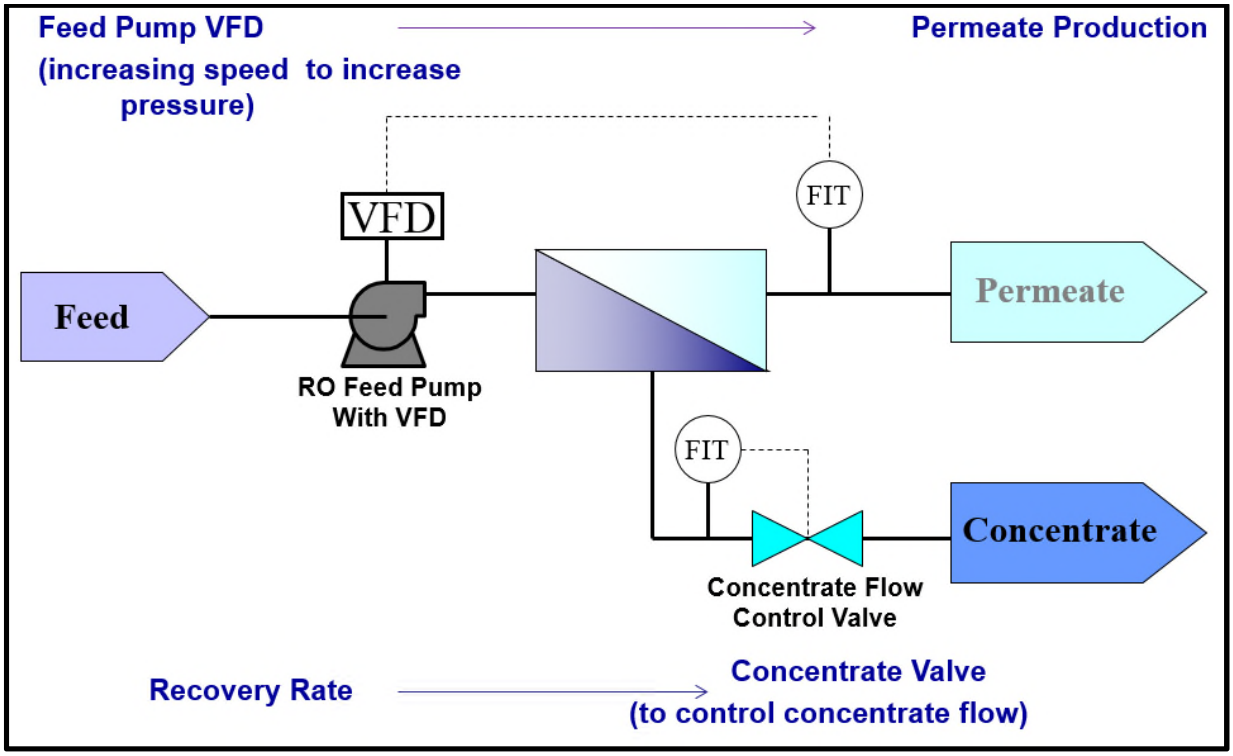


Figure 26 Typical RO Flow Control

The RO recovery is critical, as it will impact both the risk of scaling, and also to an extent the final treated water quality that is produced.

It is important that the concentrate flow is controlled effectively to minimize this risk.

We note that at the plant currently, the concentrate valve has been removed from the unit for maintenance, and in its place a smaller diameter section of pipe, acting as an orifice plant, is being used to provide some backpressure, however it cannot control to a set recovery.

Figure 27 - RO Concentrate Valve is out for maintenance. The section of pipe in use is located behind the actuator.

The impact of this valve absence is an inability to control recovery. As the graph below shows, the RO recovery has been fluctuating during periods of operation. Typically, as the membranes operate and become more fouled, the recovery tends to reduce with time, as can be seen in the Figure 28 below.

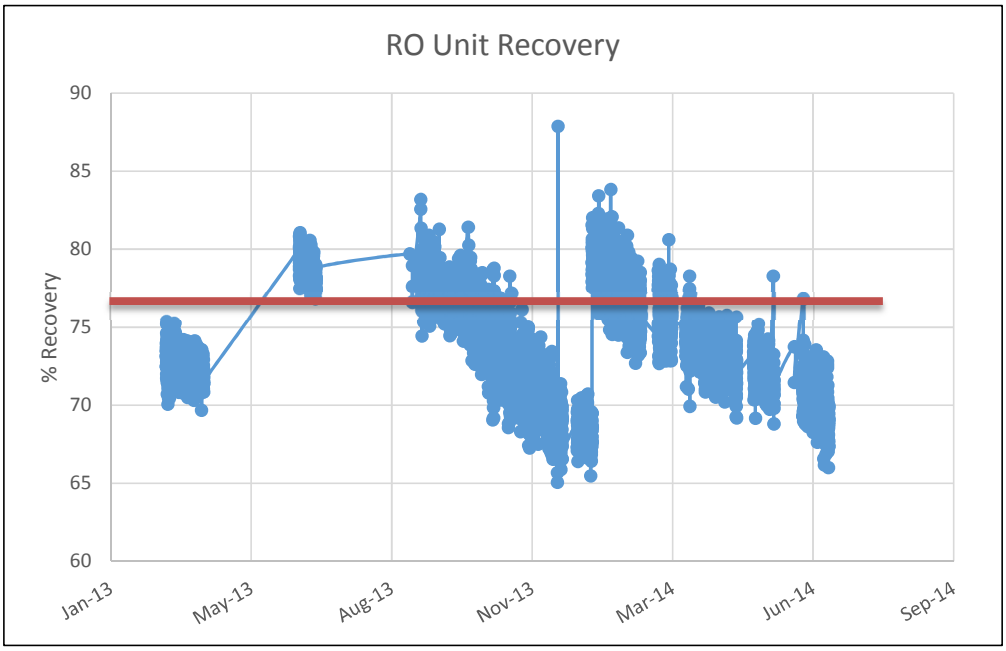


Figure 28- RO Unit Recovery 2013 to 2014

AS we can see, the RO recovery begins high, then reduces with operating time. It appears that this valve may have been out of service for some time. It is undesirable to operate without this control in place. Given the current configuration, it is difficult to adjust this manually, and we recommend that this valve be returned to service as soon as possible.

Hydrogen Sulfide Removal

We have noted at site that there have been some difficulties in achieving removal of hydrogen sulfide.

Hydrogen sulfide is removed from the RO permeate, and bypass streams by stripping H_2S in the gas phase from the water. In order to ensure that H_2S is in the gas phase, the pH must is reduced to approximately 6.0 or below. In Figure 29, the equilibrium of hydrogen sulfide in the gas phase and dissolved phase (sulfide) is shown with pH. By driving the pH lower than 6.0, more hydrogen sulfide is in the gas phase available for removal.

As previously discussed, the RO has significantly compromised membranes which are leaking significantly more dissolved salts into the permeate than anticipated. Often, the pH across an RO unit reduces as compared to the feed. This is because the RO will remove dissolved alkalinity (in the form of bicarbonate and carbonate) but not dissolved carbon dioxide as it is a gas. The change in ratio between bicarbonate alkalinity and carbon dioxide results in a reduced pH. At the plant, the operators have noticed that it requires a much higher dose of sulfuric acid

to drop the pH in the RO permeate compared to earlier in operation. This is most likely due to the fact that the RO is no longer rejecting sufficient bicarbonate, and consequently the pH reduction across the RO is less.

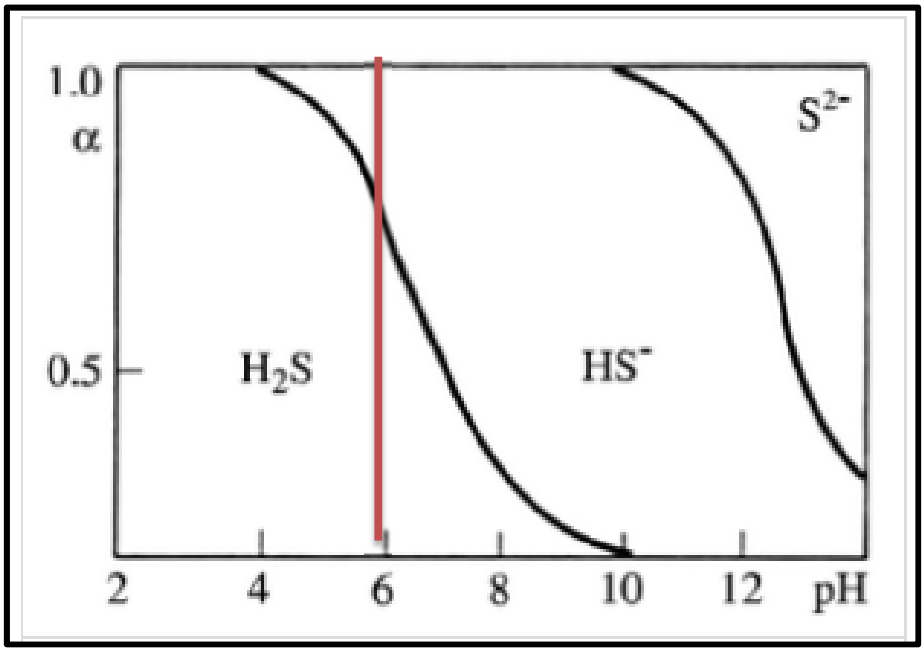


Figure 29 - H2S Vapor Gas Equilibrium

When the RO system is returned with new membranes in the first stage, we anticipate less acid will be required to lower pH across the RO unit.

At the bypass stream, a high acid dose is injected to meet the requirement of pH 6.0. We note that there have been problems with mixing of the acid dose prior to the stripper in the past, however these may have been resolved.

An additional areas that should be reviewed is the exchange of air across the strippers to ensure that this is consistent with design. This may need to be deduced from fan speeds.

Concrete Corrosion

As we have mentioned in our discussion on water quality monitoring, the RO permeate is not chemically stable with respect to hardness, alkalinity and pH, and can be corrosive to cement and copper services. Given the current blending regime, with a lower than original design bypass flow, the overall plant effluent may be at a lower than desired stability and consequently impacting infrastructure such as the clearwell tank. We note that many drains around the plant also show signs of concrete corrosion.

As discussed previously, we recommend measuring hardness, alkalinity and pH regularly to both target and trend a stability index (either LSI or CCPP).

Conclusion

The city has some significant operational challenges ahead in terms of operational systems and processes, as well as plant performance. There are some major shortcomings that put the utility at risk of non-compliance to plant permits, risk of damage and degradation to plant and distribution assets, and importantly risks to the safety of site personnel.

But these challenges are not insurmountable. The staff are dedicated, enthusiastic and committed to successful operation. With some assistance, we have no doubt that the will be able to return the plant to a very high level of performance. There are already some great strides in achieving this, notably in the management of water quality.

We stand ready to assist the city in working towards this goal. Our major findings and recommendations are as follows:

Our major findings are as follows:

- **Plant Performance Targets should be clearly defined**. Targets for operations staff in terms of production, quality, safety and other regulatory requirements are not clearly defined. We recommend this so that staff can compare performance against targets.

- **Operating Performance is not correctly analyzed.**. There is a vast amount of information recorded on the HMI/SCADA and operating log sheets, however it is not presented or reviewed adequately to gauge plant performance. We recommend that trending of important parameters be set up and regularly reviewed to measure performance against overall plant and process unit specific targets. This is important for water quality targets and internal process performance targets.

- **Water Quality Management and Monitoring has shown great improvement.** This area in particular is advancing well, with robust procedures and a sampling plan being developed. We recommend using this work as a basis for a comprehensive water quality management plan for the facility (which could be incorporated into a revised OMMP).

- **The Reverse Osmosis (RO) system is not correctly analyzed**. The RO system performance data is not normalized, and consequently performance has not been reviewed adequately, leading to a substantial worsening of condition.

- **The RO system membranes (first stage in particular) are in very poor condition**. These membranes are leaking salt an order of magnitude above what is anticipated for membranes in this operation. The overall cause for poor condition must be investigated and resolved, followed by the installation of new membranes.

- **The RO Unit is not operating correctly, and requires a concentrate valve to be replaced as a matter of urgency**. This is critical for controlling RO recovery, which is itself critical for successful unit operation.

- **A concentrate reduction strategy should be considered**, with a review of current RO feed water chemistry, membrane selection and antiscalant to determine an optimum RO unit recovery. A higher recovery, if possible, can reduce brine production from unit and increase overall treated water yield from the plant.

- **Provide options for lower RO unit throughput, based on lower well yields.** This review (combined with the concentrate reduction strategy) may provide operating cost savings in terms of membrane costs, pumping energy costs and chemical dosing) as well as provide more suitable system hydraulic operating conditions.

- **Final Treated Water blend may be corrosive to concrete**. We recommend a review of water chemistry and blending along with monitoring of water stability indices to ensure protection of plant concrete infrastructure such as cement lined pipes and the concrete clear well

- **Arsenic Management Plan, a regulatory requirement outlined in the OMMP, does not appear to be followed**. This is a requirement of the permit, and included in the OMMP, however does not appear to be entirely operational. We recommend this plan is checked for compliance.

- **The Operations Maintenance and Monitoring Manual (OMMP) is not known to operators and is not in use. We recommend creating a revised, updated OMMP**. This is a major risk of non-compliance to the plant operating permit and in itself may constitute a non-compliance. We recommend as a matter of urgency that the city confirm with the State Regional Water Quality Control Board (formerly CDPH) if the version found during our visit is the current lodged with the regulator. Further, we recommend that this form the basis of a thorough revision to include important

shortcomings as well as updates to reflect existing operation.

- **Plant Weekly Operator Logs are Unwieldy and Unhelpful.** We have recommended a revised log sheet, as the current log contains a lot of data recorded but the key trends are not reviewed to determine plant performance or identify operational risks. It is data rich, but knowledge poor.

- **A non-conformance/corrective action process is recommended.** In order to capture learnings from problems or incidents, we recommend a non-conformance and corrective action system. This will involve reporting incidents, managing incidents and effectively taking from lessons learned to improve operations into the future.

- **A Safety and Emergency Management Plan is recommended.** We could not find a comprehensive safety plan on site covering the multiple safety issues that are encountered at an operational facility. We recommend that a plan be developed, to ensure safety hazards are effectively managed.

- **An Operator Training Program is recommended as a matter of urgency.** Operators are currently not sufficiently familiar with water chemistry, RO unit operation and other plant processes. We recommend a training program be developed to encompass process, operational procedures, safety and other necessary operational elements to ensure operators are well equipped to manage the plant.

- **Development for Standard Operating Procedures is recommended.** Leveraging from work already begun by the city, we recommend developing a number of robust operating procedures, developed with and by the operators themselves, to cover operation of all aspects of the plant. There are currently few procedures in use, and much operation is performed by memory and word of mouth. We additionally recommend a document change management system be established to keep track of version control and ensure changes to plant, process and operations are captured in the procedures.

- **More use of trending from the HMI should be adopted to keep track of process and water quality performance**. There is an abundance of data reported, however trends are more useful for performance monitoring, diagnostics and decision making. We recommend that a set of standard trends be developed.

- **Develop a high level plant Dashboard Report, to define key performance requirements at a glance. This will be helpful to track performance against targets.**

Conduct a criticality and condition assessment to determine appropriate spares and maintenance strategy to meet a desired plant availability.

Appendix 1 – Revised Weekly Operations Log Sheet