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*Managing Water in the West*

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# Realizing Reverse Osmosis Potential for Potable Reuse: Demonstrating Enhanced Pathogen Removal

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This Project (1) performed challenge tests to establish the degree of virus removal and ability of standard and novel surrogates to track virus removal and (2) identified surrogates that provide higher removal credit than traditionally employed methodologies while being conservative under both normal and compromised conditions.

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## Prepared for Reclamation Under Agreement No. R16AC00132

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**U.S. Department of the Interior**
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**Water and Environmental Services Division**
**Water Treatment Engineering Research Team**

**March 2017**

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# Acronyms and Abbreviations

| | |
|---|---|
| AES | atomic emissions spectroscopy |
| AOP | advanced oxidation process |
| BAC | biological activated carbon |
| CIIM | continuous indirect integrity testing |
| CIP | clean-in-place |
| $Cl_2$ | chlorine |
| CT | concentration multiplied by time, as used for disinfection |
| Da | dalton (atomic mass unit) |
| DDW | Division of Drinking Water (State of California) |
| DIT | direct integrity testing |
| DPWF | North City Demonstration Pure Water Facility |
| DOM | dissolved organic matter |
| EC | electrical conductivity |
| EEM | excitation emission matrix |
| EfOM | effluent organic matter |
| FDOM | fluorescence dissolved organic matter |
| FI | fluorescence index |
| FRI | fluorescence regional integration |
| gfd | gallons/$ft^2$/day (flux unit) |
| GWRS | Groundwater Replenishment System |
| HDT | hydraulic detention time |
| HMI | human machine interface |
| IC | ion chromatography |
| ICP | inductively coupled plasma |
| ICR | inorganic carbon removal |
| ISE | ion selective electrode |
| IVP | integrity verification program |
| LC-MS/MS | liquid chromatography tandem mass spectrometry |
| LCL | lower control limit |
| LED | light-emitting diode |
| LOD | limit of detection |
| LMH | liters/$m^2$/hour (flux unit) |
| LRV | log removal value |
| LT2ESWTR | Long Term 2 Enhanced Surface Water Treatment Rule |
| MF | microfiltration |
| MGD | million gallons per day |
| µg/L | micrograms per liter |
| mg/L | milligrams per liter |
| MRL | method reporting limit |
| MS | mass spectroscopy |
| MS2 | male-specific bacteriophage |
| MWCO | molecular weight cut-off |
| NCDPWF | North City Demonstration Pure Water Facility |
| NCWRP | North City Water Reclamation Plant |
| $O_3$ | ozone |
| OCWD | Orange County Water District |
| PA | polyamide |
| PDT | pressure decay test |

| | |
|---|---|
| pfu | plaque forming unit |
| ppb | parts per billion (i.e., µg/L) |
| ppm | parts per million (i.e., mg/L) |
| PVDF | polyvinylidene fluoride |
| RO | reverse osmosis |
| rfu | raw fluorescence units |
| R-WT | rhodamine WT |
| SM | Standard Methods |
| SPE | solid phase extraction |
| SRT | solids retention time |
| TDS | total dissolved solids |
| TOC | total organic carbon |
| UCL | upper control limit |
| UCMR3 | third Unregulated Contaminant Monitoring Rule |
| UF | ultrafiltration |
| USEPA | United States Environmental Protection Agency |
| UV/AOP | ultraviolet light / advanced oxidation proces |

# Executive Summary

Reverse osmosis (RO) has played an important role in the practice of potable reuse for its ability to preclude both high levels of dissolved constituents and pathogens. There remains, however, a substantial discrepancy between its actual performance and awarded pathogen log removal credit. The primary objective of this study was to evaluate alternative surrogates, both naturally occurring as well as seeded to RO feed water, that can offer higher levels of removal in comparison to the currently employed methods, such as electrical conductivity and total organic carbon, while remaining conservative to the rejection of the smallest of pathogens (i.e., enteric virus). All results were obtained from experiments carried out across the 2-stage RO train at the 1 MGD (2.6 $m^3$/min) North City Demonstration Pure Water Facility in San Diego. A total of eight virus surrogate challenge tests using male-specific bacteriophage (MS2) were performed across three different sets of RO elements (varying from virgin to aged), from where a log removal value (LRV) between 4.6 and 7.3 was observed. For the naturally occurring surrogates, strontium offered the greatest potential for tracking RO membrane integrity (LRVs of 2.5-3.6, depending on stage and membrane condition) where other ions (e.g., magnesium, phosphate, sulfate) often had removal limited by their detection limit in permeate samples. For seeded surrogates, this study evaluated spiked sugar and Nalco's TRASAR dye and observed LRVs of 2.4-3.2 and 3.6-3.7, respectively, depending on stage and membrane condition. Overall, poorer rejection was achieved across aged membranes, further exacerbated in the system's second stage. Rhodamine WT was also evaluated but was considered unattractive since dye adsorption to RO membranes was observed and skewed the observed LRV scores. Surrogate removal was also assessed in response to a combination of system compromises (i.e., removal of O-rings). In all conditions, surrogate removal remained conservative or on par with MS2 rejection. Given the scale of the testing facility, it was possible to evaluate the resolution of failure for each surrogate by collecting data from multiple locations (i.e., vessel, stage, and train level). Surrogates providing less than 2-logs of removal did not provide resolution of failure to detect compromises at the train level. On the other hand, surrogates offering higher LRV (i.e., above 3-logs) were able to pick up tested failures when sampled at the train permeate. A conceptual integrity verification program is discussed in the context of this project's findings and available framework.

# 1. Introduction

## 1.1. Project background

Over the past century and a half, water management practice has emphasized the separation of drinking water and wastewater, which has been effective in protecting public health. However, given the advancements in water recycling treatment technologies and the stresses imposed on our limited conventional water bodies, a new paradigm is emerging in which reclaimed wastewater will become a significant component of future potable water portfolios.

It has long been established in the drinking water community that pathogens present the greatest acute risk to public health, and this understanding carries through to the design of potable reuse systems, which require multiple barriers providing proven and demonstrable levels of pathogen reduction. Understanding the effectiveness of such barriers is essential to the design of treatment trains that protect public health without being overly conservative and costly.

At the core of many potable reuse treatment trains is reverse osmosis (RO). Not only is RO known for providing a strong barrier to dissolved constituents and pathogens (e.g., Wintgens et al., 2005), RO is also currently required by regulations in the State of California for some Groundwater Replenishment Reuse Projects (DDW, 2014). As for pathogen removal, RO membranes have shown to provide higher than 5-logs of removal of MS2 bacteriophage (an accepted surrogate for enteric virus) in both pilot and bench scale studies (Adham et al., 1997; Adham et al., 1998; DeCarolis et al., 2006; Mi et al., 2004; Comerton et al., 2005; Lozier et al., 2003; Pype et al., 2016a, Antony et al., 2016). Because viruses are the smallest of the pathogens, demonstrating virus removal conservatively demonstrates protozoa removal as well.

Although most tests have shown that RO membranes offer high levels of MS2 removal, such is not always the case (Adham et al., 1998). As such, the extent of virus removal through RO membranes remains poorly understood in practice, and in the absence of more and better data, regulators currently take the most conservative approach for crediting RO systems, requiring daily direct integrity testing to confirm removal. The current method for determining virus removal credit for RO is through the use of surrogates whose reduction through the system can be continuously measured. As a result, albeit its high removal potential, most projects with RO systems in the State of California are only receiving 1.5 to 2.0 logs of credit using total organic carbon (TOC) or electrical conductivity (EC) as surrogates (DDB Engineering, 2014; WRD, 2016; Kumar et al., 2007; Adham et al., 1998). In other words, a significant gap of the potential RO pathogen removal potential remains uncredited. The discrepancy between the removal measured in seeding challenges and removal credited via surrogates indicates that current surrogate monitoring techniques are most likely ineffective at confirming

performance, resulting in the RO process being under-credited for virus removal - and therefore on the removal of all pathogens. Thus, there remains an opportunity for RO systems to receive higher levels of pathogen credit. Significant drivers for pursuing this effort include:

- Increasing confidence in treatment performance and improved public perception. Showing that RO is indeed removing high levels of pathogens will increase confidence to safely implement potable reuse, both in the industry and for the public.

- Improving industry understanding of process performance. Given the rate at which potable reuse projects are being developed, understanding the true effectiveness of all processes is critical for safe implementation.

- Increasing the removal credit for RO would decrease the burden placed on the rest of the treatment train in terms of operation. Additionally, designers would have flexibility in determining what other processes are required, considering factors such as cost, energy usage, and footprint.

## 1.2. Project approach and objectives

The approach of this Project was aimed to address the potential under-crediting of RO by focusing on knowledge gaps regarding pathogen removal by RO systems and ability to measure performance. To do so, this work:

> (1) performed challenge tests to establish the degree of virus removal and ability of standard and novel surrogates to track virus removal.
>
> (2) identified surrogates that provide higher removal credit than traditionally employed methodologies while being conservative under both normal and compromised conditions.

In achieving the above, this research aimed to provide further insight into the implications of system compromises on virus-surrogate relationships, and on the resolution of failure detection for a full-scale system. Additionally, this research aimed to offer further industry understanding of how RO monitoring can be improved to supplement the goal of public health protection.

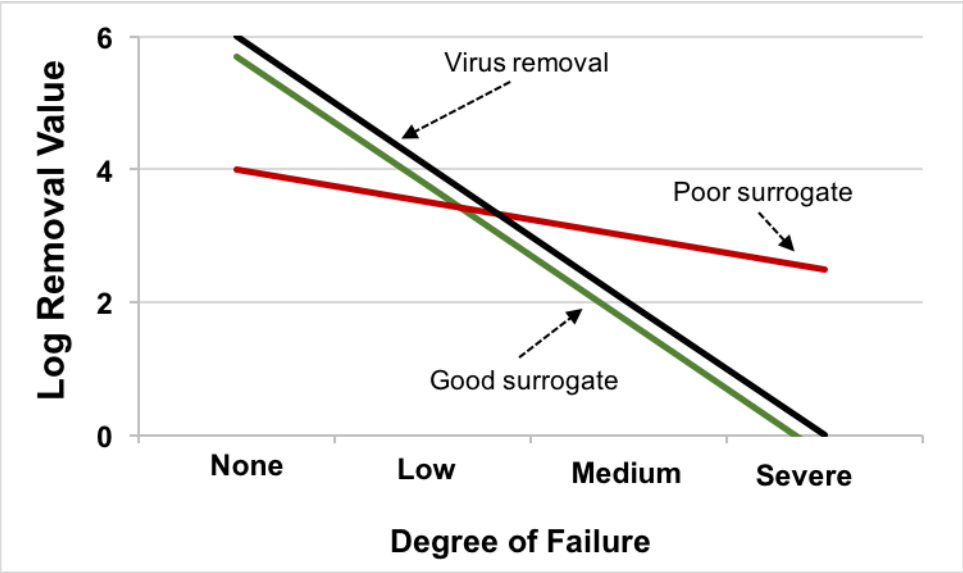


**Figure 1-1: Graphical representation of project approach**

## 1.3. Literature Review

Based on size alone, an intact RO membrane (nominal size cutoff <0.001 μm) should not allow viruses of interest in drinking water to pass (0.028 to 0.090 μm; Crittenden et al., 2012) to pass; however, variations in membrane manufacturing quality control along with the design and manufacture of the spiral wound membranes, pressure vessels, and RO skid assemblies can result in imperfections that allow pathogens to pass through. Thus, the logic behind current regulations is that membrane filtration systems must demonstrate integrity validation on an ongoing basis (USEPA, 2005; USEPA, 2006).

Under the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), a membrane filtration system must undergo periodic direct integrity testing (DIT) and continuous indirect integrity monitoring (CIIM) during operation to receive removal credit for pathogens. The EPA Membrane Filtration Guidance Manual defines a DIT as a "physical test applied on each membrane unit and monitored on a daily basis in order to identify and/or isolate integrity breaches" and a CIIM as "monitoring of some aspect of the filtrate water quality […] at a frequency of no less than once every 15 min" such that "a marked decline in filtrate quality may indicate an integrity problem." (USEPA, 2005). In the context of the industry, the current methods for demonstrating RO performance have typically been through the monitoring of total organic carbon (TOC) and/or electrical conductivity (EC). As aforementioned, these surrogates are reported to have a maximum achievable log reduction of 2, being highly dependent on feedwater quality and instrument sensitivity (Adham et al., 1998). Their performance is limited because they pass through the membranes via mechanisms like molecular diffusion that are not available to viruses, which have the equivalent molecular weight of $10^6$ to $10^7$ Da. Thus an RO membrane which passes no viruses is likely to pass significant amounts of these surrogates.

The objective of this literature review is to provide an overview of past studies which have considered alternative surrogates for demonstrating higher log removal value (LRV) for RO system applications. Additionally, a review of the EPA Membrane Filtration Guidance Manual (USEPA, 2005) was made to assess suitability of surrogates in the context of available framework.

### 1.3.1. EPA Guidance Manual on membrane filtration integrity testing

This section will focus on terminology and framework outlined by the EPA Membrane Filtration Guidance Manual in the context of surrogate selection and testing methodology. Although the *Guidance Manual* is suitable for membrane filtration systems in general, the objective of this section is to capture relevancy specific to RO membrane systems.

The *Guidance Manual* is expressly directed toward membrane filtration systems seeking to gain *Cryptosporidium* removal credit that is compliant with the LT2ESWTR. That said, the *Guidance Manual* offers Appendix E to describe how the framework can also be applied for virus removal as long as "the membrane filtration process complies with appropriate pathogen-specific criteria for the […] primary regulatory elements" (USEPA, 2005). With respect to the "pathogen-specific criteria", integrity testing shall provide resolution response to breaches of 0.01 µm for virus (3 µm for *Cryptosporidium*). With respect to the "primary regulatory elements", the membrane system must meet the following three criteria:

- The process must comply with the definition of a membrane filtration system as stipulated by the rule.
- The removal efficiency of a membrane filtration process is established through a <u>product-specific challenge test</u> or <u>direct integrity testing</u>.
- The membrane filtration system must undergo periodic <u>direct integrity testing</u> and <u>continuous indirect integrity monitoring</u> in order to verify the removal efficiency of a membrane process during operation.

The *Guidance Manual* specifically addresses reverse osmosis as eligible for pathogen removal credit under LT2ESWTR in §2.2.2:

> "[…] RO [is] eligible for Cryptosporidium removal credit under the LT2ESWTR based on the demonstrated ability of these technologies to remove pathogens, as well as on the high probability that these processes can meet the requirements for membrane filtration specified in the rule"

Table 1-1 provides a summary for the three primary regulatory elements in terms of frequency, resolution, sensitivity provided, and additional notes with respect to RO applications. Subsequent subsections detail each of them on an individual basis.

**Table 1-1: Summary of regulatory elements for membrane filtration systems seeking to gain pathogen removal credit**

| | Product-specific challenge testing | Direct integrity testing (DIT) | Continuous indirect integrity monitoring (CIIM) |
|---|---|---|---|
| **Summarized Definition** | Conducted to determine the removal efficiency (i.e., LRV) of a membrane system for a particular pathogen. | Physical test applied to a membrane unit to identify and isolate integrity breaches. | Monitoring some aspect of filtrate water quality as a surrogate to measure membrane integrity. |
| **Frequency** | Once, as long as significant modifications are **NOT** made to the membrane process. | Every 24 hours* | Continuous (once every 15 min) |
| **Sensitivity (i.e., LRV)** | Dependent on detection limit of challenged constituent. | Must verify LRV is equal or greater than awarded removal credit value | N/A |
| **Resolution** | N/A | Must be responsive to a 3 µm breach in the case of *Cryptosporidium* and 0.01 µm for enteric virus.<br>A lower control limit (LCL) shall be established to indicate an integrity compromise before becoming a compliance concern. | Shall be able to perform readings at a level which constitutes an integrity compromise. If an integrity compromise is detected, direct integrity testing is triggered. |
| **Additional notes** | Often performed by membrane manufacturers on a product-specific basis. | Distinguished between pressure-based and marker-based tests. | Turbidity is set as default method for membrane filtration, where a 0.15 NTU reading on the filtrate side is set as the threshold. |
| **Applicability to RO** | Challenge testing data currently not available by RO membrane manufacturers | Marker-based tests are more suitable for RO. | Because RO also removes dissolved constituents, methods that monitor these constituents (e.g., EC) are also suitable. |

*Unless otherwise approved by the State if supported by demonstrated process reliability, the use of multiple barriers effective for the pathogen of concern, or reliable process safeguards.

#### *1.3.1.1.Product-specific challenge testing*

The primary purpose of a challenge test is to establish the LRV that an intact membrane can achieve. Per the *Guidance Manual*, challenge testing must be conducted on a membrane module identical in material and construction to one implemented in full-scale applications. The seeded particulate must be representative of the microbial pathogen being sought for removal credit, such that removal of the seeded particulate cannot exceed removal of the pathogen itself. Additionally, maximum allowable feed concentration of the seeded particulate shall be no greater than:

$$\text{Maximum feed concentration} = (3.16 \times 10^6) \times (\text{filtrate detection limit})$$

In microfiltration (MF) and ultrafiltration (UF) applications, membrane manufacturers are commonly the ones to carry out challenge testing on a product-specific basis. This is advantageous since challenge testing is required to take place no more than once as long as significant modifications are not made to the membrane manufacturing process. State-approved reports have been issued for MF and UF membranes acknowledging pathogen removal credit under specified operational conditions, whereas such reports for RO systems have yet to be issued – to the best knowledge of the authors.

#### *1.3.1.1. Direct integrity testing (DIT)*

Direct Integrity Testing (DIT) is defined by the *Guidance Manual* as a physical test applied to a membrane unit in order to identify and isolate integrity breaches. The *Guidance Manual* provides details on the requirements of such testing, which fall under three categories: frequency, resolution, and sensitivity.

- ***Frequency***: DIT must be conducted on each membrane unit no less than once a day. Less frequent testing may be approved by the State if supported by demonstrated process reliability, the use of multiple barriers effective for microbial pathogens, or reliable process safeguards.

- ***Resolution***: DIT must be responsive to an integrity breach on the order of 3 µm or less for *Cryptosporidium* compliance purposes (0.01 µm or less for virus).

- ***Sensitivity***: DIT must be able to verify an LRV equal to or greater than the removal credit awarded to the membrane filtration process.

Furthermore, DIT is broken down in two general classes: pressure-based tests and marker-based tests.

### *Pressure-based tests*

Pressure-based tests have been the basis for DIT in low-pressure membrane filtration systems (i.e., microfiltration and ultrafiltration), in the form of pressure decay tests (PDT). For this class of DIT, pressure or vacuum is applied to one side of the membrane such that the monitoring of pressure loss (or gain) gives insight into whether an integrity breach is present.

The use of pressure-based tests has been explored for RO applications with limited success. One limitation is that such tests only provide insight on mechanical integrity (such as compromised O-rings) of the membranes and render limited, if any, understanding on chemical impairments (Jacangelo et al., 2013). Chemical impairements could ultimately allow undesired permeation of concerning constituents and/or microbial pathogens by mechanisms beyond size exclusion (i.e., diffusion). In addition, pressure-based integrity tests require elements to be drained prior to testing which further limits its implementation for full-scale RO systems (Wilbert & Linton, 2000). Nonetheless, pressure-based integrity tests have been made useful as a screening procedure to identify significant defects across individual RO modules prior to full-scale comissioning.

The validation of virus removal is another important limitation of pressure-based tests in that such tests rely on the relationship of the diameter of the defect in the membrane to the pressure required for the air used in the test. That pressure must be sufficient to overcome the surface tension of water and force the water through the hole (i.e., the defect). It can be shown that the required pressure is inversely proportional to the size of the defect (ASTM, 2010). Thus the pressure required to conduct a pressure decay test that will find defects that can pass viruses (0.01 μm) is 300 times higher than the pressure required to conduct a pressure decay test that will find defects that can pass *Cryptosporidium* (3 μm).

### *Marker-based tests*

With respect to marker-based tests, the *Guidance Manual* characterizes this class as the utilization of "[…] either a spiked particulate or molecular marker to verify membrane integrity by directly assessing removal of the marker, similar to a challenge test." (USEPA, 2005). The characteristics of a marker-based surrogate are analogous to those used for a challenge testing surrogate, such that it shall be representative and conservative in size to the microbial pathogen for which removal credit is sought. The *Guidance Manual* provides direction for the use of alternative surrogates, as listed in Table 1-2.

**Table 1-2: Comparative summary of *Cryptosporidium* and Potential Surrogates**

**(From USEPA, 2005)**

| Challenge Particulate | Size Range | Advantages | Disadvantages |
|---|---|---|---|
| *Cryptospridium parvum** | 3–7 µm | • No verification of surrogate required | • High cost<br>• Difficult to measure |
| Alternate microorganisms | 0.01–1 µm | • Low cost<br>• Easy to measure<br>• Accepted use | • Difficult to handle<br>• Potential clumping |
| Inert particles | ≤ 1 µm | • Moderate cost<br>• High uniformity<br>• Easy to use | • Difficult to measure accurately |
| Molecular markers | < 100,000 Daltons | • Low cost<br>• Easy to measure | • Inappropriate for some applications |

*may be adapted to other microbial pathogens of concern

With respect to RO applications, the *Guidance Manual* advises the use of molecular markers since such membrane filtration systems are "not designed to accommodate large particulate concentrations" (USEPA, 2005). Although the removal mechanisms for molecular markers (i.e., passage via diffusion and/or through defects) may be different than those associated with discrete particles, the *Guidance Manual* states that semi-permeable membranes (such as RO) are expected to provide similar microbial pathogen removal given their very high removal efficiencies for dissolved substances (USEPA, 2005).

On this note, the *Guidance Manual* states that fluorescent dyes, such as Rhodamine WT and FDC Red #40, may be considered as a viable molecular markers for characterizing RO membrane integrity. Such dyes offer the benefit of being detectable at ng/L levels via spectrophotometric absorbance/fluorescence, yet may be problematic due to adsorption losses (Lozier et al., 2003). In any case, sufficient analytical range should be available for such molecular markers to be discretely quantified between feed and permeate streams. On the other hand, the *Guidance Manual* declares that the use of gross measurements (such as TOC and conductivity monitoring) cannot be used for the purpose of quantification of the challenge particulates *in most cases*. In addition, it is desired that the molecular marker be inert and suitable for use in a water treatment facility (e.g., approved by the Food and Drug Administration (FDA) or certified by the National Sanitation Foundation (NSF)).

When applying marked-based tests for DIT applications, it is important to also record background levels in both feed and fitrate to have them subtracted from the respective streams during testing in order to yield an accurate LRV. Additionally, it is important to establish control limits for DIT purposes. The *Guidance Manual* defines control limits "as a response that, if exceeded, indicates a potential problem with the system and triggers a response" (USEPA, 2005). In other words, the DIT procedure must be sufficiently sensitive to establish thresholds that are

indicative of the membrane's integrity to achieve the awarded pathogen removal credit. The *Guidance Manual* expands on two levels of control limits: an upper control limit (UCL) and a lower control limit (LCL). For marker-based test purposes, the UCL "is simply equal to the log removal credit awarded by the State" for the membrane filtration system (USEPA, 2005). A LCL is "established to provide operators with an indication that there may be an integrity breach before becom[ing] a compliance concern." (USEPA, 2005). The *Guidance Manual* suggests that a practical *lower* bound for an LCL is the "lowest response that can be reliably measured that is indicative of an integrity breach" (USEPA, 2005).

#### *1.3.1.2. Continuous indirect integrity monitoring (CIIM)*

The *Guidance Manual* defines continuous indirect integrity monitoring (CIIM) as the monitoring of some aspect of filtrate water quality as a surrogate to measure membrane integrity (USEPA, 2005). The monitored parameter typically consists of turbidity monitoring with up to 15-minute frequency intervals, where an explicit decrease in filtrate quality may be indicative of an integrity problem and trigger a DIT as a result.

As opposed to DIT testing, performed on daily basis with methods sensitive enough to verify high LRVs, CIIM "provides a real-time indication of membrane integrity, albeit with generally less sensitivity" (USEPA, 2005). Thus, it can be said that DIT and CIIM are complementary to each other and provide comprehensive integrity verification of the membrane filtration system.

Turbidity is defined as the default method for CIIM under the LT2ESWTR, where "[…] two consecutive filtrate readings above 0.15 NTU trigger direct integrity testing" (USEPA, 2005). Nevertheless, the LT2EWSTR contains a provision where other methods, such as conductivity and TOC, may also be approved as an alternative for CIIM.

### 1.3.2. Viable surrogates for integrity testing

A number of viable surrogates have been evaluated for the purpose of integrity monitoring for RO applications. Following is a list of surrogates that possess comercially available meters and/or viable methods for analysis.

#### *1.3.2.1. Naturally occurring surrogates*

Naturally occuring surrogates are those that are already present in RO feed water at high enough concentrations, and have a sufficiently low detection limit, to evaluate membrane integrity. A clear advantage is that such surrogates do not require spiking to verify integrity such that the system can remain in normal production mode as membrane integrity is assessed. On the other hand, removal of such surrogates is typically lower than what is observed for seeded surrogates.

Because of these characteristics, ambient surrogates have mostly been considered for CIIM rather than for DIT. There is, however, an opportunity to explore other ions and/or metals that potentially offer higher removal than TOC and conductivity (for example) to implement as a DIT surrogate.

### *Conductivity*

Conductivity is an accepted surrogate for Total Dissolved Solids (TDS) and currently implemented for pathogen removal credit at the Claude "Bud" Lewis Carlsbad Desalination Project, owned by Poseidon Water and operated by IDE Technologies, as well as at the Sand City Desalination Plant, operated by California American Water. The underlying reason why TDS is accepted for integrity monitoring is due to its size, which might be characterized by the Van der Waals radius of sodium chloride (NaCl) or 0.00025 µm. This represents a size considerably lower than any known viral, pathogen, or protozoan species, such that California regulators (DDW) are confident that TDS rejection provides a conservative assessment for pathogen removal across an RO system. The benefit of using conductivity as an integrity monitoring parameter is that, by definition, RO membrane systems are highly effective in removing high concentrations of salts. Additionally, conductivity monitoring can be implemented either on-line or through intermittent probing, making it a highly versatile and relatively inexpensive method to implement. Moreover, conductivity is present at high enough ambient concentrations that it can be utilized for integrity monitoring without seeding. A considerable downside of conductivity is the relatively low sensitivity (i.e., LRV) that can be achieved across RO systems. This sensitivity is reported to be typically less than an LRV of 2 (99% removal) in water treatment applications and gradually declines over the course of membrane use (Adham et al., 1998). This is because transport of salts through the membrane by diffusion limits to overall removal of salts by the brackish water membrane to between 1 and 1.5 logs. Nevertheless, conductivity has been shown to be sensitive enough to be used to detect compromised elements, particularly for O-rings as shown in Figure 1-2.

Commercially available conductivity meters include the Georg Fischer Signet 2850 Conductivity/Resistor Sensor. This particular meter offers a conductivity range from 0.055 to 400,000 µS (*Georg Fischer Signet LLC, 2015). In addition, such meters are relatively inexpensive and will likely continue playing a role in RO membrane integrity monitoring. Conductivity also has the advantage that the sensors are stable and reliable, requiring limited maintenance.

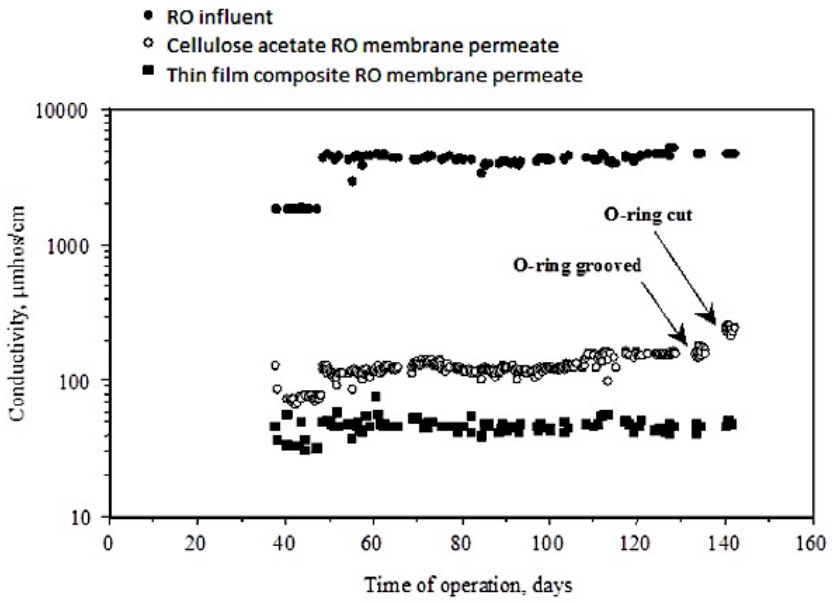


**Figure 1-2: RO conductivity monitoring under compromised conditions**

**(From Adham et al., 1998)**

### *Total organic carbon*

Total organic carbon (TOC) has been used at Orange County Water District's Groundwater Replenishment System (OCWD GWRS) to assess membrane integrity using TOC analyzers before and after the RO system. For such applications, it is common practice to have a low range instrument for the RO permeate side and a separate (and less sensitive) instrument for the feed water. It is undesirable to use the same instrument for both streams as cross contamination may take place since TOC of the two streams are different by orders of magnitude.

TOC has been reported to be more sensitive than conductivity – with removals of approximately 2 logs without influent spiking necessary (Adham et al., 1998). Yet, like conductivity, it fails to reflect an LRV that is representative to that of virus (i.e., MS2 bacteriphage) removal found in challenge tests. TOC has also been identified as means to monitor the passage of small molecular weight compounds across RO caused by an accidental chemical spillage to the sewershed (Olivieri et al., 2016). Although the bulk of the effluent organic matter in the TOC is of high moleular weight, there is a significant fraction that can pass through the membrane by diffusion. Thus the passage of TOC, like the passage of TDS, is subject to mechanisms not available to viruses.

General Electric offers online TOC meters that have been used in the industry for RO integrity monitoring. Specifially the Sievers 5310 C offers detection from 4 µg/L to 50 mg/L (*GE Power & Water, 2015). Although this meter offers a range to demonstrate LRVs greater than 4, typical removal of effluent organic matter (EfOM) by current RO membranes is limited to approximately 2 logs as TOC.

### *Sulfate*

Sulfate, which is often present at high enough ambient concentrations to quantify removal across RO membranes (typically ranging in 10s-100s mg/L in municipal wastewater), has been identified as a potential naturally occurring surrogate for monitoring membrane integrity. A log reduction as high as 3 has been reported for a study that observed reduction from 140 mg/L in the feed to 0.1 mg/L in the permeate (Kruithof et al., 2001). Additional testing with sulfate was recently conducted at the Beenyup Advanced Water Recycling Plant in Perth, Australia. At this facility, an LRV slightly above 3-logs was achieved when sulfate feed concentration was sufficient (Lozier, 2016). On-line measurement of sulfate can be performed by ion chromatography (IC) although such on-line systems are relatively expensive (Jacangelo et al., 2013). An alternative may be via grab sampling and performing same-day analysis. This procedure may still be under compliance of regulatory mandates for a DIT surrogate as long as measurements can be carried out within the stipulated frequency (i.e., every 24 hours). In terms of conservatism, sulfate is expected to offer a conservative evaluation of membrane integrity, as this ion is smaller than viruses. In addition, sulfate is expected to pass through membranes by both diffusion and through available defects. The suitability of sulfate will depend on the level of sulfate in the RO feed (the higher the better) and the availability of sufficiently sensitive rapid-response analytical methods.

For available on-line IC units, Metrohm does offer this possibility by combining their 850 Professional IC and the 872 Extension Module Liquid Handling device (*Metrohm, 2015). There is, however, to date limited experience and validation of such an apparatus for the application of membrane integrity monitoring and it seems likely to require significant maintenance.

### *Phosphate*

Like sulfate, phosphate has been another ion proposed for monitoring membrane integrity. Limited work has been performed on its applicability, yet 3-log reductions have been demonstrated when seeding phosphate into the RO feed as shown in Figure 1-3 (Trussell et al., 2015). Within the same study, a log reduction up to 2.7 was observed when phosphate was not spiked. Slightly higher log removal was achieved when phosphate was spiked as the permeate was not limited by the detection limit. Seeding of phosphate is undesirable as it poses an additional cost to demonstrate membrane integrity and the potential to add to membrane scaling. Not only is phosphate rejection subject to diffusion and defect

mechanisms, it is also subject to removal via chemical precipitation, a mechanism unrelated to virus removal. It can be shown that a very small degree of removal by precipitation would bias phosphate toward an exaggerated removal.

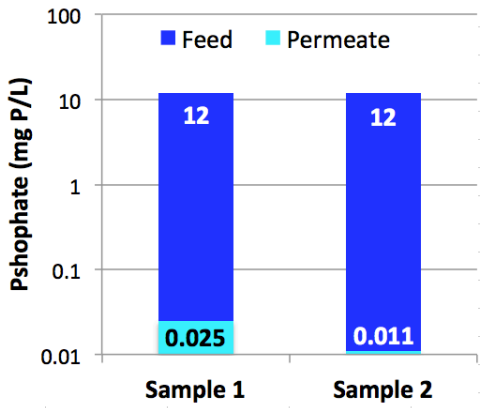


**Figure 1-3: Phosphate removal through RO system during spiking events (From Trussell et al., 2015)**

In terms of meter availability, Hach provides two on-line phosphate analyzers suitable for different concentration ranges. The PHOSPHAX sc Phosphate Analyzer has a detection range of 0.05 – 15 mg/L $PO_4$-P while the 5500 sc Phosphate low range analyzer of 4 – 5000 µg/L as $PO_4$ (*Hach, 2015a; *Hach, 2015b). Both analyzers are geared for the water/wastewater industry, with limited proven experience in the field of RO integrity monitoring. Like sulfate, phosphate monitoring can also be carried out via grab samples. Eurofins Eaton Analytical analyzes Orthophosphate as P with a method reporting limit (MRL) of 0.01 mg/L. Like sulfate, the suitability of phosphate will depend on the levels in the RO feed and the availability of sufficiently sensitive analytical methods that offer result turnaround within the required frequency, but its suitability as a surrogate is considerably flawed by potential removal via chemical precipitation.

### *Fluorescence excitation emission matrix (EEM)*

Excitation−emission matrix (EEM) is a fluorescence spectroscopy technique that has been widely used to characterize dissolved organic matter (DOM) or effluent organic matter (EfOM) in water matrices. Quantitative techniques have been employed to integrate the volume beneath an EEM for further analysis. Using fluorescence regional integration (FRI), as described in Chen et al. (2003), researchers have been able to quantify rejection of dissolved organic matter (DOM) across an RO process. Using this technique, a DOM rejection of 99.5% (2.3-logs) was reported by Pype et al. (2013). A standardized method remains to

be developed for interpreting EEM data. Additionally, as recently discussed in scientific opinion publication (Rosario-Ortiz & Korak, 2017), there needs to be caution when using fluorescence as a method for DOM analysis. This discussion is granted since fluorescence only considers a small fraction of DOM, particularly fluorescence dissolved organic matter (FDOM).

#### *Other ions and metals*

Other ions and metals have not yet been explored for the intent of monitoring RO membrane integrity. A common benefit is that metals and ions are already present in source waters where RO systems are employed. This eliminates the need for seeding a surrogate (i.e., challenge testing), which in turn, may reduce costs and allow the system to continue operations when demonstrating integrity. The attainable LRV of each metal/ion will provide an indication of how applicable such a surrogate may be for direct integrity testing.

Part of the scope of this project was to focus on ions and metals that are highly rejected across RO (>2 LRVs) while remaining detectable in the permeate stream. Additionally, lower detection analytical methods offered by the subcontracted analytical laboratory (Eurofins Eaton Analytical) were explored. Magnesium, calcium, and strontium were among the ions of interest.

### *1.3.2.2. Challenge testing*

Another method for evaluating membrane integrity is through challenge testing. In such applications, a marker (particle, dye, chemical, etc.) of known concentration is seeded into the feed water and a discrete log reduction value is calculated based on the amount of marker that passes through the system and is left in the permeate.

Through this method, it is possible to measure the potential removal of each marker and relate it to a parameter of interest (e.g., virus). Seeding a surrogate is necessary as the permeate sample is otherwise non-detect. The *Guidance Manual* discusses that the surrogate used for challenge testing shall be relatively easy to measure, approved for drinking water purposes, accessible, and inexpensive. Based on the earlier discussion, it is also evident that a good surrogate would show no adsorption on the membrane surface, would not react with other constituents in the RO feed to form precipitates, and would pass through the membrane by diffusion at the lowest degree possible. The surrogate should also not be degraded by the conditions in the RO feed, especially by chloramines.

### *Microbial Surrogates (MS2 Bacteriophage)*

Microbial surrogates, specifically male-specific bacteriophage (MS2), have been used for validating pathogen removal across RO membranes due to their similarities to enteric virus (Jacangelo et al., 2015a). Similar to other challenge testing surrogates, the MS2 bacteriophage is added to the feed at a known concentration from which an LRV is determined according to measured feed and permeate concentrations. Results and protocols for this method are widely reported (Adham et al., 1997; Colvin et al., 2000; Acker et al., 2001; Lozier et al., 2003; DeCarolis et al., 2006; Pype et al., 2016b; Antony et al., 2016). LRVs higher than 5 are usually achieved across intact membranes as captured in Table 1-3. It should be noted that Table 1-3 also shows some results with reduced removals which can only be explained by defects in the membranes or in the RO assembly itself, an observation that supports the enthusiasm for regulators in requiring regular RO performance confirmation. In essence, MS2 challenge testing at full-scale is costly and logistically involved due to amount of phage needed and is thus not feasible for large facilities. False positives have also been reported as a drawback for this method (Gitis et al., 2006). Finally there are concerns about the unforseen consequences of large concentrations of MS2 in the environment. For such reasons, MS2 challenge tests are often used to benchmark RO membrane virus removal that can be used for a basis for comparison to other surrogates, but not for daily integrity testing.

**Table 1-3: Summarized Literature Review of MS2 LRVs achieved**

**(From Jacangelo et al., 2015b)**

| MS2 Log Removal Value (LRV) | Reference |
|---|---|
| 2 – >5.9 | Gagliardo et al. (1997a); Gagliardo et al. (1997b) |
| 3.4 | Adham et al. (1998) |
| 2.7 – >6.5 | Adham et al. (1997) |
| 3 – 4.8 | Kruithof et al. (2001) |
| 4 | Lozier et al. (2004) |
| 5.4 | Mi et al. (2004) |
| 7 | Casani et al. (2005) |
| 1.4 – >7.4 | Kumar et al. (2007) |
| 4.2 - > 6 | Pype et al. (2016a) |

### *Rhodamine WT*

Rhodamine WT (R-WT) is a non-toxic fluorescent dye that was specifically formulated for water tracing applications (Smart & Laidlaw,1977; Sutton et al., 2001). Rhodamine WT is reported to be stable under a range of environmental conditions (Stanbro & Pyrch, 1979; Magal et al., 2008). Furthermore, R-WT is highly selective and sensitive, allowing detection in the ng/L range (Kitis et al.,

2003a). Intrumentation such as commericial probes for measuring R-WT are readily available.

For these features, R-WT has been widely investigated for RO integrity monitoring purposes. Under full- and pilot-scale conditions, R-WT has shown to demonstrate >4 LRVs (Lozier et al., 2003; Lozier et al., 2011; Lozier et al., 2015; Kitis et al., 2003a; Kitis et al., 2003b; Ostarcevic et al., 2013). Table 1-4 summarizes the reported R-WT integrity test results from field and laboratory applications. In terms of rejection mechanisms, R-WT passes through RO membranes by both diffusion and through available defects, in addition to size exclusion.

**Table 1-4: Summary of reported R-WT integrity test results**

**(adapted from Jacangelo et al. 2013)**

| Feed concentration (type*) | LRV** | Reference(s) |
|---|---|---|
| 0.1-1 mg/L (C) | 3–5 – 5.3 | (Kitis et al. 2003a) |
| 1-2 mg (C) | 3.9 | (Kitis et al. 2003b) |
| 1mg/L (C) | 2.7 – 3.0 | (Lozier et al. 2003) |
| 1 IL (C) | 3.6 – 4.8 | (Lozier 2016) |
| 0.1-1 mg/L (C) | 2.5 | (Lozier et al. 2013) |
| 0.1 mg/L (C) | 2.6 | (Lozier et al. 2011) |
| 5-10 mg/L (P) | >4 | (Ostarcevic et al. 2013) |

* application of spike: C = continuous; P = pulse
** adsorption not reported

Online fluorescence instrumentation is commercially available for the monitoring of R-WT. Aqualab offers a sensor with a sensivity range of 0.04 to 1000 µg/L (*Aqualab Scientific, 2015). Other providers include YSI and TurnerDesigns (*TurnerDesigns, 2015) (*YSI, 2015).

### *3D TRASAR*

3D TRASAR is a real-time monitoring technology developed by Nalco Company to detect changes in system demands and identify potential causes of system variability (*Nalco, 2015). It was originally developed for managing antiscalants, biocides and blowdown control in cooling towers and adapted to the control of similar chemicals in the reverse osmosis process. More recently Nalco has also been promoting the technology for integrity monitoring in reverse osmosis. For such application, real-time monitoring is achieved by addition of a proprietary fluorescent chemical, or dye, and monitoring removal dye removal across RO systems. The City of San Diego explored the applicability of TRASAR during a pilot-scale RO study (MWH, 2007). When dosed continuously, up to 6 LRVs were acheived (MWH, 2007). Another application investigated coupling TRASAR injection with the antiscalant; in this study an LRV of 3.5 was observed (Jacangelo, et al., 2015b). A more recent application of TRASAR was employed

at a raw water production facility at Big Springs (Texas) where 4 logs of removal were observed (Steinle-Darling et al., 2015). The use of TRASAR was also employed under Water Research Foundation Project 4536 (Blending Requirements for Water from Direct Potable Reuse Treatment Facilities) in Ventura, CA. Testing at this facility demonstrated a TRASAR LRV of up to 4.2 across an intact membranes when dye was continuously fed. The results from this study also showed that TRASAR rejection was affected by oxidized membranes yet provided a conservative assessment to virus removal across all of the tested conditions.

The application of 3D TRASAR is potentially valuable for potable reuse applications. However, limited studies have been performed to evaluate its applicability for full-scale systems in a long term trial. The rejection mechanism for TRASAR dye is size exclusion, although diffusion and passage through available defects can occur through the membrane. This is supported by the fact that TRASAR showed a reduced LRV across oxidized membranes.

#### *1.3.2.3. Discussion on available methods*

Table 1-5 summarizes the reviewed methods for RO integrity monitoring. A brief description as well as advantages/disadvantages and applicable products (i.e., meters) are also provided.

Plenty of techniques were not presented in this literature review, yet are available elsewhere (Jacangelo et al., 2013; Pype et al., 2016b). The methods presented here are those believed to be the most applicable for full-scale RO integrity monitoring as they either have comercially available meters or standard methods that can be used to calculate LRV.

Two distinct categories can be outlined for RO integrity monitoring methods – those that are continously monitored and those that are not. The former being applicable for CIIM and the latter used to periodically demonstrate high LRV to assure membrane integrity periodically (i.e., DIT). For CIIM, it is likely that TOC and conductivity will continue to play a major role in assessing RO membrane integrity on a continual basis. In terms of other ambient surrogates (e.g. sulfate, phosphate, and other metals/ions), further assessment is needed to determine their applicability as a DIT surrogate. This is true since only sparse amounts of data have been published on the applicability of such surrogates for RO integrity monitoring. There are commercially available meters to measure to occurrence of several naturally occuring constituents, yet the price of such equipment is often high and maintenace requirements are uncertain. For this reason, another route to be taken is to assess membrane integrity through analysis of grab samples. Such an avenue would be suitable for a utility that already routinely conducts laboratory analysis of constituents that could be integrated for integrity monitoring as well.

The use of challenge testing has shown true potential to demonstrate membrane integrity for full-scale applications. Of the methods laid out, Rhodamine WT appears to be the most suitable for full-scale applications since it is relatively inexpensive according to previous accounts (Kitis et al., 2003a). MS2 seeding experiments will continue to be an important component in demonstrating RO rejection potential as it serves as a referee for actual virus removal and serves as a basis for comparison for surrogate contenders. 3D TRASAR testing has also shown potential for RO membrane integrity given its ability to demonstrate LRVs beyond 3 on a continuous basis. That said, long term studies are needed to validate its use in a full-scale setting and the cost of the proprietary tracer may be a concern.

It is clear that each method has its advantages and disadvantages. It is key that any adopted technique be both not too expensive and not too demanding on operators for its successful implementation.

**Table 1-5: Summary of potential markers for RO membrane integrity monitoring**

| Monitoring Technique | Ambient or spiked? | Description | Scale | Method | Advantages/ Limitations | LRV potential | Reference |
|---|---|---|---|---|---|---|---|
| Conductivity (i.e., EC) | Ambient | Feed/permeate monitoring | Pilot & full-scale | Conductivity meter (e.g., Signet 2850) | • Fluctuates with temperature and fouling<br>• Inexpensive meters<br>• Can identify compromised membranes | Up to 2 | Adham et al. (1998) |
| TOC | Ambient | Feed/permeate monitoring | Pilot & full-scale | TOC meter (e.g., GE 5310 C) | • Method of choice at OCWD GWRS<br>• Higher LRV than conductivity | Slightly above 2 | Adham et al. (1998a) |
| Sulfate | Ambient | Feed/permeate monitoring | Full-scale | Online IC; Off-site analysis (e.g., EPA 300.0) | • Higher LRV given sufficient $SO_4$ in feed<br>• No spiking necessary<br>• Expensive online application | Up to 3 | Kruithof et al. (2001)<br>Jacangelo et al. (2013)<br>Lozier et al. (2015) |
| Phosphate | Ambient | Feed/permeate monitoring | Pilot & full-scale | Phosphate meter; (e.g., Hach 5500sc) Off-site analysis | • Higher LRV given sufficient $PO_4$ in feed<br>• No spiking necessary<br>• Limited experience for this application | Up to 3 | Trussell et al. (2015) |
| Fluorescent Dye (i.e., R-WT) | Spiked | Monitor removal of spiked dye with calibrated instrument | Pilot & full-scale | R-WT fluorometer (e.g., TurnerDesign) | • High LRV potential<br>• Spiking necessary<br>• Facility not producing during testing<br>• Possible membrane dye adsorption | Above 4 | Lozier et al. (2011)<br>Lozier et al. (2003)<br>DeCarolis et al. (2006)<br>Ostarcevic et al. (2013) |
| Microbial surrogate (i.e., MS2)[a] | Spiked | Measure removal of spiked bacteriophage | Pilot & full-scale | Off-site analysis (e.g., EPA 1602) | • High LRV potential<br>• Similar characteristics as microbial pathogens<br>• Serves as a referee for virus removal<br>• High cost at full-scale<br>• Health concerns at high concentrations | Above 6 | DeCarolis et al. (2006)<br>Adham et al. (1997)<br>Jacangelo et al. (2015a) |
| 3D TRASAR | Spiked | Monitor removal of spiked dye with calibrated instrument (proprietary) | Pilot & full-scale | Proprietary fluorescence meter (e.g., 3D TRASAR) | • High LRV potential<br>• Can be added together with antiscalant<br>• NSF approved (up to 15 mg/L)<br>• Spiking necessary<br>• Proprietary technology | Up to 6[a]<br>Up to 3.4[b] | MWH (2007)<br>Steinle-Darling et al. (2015)<br>Jacangelo et al. (2015b)<br>DeCarolis et al. (2006) |

[a] MS2 seeding experiments are understood as a referee for actual virus removal
[b] for continuous spikes
[c] coupled to antiscalant injection

# 2. Methods and Materials

## 2.1. Description of the North City Demonstration Pure Water Facility

Testing for this project occurred at the North City Demonstration Pure Water Facility (DPWF) in San Diego, California. The facility began operations in 2011 with the capacity to treat non-chlorinated tertiary effluent from the North City Water Reclamation Plant (NCWRP) to produce up to 1 MGD (158 $m^3$/h) of purified water. NCWRP is a 30 MGD (4732 $m^3$/hr) capacity facility consisting of primary, secondary, and tertiary treatment. Primary treatment includes of bar screens, grit removal, and conventional primary sedimentation. Secondary treatment provides biological nitrification and partial denitrification in a Modified Ludzack-Ettinger process with a solids retention time (SRT) typically at 10 days. Reclaimed water is distributed after tertiary treatment which includes anthracite media filtration, demineralization via electrodialysis reversal (EDR), and chlorine disinfection.

The DPWF facility was constructed with a full advanced treatment train consisting of parallel microfiltration (MF) and ultrafiltration (UF) skids followed by reverse osmosis (RO) and ultraviolet advanced oxidation process (UV/AOP). The full advanced treatment train (MF/UF-RO-UV/AOP) has been established as a system capable of meeting the treatment requirements of the Groundwater Replenishment Regulations adopted by California DDW in June 2014 (DDW, 2014). In addition to this core treatment train installed in 2011, ozone ($O_3$) and biological activated carbon (BAC) were added as pre-treatment in 2014. A schematic of the DPWF treatment train is given in Figure 2-1. A summary of unit process characteristics and design parameters is provided in Table 2-1.

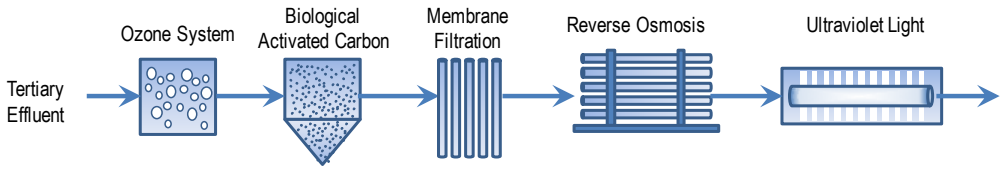


**Figure 2-1: Schematic of the North City Demonstration Pure Water Facility**

**Table 2-1: Summary of the North City DPWF unit process characteristics and design parameters**

| Ozone System | BAC System | UF System | MF System | RO Train A System | RO Train B System | UV/AOP System |
|---|---|---|---|---|---|---|
| Manufacturer WEDECO (A Xylem Brand) | Manufacturer Leopold (A Xylem Brand) | Manufacturer Toray (modules) H2O innovation® (system) | Manufacturer Pall Corporation® | Manufacturer Hydranautics (elements) EnAqua (system) | Manufacturer Toray (elements) EnAqua (system) | Manufacturer TrojanUV |
| Generator max capacity 190 lbs/day (86.2 kg/day) | Area per filter 180 sf (16.7 $m^2$) | Module model HFU-2020N | Module model UNA-620A | Element model[1] ESPA2 LD | Element model[1] TML20D-400 | System model TrojanUVPhox ECT |
| Ozone concentration 10% | Media Depth 6.5 ft (2 m) | Nominal pore size 0.015 µm | Nominal pore size 0.1 µm | Skid configuration 10:5 array | Skid configuration 10:5:3 array | Number of Lamps 72 |
| Typical applied ozone 10.2-10.8 mg-$O_3$/L | Filter loading rate 3.05 gpm/sf (2.07 L/$m^2$/s) | Membrane area 775 $ft^2$ (72.0 $m^2$) | Membrane area 538 $ft^2$ (50.0 $m^2$) | Membrane area 400 $ft^2$ (37.1 $m^2$) | Membrane area 400 $ft^2$ (37.1 $m^2$) | Total Power 18.0 kW |
| Contactor HDT 7 minutes | Empty bed contact time 15 minutes | Membrane material PVDF | Membrane material PVDF | Membrane material Composite polyamide | Membrane material Composite polyamide | Lamp spectral radiation Low pressure |
| Design CT 14 mg-min/L | Filter Media Exhausted granular activated carbon | Recovery > 95% | Recovery > 95% | Recovery[2] 75-85% | Recovery[2] 75-85% | AOP oxidant Free Chlorine ($Cl_2$) |

1 – Replaced with Toray TMG20D-400 partway through this project
2 – Recovery adjustments made in August 2016 as part of Sulfuric acid addition to RO feed

## 2.2. Reverse osmosis system

The reverse osmosis system at the DPWF consists of two parallel RO trains that treat the MF/UF product water. Train A consists of two stages in a 10:5 array, and Train B is comprised of three stages in a 10:5:3 array configuration. Testing for this project was performed exclusively across Train A. Train A is a 450 gpm (102 $m^3$/hr) feed flow skid operated at 75-85% recovery. Stage 1 of Train A is equipped with ten pressure vessels each holding seven 8-inch elements. The concentrate of Stage 1 is fed to a low pressure turbocharger (LPT-250) from Pump Engineering, Inc. (Monroe, MI) which serves as "booster" pump for the stream feeding Stage 2. Stage 2 is equipped with five pressure vessels each housing seven 8-inch elements. A picture of the RO system at the DPWF is provided in Figure 2-2 while Figure 2-3 provides a schematic of Train A. In terms of online monitoring, Train A is equipped with online Signet 2850 conductivity sensors from GF Signet (El Monte, CA) located on the system's inlet as well as on the combined permeate. In addition, an online 5410 C Portable TOC Meter from GE Sievers (Boulder, CO) measured the TOC from the combined permeate of Train A and Train B.

**Figure 2-2: RO System at the North City Demonstration Pure Water Facility**

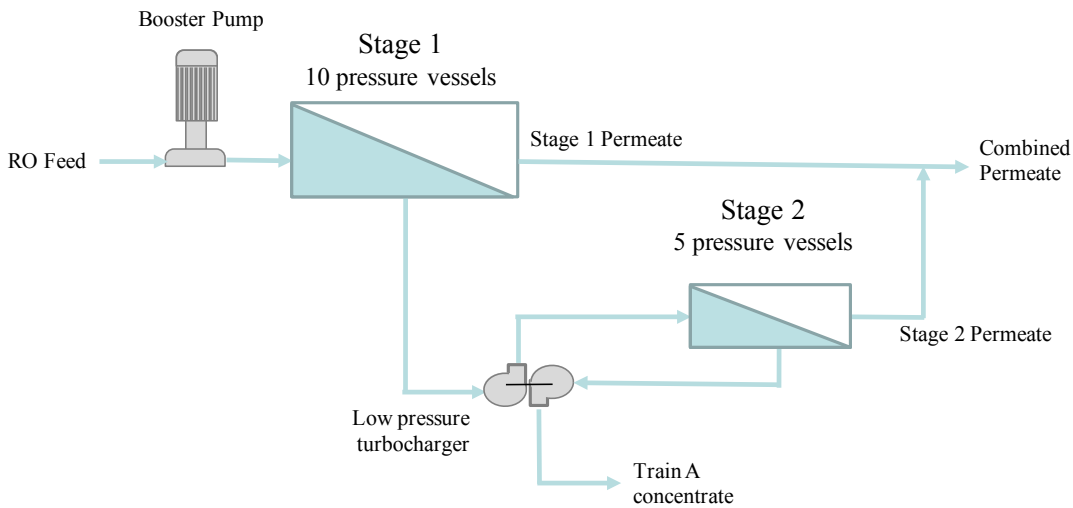


**Figure 2-3: Schematic of Train A of the RO system at NCPWDF**

### 2.2.1. Reverse osmosis elements

At the start of this project (October 2015), Train A was fitted with Hydranautics (Oceanside, California) ESPA2 LD elements. These elements had an accumulated runtime of approximately 30,000 hours at the time these investigations took place. Testing also took place with unused ESPA2 LD elements when a single vessel had its elements replaced with these unused elements from the same model and production batch. In addition, as part of the facility's regular maintenance, all elements from the RO system were replaced with Toray (Poway, USA) TMG20D-400 during the project. As a result, a total of three different types of RO elements were evaluated as summarized in Table 2-2 and captured in Figure 2-4.

**Table 2-2: Description of RO elements**

| Parameter | Hydranautics ESPA2 LD | Toray TMG20D-400 |
|---|---|---|
| Material | Composite polyamide | Composite polyamide |
| Element size | 8-inch | 8-inch |
| Max operating pressure | 600 psi (41.4 bar) | 365 psi (25.2 bar) |
| Membrane condition at time of testing | Aged (5 years). Approx. 30,000 runtime hours. Underwent numerous CIP cleans with citric acid and caustic soda. Unknown free chlorine exposure. 30,000 – 90,000 ppm-h estimated chloramine exposure. | Virgin. No CIP cleans. |
| Notes | Testing also performed across a single vessel fitted with unused ESPA2 LD elements from original batch. | Additional RO protection measures (e.g., $Cl_2$, ORP, $NH_3$-N meters) at the time of testing. CIP had not been performed at the time of testing. |

**Figure 2-4: RO elements**

**(ESPA2 LD shown on left of each figure; TMG20D-400 shown on right of each figure)**

## 2.3. Naturally occurring constituent surrogates

A number of naturally occurring constituents were evaluated for the purpose of monitoring RO integrity. Sampling for naturally occurring constituents took place at the Train A sampling station (Figure 2-5) which provides permeate from individual vessels, Stage 1, Stage 2, and combined (Stage 1 plus Stage 2), as well as RO feed, Stage 2 feed, and overall concentrate. Sampling for naturally occurring constituents took place during typical operations. Samples were collected in dedicated containers once sampling ports were flushed out for approximately 1 minute. Samples were either subsequently chilled to be sent off for analysis or measured on-site.

**Figure 2-5: Train A Sampling Station**

### 2.3.1. Naturally occurring metals and ions

Analysis of naturally occurring metals and ions were measured by a subcontracted laboratory (Eurofins Eaton Analytical – Monrovia, CA). Table 2-3 provides a list of the relevant analytes along with the corresponding method, instrumentation, and Eurofins' method reporting limit (MRL). During the project, strontium was measured using two different methods, EPA 200.7 (MRL = 0.01 mg/L) and EPA 200.8 (MRL = 0.3 µg/L); EPA 200.8 is the method specified in the Unregulated Contaminant Monitoring Rule (UCMR3). Both methods use inductively coupled plasma (ICP): EPA-200.7 with detection by atomic emissions spectroscopy (AES) and EPA-200.8 with detection by mass spectroscopy (MS).

**Table 2-3: List of investigated naturally occurring metals and ions**

| Analyte | Method | Instrumentation | MRL[1] |
|---|---|---|---|
| Calcium | EPA 200.7 | ICP-AES | 1 mg/L |
| Magnesium | EPA 200.7 | ICP-AES | 0.1 mg/L |
| Potassium | EPA 200.7 | ICP-AES | 1 mg/L |
| Sodium | EPA 200.7 | ICP-AES | 1 mg/L |
| Strontium | EPA 200.7 | ICP-AES | 0.01 mg/L |
| | EPA 200.8 | ICP-MS | 0.3 µg/L |
| Chloride | EPA 300.0 | IC | 1 mg/L |
| Sulfate | EPA 300.0 | IC | 0.5 mg/L |
| Fluoride | SM 4500F-C | ISE | 0.05 mg/L |
| Orthophosphate | 4500P-E/365.1 | Automated colorimetry | 0.01 mg-P/L |

1 - Method reporting limit from Eurofins Eaton Analytical

### 2.3.2. Electrical conductivity (EC)

Electrical conductivity was also used to measure RO integrity. EC was either measured on-site using a portable Hach SensION 156 multi-parameter meter or sent for analysis by Eurofins under the SM2510B method (MRL = 2 µmho/cm). On-site conductivity was measured immediately upon sampling at system operational temperature.

### 2.3.3. Total organic carbon (TOC)

Total Organic Carbon (TOC) was measured onsite using a GE Sievers 5310 C Portable meter in grab mode which has an operating range 4 µg/L to 50 mg/L. The grab mode was configured to perform four readings with the first rejected and remaining three handled as measurements in triplicate. Oxidizer and acid were both manually set at a 2.0 µg/L flow rate with an inline inorganic carbon remover (ICR). Samples were collected in GE Certified (<10 ppb) TOC vials and any dilutions were performed using Milli-Q water and handled using Class A glassware.

### 2.3.4. Fluorescence excitation-emission matrix (EEM)

Fluorescence excitation-emission matrices (EEMs) were performed to characterize organic matter in water samples relevant to the reverse osmosis system. Samples were collected and sent to Trussell Technologies' laboratory in Pasadena, CA for analysis. Analysis of samples was performed using an Aqualog benchtop fluorometer from Horiba Scientific for an excitation range 240-470 nm and emission range of 280-580 nm. Data was acquired using Aqualog supplied software and processed in MatLab using a modified Fluorescence Regional Integration (FRI) method described elsewhere (Stanford et al., 2011; Gerrity et al., 2011) and the Fluorescence Index (FI) (McKnight et al., 2001) were used to assess changes in dissolved organic matter (DOM). The EEM images were corrected for the Raman Scatter by subtracting emission of the blank and corrected for inner-filter effect, following a previously described method in MacDonald et al. (1997).

## 2.4. Spiked constituents

Spiking was performed for constituents lacking sufficient RO influent concentration to measure detectable removal across the RO system. A spike solution (i.e., batch) was prepared using neat product and contents were pumped ahead of an inline static mixer and booster pump to ensure proper mixing before reaching RO treatment. A PULSAFeeder PULSAtron chemical pump was used to pump the spike solution into the process line. Target influent concentrations were based on the method detection limit, expected removal across the RO system, and system process flow. Batch concentration and pumping flow rate were adjusted to meet the desired target influent concentration. Approximately 30 minutes were given from when the spike commenced to the collection of the first samples in order to reach steady-state conditions. Figure 2-6 provides a schematic of the setup for when constituents were spiked ahead of the RO system.

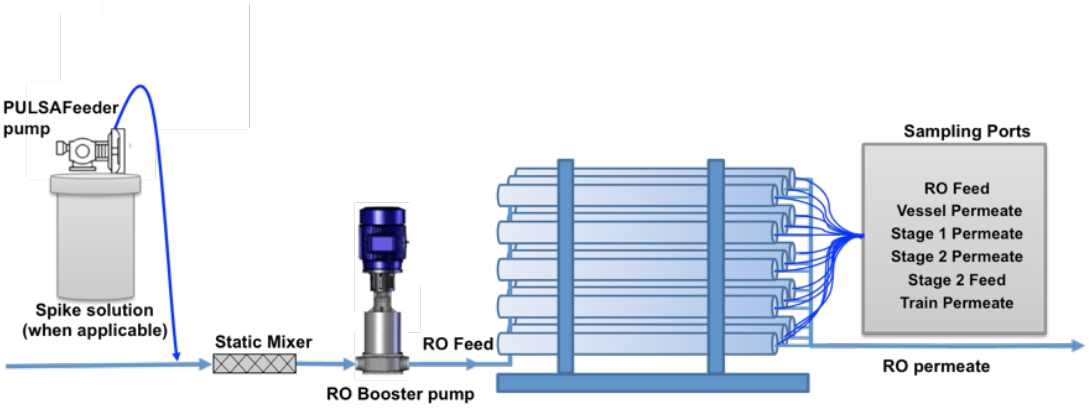


**Figure 2-6: Setup for spiking constituents ahead of the RO system**

### 2.4.1. MS2 bacteriophage

The MS2 bacteriophage spiking solution was prepared using MS2 stock solution ($10^{11}$ pfu/mL) supplied by IEH-BioVir Laboratories (Benicia, CA) and non-chloraminated UF/MF filtrate. The use of non-chloraminated filtrate was chosen to avoid unintentional phage inactivation caused by any residual disinfectant (e.g., chloramines). In addition, typical pre-membrane filtration chloramination was turned off prior to and during MS2 challenge testing.

A target feed concentration was set at approximately $10^6$ pfu/mL for all MS2 challenge tests. All MS2 spiking events were performed with a single RO train (Train A) in operation. For each MS2 spiking event, triplicates samples were collected from the RO feed and permeate. Upon sampling, samples immediately chilled and subsequently overnighted to IEH-BioVir Laboratories where they were assayed. Analysis was primarily performed using a double-agar-layer (Adams 1969) with a detection limit of 1 pfu/mL. EPA 1602 (single-agar-layer) was used as a backup method when Adams 1959 samples were found to be non-detect. EPA 1602 offers a lower detection than Adams 1959 at 1 pfu/100mL.

### 2.4.2. Rhodamine WT

The R-WT spiking solution was made by diluting 20% strength Rhodamine WQ obtained from ACROS Organics with potable water. R-WT analysis was performed on-site. Feed samples were collected as grabs and measured using a tabletop spectrophotometer (Hach DR/4000). Permeate samples were continuously measured using a flow-through cell Turner Design C3 fluorometer fitted with a Rhodamine WT optical sensor.

Feed samples had their absorbance converted to R-WT concentration using Beer's law and an extinction coefficient from Tai and Rathbun (1988). The equation below provides the parameters used for Beer's Law. Assuming a reliable absorbance reading of 0.010 $cm^{-1}$ using the 10 cm quartz cuvette, a detection limit of approximately 10 ppb R-WT was established for the UV/Vis spectrophotometer.

$$A = \varepsilon \, l \, C$$

where:

A = absorbance ($cm^{-1}$)
ε = Extinction coefficient (87,000 $M^{-1}$ $cm^{-1}$ at pH 5.6 and 550 nm)
l = path length (cm)
C = molarity (M)

Raw fluorescence units (rfu) measurements of the C3 fluorometer were converted to R-WT concentration from a calibration curve using standards prepared in-house ($r^2$ >0.99). The y-intercept was forced through the background permeate R-

WT fluorescence. An example of such a calibration curve is provided in Figure 2-7. Turner Design specifies a detection limit of 0.01 ppb for the R-WT optical sensor, yet observable R-WT removal across the RO system was dependent on background R-WT levels. Background RO permeate R-WT fluctuated between 10 and 60 rfu during testing. An R-WT target feed concentration between 1 and 8 mg/L was evaluated throughout the Project.

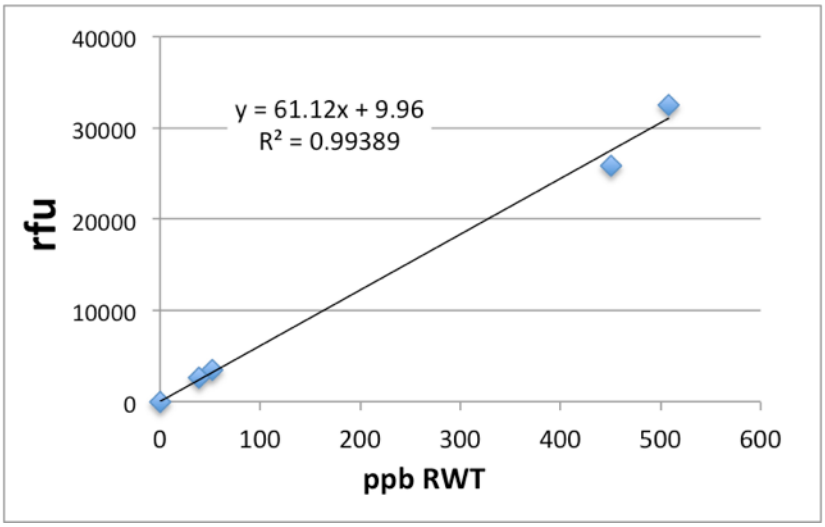


**Figure 2-7: Example of calibration curve for R-WT concentration and rfu C3 readings**

### 2.4.3. Nalco 3D TRASAR

The 3D TRASAR system operates by adding a proprietary dye (TRASAR 23299) to the feed stream for the process in question and measuring its concentration in different parts of the system using fluorometry. Because the dye does not precipitate or adsorb, its concentration in the system can be used in mass-balance calculations essential for managing process control. The TRASAR dye can also be measured at very low concentrations using low range fluorometers. In the RO integrity application, the removal across the RO system is assessed using proprietary LED low range fluorometers located on the RO feed and permeate. Within this project, a 110-day field trial with Nalco's system took place. Monitoring was performed solely on Train A, and specifically on RO feed, Stage 1 permeate, and Stage 2 permeate. An additional fluorometer was also positioned on the RO feed prior to dye injection to account for background fluorescence. A schematic of the 3D TRASAR setup throughout the trial is provided in Figure 2-8. During certain instances, monitoring was switched to the permeate of individual vessels and combined permeate to measure removal of the dye at these locations. Feed dye concentration was tested between 0.4 and 0.05 mg/L as active compound (TRASAR 23299, 10% active). A detection limit of 0.4 ng/L was

established for the low range fluorometers, but the ability to trace removal of the dye was limited by background fluorescence in the permeate. The background fluorescence in the RO feed water was equivalent to 1-5 µg/L as dye depending on the extent of pre-ozonation. Accordingly, the background fluorescence in the RO permeate was equivalent to mostly 1-5 ng/L as dye in Stage 1 and 5-15 ng/L as dye in Stage 2. Data acquisition was performed on minute-to-minute basis and provided by a Nalco representative.

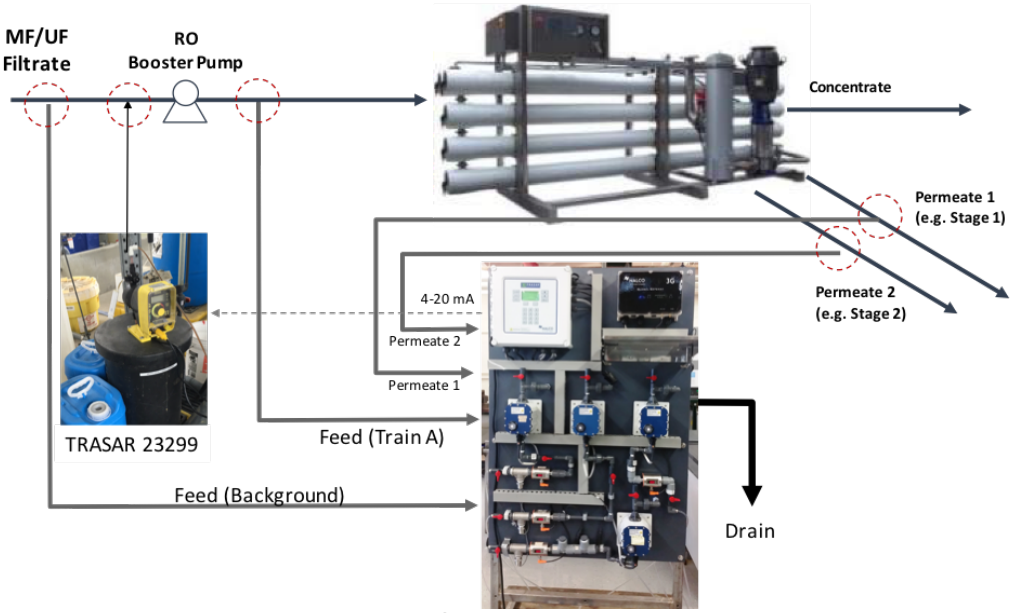


**Figure 2-8: 3D TRASAR setup during Project trial**

**Figure 2-9: Close-up of 3D TRASAR fluorometer**

### 2.4.4. Sugar

Table sugar, or sucrose (342 Da) was also investigated for monitoring RO integrity. A spiking solution was made up by dissolving granulated pure cane sugar in potable water. Figure 2-10 provides an image of the sugar spiking solution being prepared. The solution was spiked to the process stream to achieve a target RO feed concentration between 300 and 600 mg/L. The extent of sugar removal was based on TOC measurements from feed and permeate samples. Duplicate grab samples were collected for each location and measured on-site using the GE Sievers 5310 C Portable TOC meter. All grab samples were collected in GE Certified (<10 ppb) TOC vials. In addition, feed and permeate TOC grabs were collected both before and after every spike to account for background TOC contribution to that of sugar. The target sugar feed concentration was chosen based on expected removal by the system and having sufficient sugar remaining in the permeate to be able to distinguish it from the ambient TOC.

**Figure 2-10: Preparation of sugar spiking solution**

### 2.4.5. Sucralose

Sucralose is a known artificial sweetener (i.e., sugar substitute) with a molecular weight of 397 Da. Because of its similarity to sugar in terms of molecular weight, removal of sucralose was assessed as a cross-reference to sugar, which was quantified by a gross measurement (i.e., TOC). The sucralose spiking solution was prepared using pure sucralose powder and potable water and spiked to achieve a target sucralose feed of 5 mg/L into the process line. Upon collection, samples were sent to Eurofins Eaton Analytical (Monrovia, CA) for analysis using solid phase extraction Liquid chromatography with tandem mass spectrometry (SPE LC-MS/MS) instrumentation. The method used has a minimum reporting limit of 100 ng/L.

### 2.4.6. Uncharged low molecular weight organic compounds

A suite of uncharged low molecular weight (32 to 150 Da) organic compounds were individually spiked to measure extent of rejection across the RO system. Compounds were spiked across both aged and unused ESPA2 LD elements. A list of the spiked compounds, including relevant characteristics is provided in Table 2-4. All chemicals were Sigma-Aldrich of ACS reagent-grade or higher. Organics were measured on a TOC-basis using the on-site meter in grab mode. A target feed concentration of 5 mg/L as carbon was spiked for all compounds with exception to xylose; spiked at a target feed concentration of 100 mg/L as carbon given the higher expected removal per its molecular weight. Boron (as boric acid) was not spiked, yet included in this evaluation given its reported usefulness in assessing membrane performance, including rejection of NDMA (Tu et al., 2013). Background TOC samples were taken for both permeate and feed streams before and after spiking events, such that background TOC removal was accounted for when calculating spiked compound removal.

**Table 2-4: List of spiked uncharged low molecular weight constituents**

| Compound | Molecular Weight (Da) | Log $K_{ow}$ | Concentration of neat chemical |
|---|---|---|---|
| Methanol | 32 | -0.77 | 99.8% |
| Ethanol | 46 | -0.31 | ≥99.5% |
| 2-propanol | 60 | 0.05 | 99.5% |
| Ethylene glycol | 62 | -1.36 | 99.8% |
| Boron (boric acid)* | 62 | 0.18 | naturally occurring |
| 2-butanol | 74 | -0.61 | ≥99.5% |
| Glycerol | 92 | -1.76 | ≥99% |
| Xylose | 150 | -1.98 | ≥99% |

*measured at ambient levels.
*analysis by City of San Diego Laboratory (EPA 200.7)

## 2.4.7. Summary of spiked constituents

Table 2-5 summarizes relevant parameters from the spiked constituents investigated throughout this project, including detection limit, expected LRV, and target feed concentration.

**Table 2-5: Summary of investigated spiked constituents**

| Spiked Constituent | Size/ MW | Analysis Method/ Instrumentation | Detection Limit | Exp. LRV | Target Feed Concentration[2] |
|---|---|---|---|---|---|
| MS2 bacteriophage[1] | 25–27 nm | EPA 1602<br><br>Adams 1959 | 1 pfu/100mL<br><br>1 pfu/mL | 4.0 to 7.0 | ~$10^6$ pfu/mL |
| Rhodamine WT | 567 Da | Feed samples: Absorbance (Hach DR/4000)<br><br>Permeate Samples: Fluorescence (Turner Design C3) | ~10 ppb[3]<br><br>0.01 ppb[4] | 3.0 to 4.5 | 1 – 8 mg/L[5] |
| 3D TRASAR 23299 | unknown | Proprietary low range LED fluorometers | 0.004 ppb[6] | 3.0 to 4.5 | 0.05 – 0.4 mg/L[7] |
| Sugar | 342 Da | TOC | 5 ppb[8] | 2.5 to 3.5 | 300 – 600 mg/L[9] |
| Sucralose | 397 Da | SPE LC-MS/MS | 0.1 ppb[10] | 2.5 to 3.5 | 5 mg/L |
| Low MW organics | 32-150 Da | TOC | 5 ppb[11] | 0 to 2 | 5 mg/L[12] |

1 – MS2 stock ($10^{11}$ pfu/mL) and analysis performed by IEH-BioVir Laboratories
2 – Target feed achieved by spiking batch solution to process stream using pump.
3 – Based on conversion using Beer's Law using extinction coefficients from Tai and Rathbun (1988) and reliable spectrophotometer reading (Abs = 0.010 with 10cm cuvette)
4 – From Turner Design C3 product specifications. Actual observable removal is dependent on background fluorescence.
5 – Concentration representative of active Rhodamine WT.
6 – Based on conversations with Nalco representative. Actual observable removal is dependent on background fluorescence.
7 – Concentration representative of active dye. TRASAR 23299 is 10% active based on conversations with Nalco representative.
8 – Detection limit from GE Sievers M5310 C Portable. Actual observable removal is dependent on background TOC.
9 – Function of ΔTOC that must be present in relation to ambient permeate TOC
10 – From Eurofins Eaton Analytical SPE LC-MS/MS Endocrine Disruptor method
11 – Actual detection limit depends on ΔTOC spiked compound and ambient TOC
12 – 5 mg/L as carbon was spiked to differentiate from ambient TOC. 100 mg/L as carbon was used for Xylose

## 2.5. Data Analysis

Throughout this project, membrane removal efficiency (i.e., LRV) was calculated using Equation 3.7 of the EPA Membrane Filtration Guidance Manual:

$$\boldsymbol{LRV = \log(C_f) - \log(C_p)}$$

where:

| | | |
|---|---|---|
| LRV | = | log removal value demonstrated during challenge (or sampling of naturally occurring constituent) |
| $C_f$ | = | feed concentration of the challenge constituent (or naturally occurring constituent) (number or mass / volume) |
| $C_p$ | = | filtrate concentration of the challenge constituent (or naturally occurring constituent) (number or mass / volume) |

For Stage 2 removal efficiency, Stage 2 feed was used as $C_f$ and Stage 2 permeate was used as $C_p$. For non-detect permeate samples, the term $C_p$ was set equal to the detection limit. Background feed and permeate concentrations were taken into account for sugar and Rhodamine WT by measuring the respective parameters, TOC and absorbance/fluorescence, at ambient conditions prior to and after the spike was conducted.

Exclusive to TRASAR, Stage 1, 2, and Train log removals were calculated using the following equations. Recoveries were based on individual stage flows recorded on the RO system's Human Machine Interface (HMI) data management system.

$$Stage\ 1\ TRASAR\ LRV = -\log\left[\frac{\left(Stage\ 1\ TRASAR, \frac{\mu g}{L}\right)\left(\frac{1\ mg}{1000\ \mu g}\right)}{RO\ Feed\ TRASAR, \frac{mg}{L} - Background\ TRASAR, \frac{mg}{L}}\right]$$

$$Stage\ 2\ TRASAR\ LRV = -\log\left[\frac{\left(Stage\ 2\ TRASAR, \frac{\mu g}{L}\right)\left(\frac{1\ mg}{1000\ \mu g}\right)}{\frac{RO\ Feed\ TRASAR, \frac{mg}{L} - Background\ TRASAR, \frac{mg}{L}}{(1 - Stage\ 1\ recovery, \%)}}\right]$$

$$Train\ TRASAR\ LRV = -\log\left\{\frac{\left[\left(\frac{Stage\ 1\ TRASAR, \frac{\mu g}{L}}{Stage\ 1\ recovery, \%}\right) + \left(\frac{Stage\ 2\ TRASAR, \frac{\mu g}{L}}{Stage\ 2\ recovery, \%}\right)\right]\left(\frac{1\ mg}{1000\ \mu g}\right)}{RO\ Feed\ TRASAR, \frac{mg}{L} - Background\ TRASAR, \frac{mg}{L}}\right\}$$

## 2.6. Investigated membrane compromises

Previous reverse osmosis integrity monitoring studies (Jacangelo et al., 2015b; Walker et al., 2016) have shown that compromises to O-rings cause the greatest impact on a system's integrity (Figure 2-11). The function of the O-rings is to seal the connection that keeps the feed and permeate streams separate. When an O-ring is compromised, feed water may pass into the permeate stream without passing through the membrane, causing unintentional contamination of the permeate. O-rings degrade naturally over time due to exposure to chemicals (e.g., chloramines) and can also slip or deform during placement, compromising the intended seal. At the extreme end of O-ring failures, they can simply be missing. Given the hundreds or thousands of O-rings present in a large system, this impairment is an apparent threat to an RO system.

Based on these published results, this project focused on O-ring impairments by both cutting and removing O-rings from permeate interconnectors and vessel endcaps. Permeate interconnectors are located between each set of membrane elements to prevent the entry of feed water/brine into the permeate channel. For this system, each interconnector has two O-rings on each end, for a total of 4 O-rings. Vessel endcaps are located at both ends of pressure vessels and hold the vessel together under operation while providing a final channel for the permeate before entering a manifold containing permeate from other vessels. Each endcap contains two O-rings. Figure 2-12 provides a schematic for a typical RO pressure vessel, showing location of O-rings in the different locations. All compromises were carried out in a single pressure vessel in Stage 1 of Train A (see Figure 2-13 for location of vessels that were tested). Figure 2-14 captures the compromises that were investigated throughout this project on both Hydranautics ESPA2 LD and Toray TMG20D-400 elements.

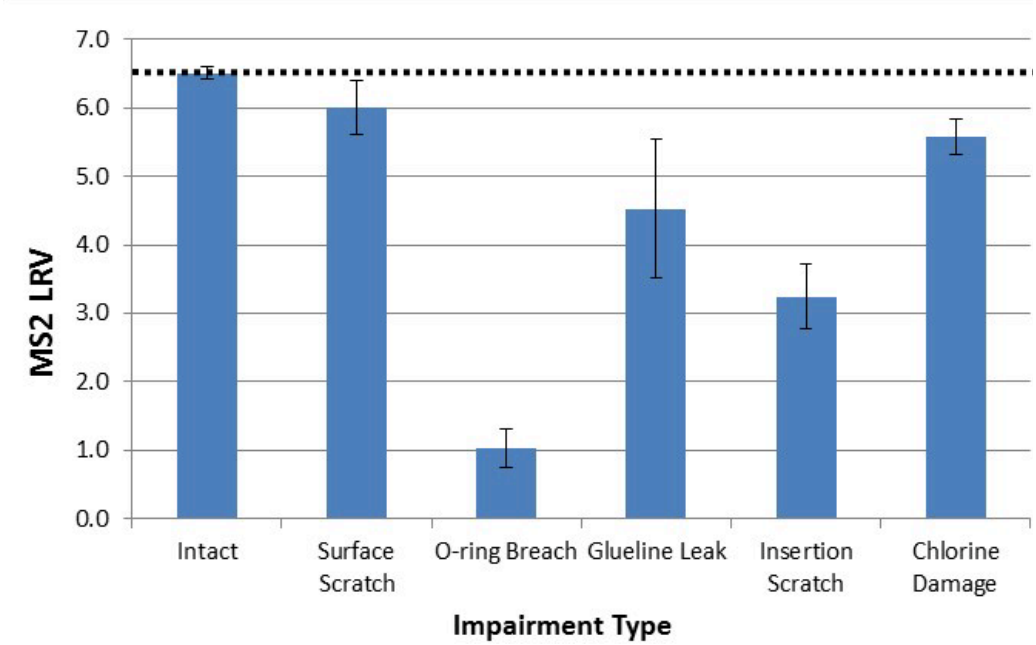


**Figure 2-11: Impact of membrane impairments on MS2 rejection by RO (From Jacangelo et al., 2015b; dashed line indicates maximum log removal based on lower detection limit of the viral assay)**

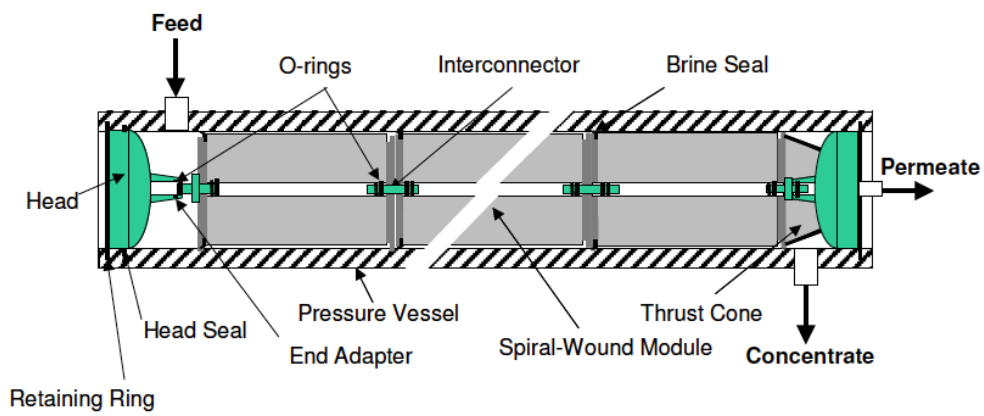


**Figure 2-12: RO pressure vessel schematic (From USEPA, 2005)**

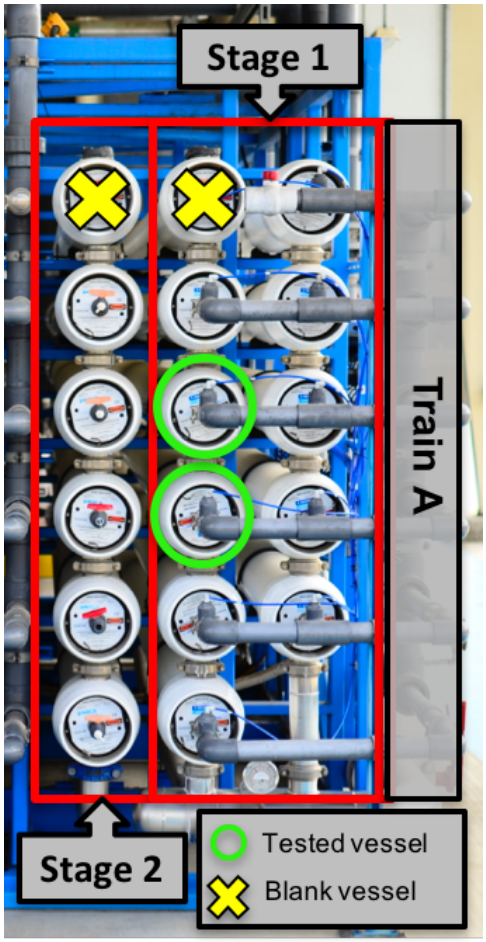


**Figure 2-13: Train A with location of vessels that were tested**

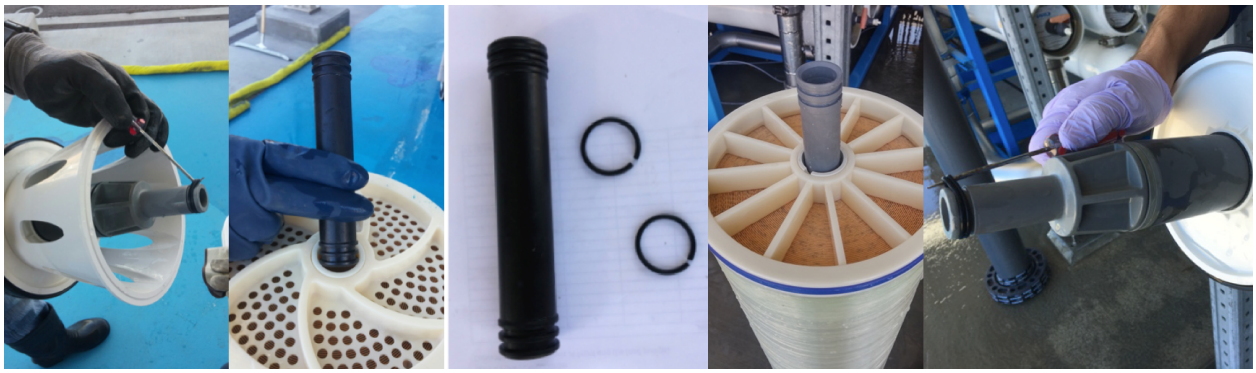

**Figure 2-14: Investigated compromises during this project**

**(From left to right: brine endcap O-ring removal, ESPA2 LD interconnector O-ring removal, ESPA2 LD interconnector cut O-rings, TMG20D interconnector O-ring removal, feed endcap O-ring removal)**

To carry out the compromises, it was necessary to shut down the RO system, allow it to undergo a permeate flush, and depressurize. The pressure vessels were then opened by removing the retaining ring. It was necessary to push out elements to gain access to permeate interconnectors and perform desired compromises. The vessel endcap compromises were made without moving elements.

# 3. Results and discussion

## 3.1. RO feed water and membrane operational characteristics

Table 3-1 provides typical RO feed water quality at the testing facility, which was consistent throughout the project. Data shown was compiled from the facility's monthly RO water quality sampling events, which is routinely performed as part of the facility's operation. Analysis of the samples was performed by City of San Diego's laboratory.

**Table 3-1: RO feed water quality during project timeframe**

| Parameter | Unit | Value[1,2] |
|---|---|---|
| TDS | mg/L | 1072 ± 110 |
| pH | - | 6.9 ± 0.2 |
| Total Alkalinity | mg/L | 117 ± 27 |
| Lab Conductivity | µmho/cm | 1825 ± 84 |
| Total Hardness | mg/L | 390 ± 19 |
| Bromide | mg/L | 0.3 ± 0.1 |
| Calcium | mg/L | 67 ± 8 |
| Chloride | mg/L | 299 ± 25 |
| Fluoride | mg/L | 0.6 ± 0.0 |
| Sulfate | mg/L | 271 ± 27 |
| TOC | mg/L | 5.6 ± 1.1 |
| Iron | µg/L | 63 ± 14 |
| Magnesium | mg/L | 33 ± 2 |
| Potassium | mg/L | 22 ± 2 |
| Sodium | mg/L | 198 ± 12 |
| Ammonia ($NH_3$-N) | mg/L | 0.9 ± 0.1 |
| Nitrate ($NO_3$-N) | mg/L | 14.7 ± 3.1 |
| Nitrite ($NO_2$-N) | mg/L | 0.03 ± 0.01 |
| Total Phosphorus | mg/L | 2.2 ± 0.6 |
| Silica | mg/L | 11 ± 1 |
| Aluminum | µg/L | 12 ± 10 |
| Barium | µg/L | 28 ± 3 |
| Boron | µg/L | 326 ± 23 |
| Manganese | µg/L | 7 ± 18 |
| Strontium | µg/L | 1006 ± 48 |

1 - average ± standard deviation
2 - sample count = 18 with exception to bromide, iron and nitrite which was 12, 5 and 4, respectively.

Table 3-2 provides values for feed pressure, permeability, and EC rejection for the different membranes as collected from facility's HMI data management system. Data shown for the ESPA2 LD is representative of the aged elements. Permeability and salt rejection have already been proposed as performance indicators for assessing membrane condition (Pype et al., 2016a; Kwon & Leckie, 2006a; Do et al., 2012; Antony et al., 2010; Antony et al., 2016). As such, the relatively lower EC rejection measured across the aged ESPA2 LD elements suggests relative membrane degradation in comparison to the virgin TMG20D-400 elements. In addition, water permeability was slightly higher across the aged ESPA2 LD membranes in relation to the virgin TMG20D-400 membranes, which may be indicative of chlorine degradation. The increase in permeability may have been caused by polyamide (PA) layer rearrangement, including changes in hydrogen bonding behavior, and/or PA chain cleavage (Antony et al., 2010; Do et al., 2012; Kwon & Leckie, 2006a). Table 3-2 shows that these trends were exacerbated across Stage 2 when the system had aged ESPA2 LD elements, and supports the theory that trailing stages are more vulnerable to deterioration in membrane performance. Trailing stages treat the brine of leading stages and are thus exposed to more challenging conditions, including higher concentration of membrane oxidizing species, such as chlorine. The formation of colloidal deposits may also play a role.

**Table 3-2: Relevant operational characteristics of investigated membranes[1]**

| Parameter | Hydranautics ESPA2 LD[2] | Toray TMG20D-400 |
|---|---|---|
| Feed Pressure | 129 ± 8 psi<br>8.89 ± 0.55 bar | 130 ± 10 psi<br>8.96 ± 0.69 bar |
| Stage 1 Specific flux @ 25°C | 0.129 ± 0.011 gfd/psi<br>3.22 ± 0.27 LMH/bar | 0.129 ± 0.014 gfd/psi<br>3.22 ± 0.35 LMH/bar |
| Stage 2 Specific flux @ 25°C | 0.170 ± 0.012 gfd/psi<br>4.24 ± 0.30 LMH/bar | 0.143 ± 0.017 gfd/psi<br>3.49 ± 0.42 LMH/bar |
| Overall Specific flux @ 25°C | 0.149 ± 0.012 gfd/psi<br>3.72 ± 0.30 LMH/bar | 0.131 ± 0.013 gfd/psi<br>3.27 ± 0.32 LMH/bar |
| Stage 1 EC rejection | 98.0 ± 0.3% | 98.7 ± 0.4% |
| Stage 2 EC rejection | 95.5 ± 0.8% | 98.8 ± 0.3% |
| Overall EC rejection | 95.9 ± 0.6% | 98.2 ± 0.5% |

1 – all data displayed as average ± standard deviation

2 – ESPA2 LD membranes after 30,000-h of operation

## 3.2. Male-specific bacteriophage (MS2) challenge testing

Eight rounds of male-specific bacteriophage (MS2) challenge tests were carried out across three different sets of RO elements: (1) aged Hydranautics ESPA2 LD, (2) unused Hydranautics ESPA2 LD and (3) virgin Toray TMG20D-400. Figure 3-1 provides RO feed and Stage 1 vessel permeate MS2 phage concentrations (average from triplicate samples) for the eight rounds of testing that were performed. Table 3-3 provides log removal values that were achieved for the individual MS2 challenge tests. An LRV of 4.6 to 7.3 was achieved across the different membranes; one round across aged ESPA2 LD elements was limited by the permeate detection limit. Overall, all of the investigated membranes provided a strong barrier to MS2 regardless of their condition. This is consistent to other findings, which only observed a decrease in MS2 rejection once salt rejection fell under 80% (Antony et al., 2016). Other published studies also support the fact that aged membranes maintained a strong barrier to MS2 such that other surrogates (e.g., R-WT, sulfate, DOM), all of which pass through the membrane via diffusion as well as defects, remained conservative to MS2 rejection (Pype et al., 2016a; Antony et al., 2016).

The MS2 log removals observed throughout the Project were consistent to those presented in literature as summarized in Table 1-3. These results were used to assess if integrity monitoring surrogates were conservative to virus removal.

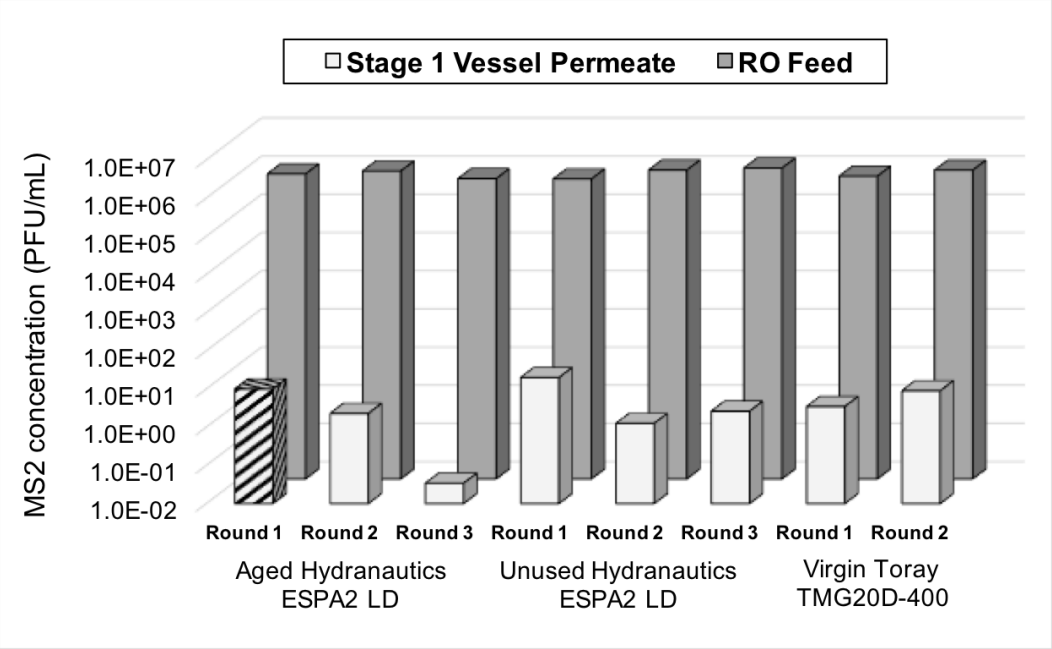


**Figure 3-1: RO feed and permeate MS2 concentrations from challenge tests performed (shaded bar indicates permeate sample limited by detection limit)**

**Table 3-3: Log removal values achieved for MS2 challenge tests**

| Membrane | Round of testing | Log removal value (LRV)[1] |
|---|---|---|
| Aged Hydranautics ESPA2 LD | Round 1 | >5.0 |
| | Round 2 | 5.7 |
| | Round 3 | 7.3 |
| Unused Hydranautics ESPA2 LD | Round 1 | 4.6 |
| | Round 2 | 6.0 |
| | Round 3 | 5.7 |
| Virgin Toray TMG20D-400 | Round 1 | 5.4 |
| | Round 2 | 5.1 |

1 – LRV based on concentrations from RO feed and permeate of a Stage 1 vessel

## 3.3. Integrity monitoring with naturally occurring constituents

Several naturally occurring constituents were evaluated as candidates for monitoring RO integrity. Table 3-4 provides the LRV achieved for selected ions and metals achieved across an intact Stage 1 vessel fitted with aged ESPA2 LD elements. Largely, the extent of rejection was limited by the detection limit for a number of the evaluated constituents. This took place since permeate concentration was not detectable using the detection limit of the method in place. This way, the calculated LRV was based off the method reporting limit (MRL), as directed by the EPA Membrane Filtration Guidance Manual. It is anticipated that the LRV potential can be enhanced with the development of more sensitive (i.e., lower MRL) methods. One example of this was published in the study from Kruithof et al. (2001), where a sulfate limit of detection (LOD) of 0.1 mg/L rendered a slightly higher and detectable LRV of 3 logs in contrast to when the Eurofins 0.5 mg/L MRL EPA 300.0 was employed (LRV ≥ 2.7). Another way of enhancing an LRV potential is through increasing the feed concentration of specific constituents with spiking. However, this involves other complications such as increasing the potential for scaling or fouling on membrane surfaces and the high cost to perform such spikes. Other constituents, predominantly those that are monovalent (e.g., sodium and chloride), are inherently limited to a rejection of 2-logs, or below. As such, these constituents would not be attractive candidates for demonstrating RO LRV via DIT. On the other hand, conductivity monitoring (i.e., transmittance of electricity due to the presence of dissolved ions) has been an attractive method for CIIM as it is feasible to implement for full-scale facilities for continuous monitoring. As for the other naturally occurring constituents evaluated, strontium showed the greatest potential for integrity monitoring purposes. As a divalent cation, it provided a detectable LRV of 3.3 when measured using the EPA 200.8 method (MRL = 0.3 μg/L). Another method (EPA 200.7) was also used to measure strontium rejection, yet LRV was limited by the method's MRL (0.01 mg/L), which depicts the importance of method sensitivity on evaluating surrogates for the purpose of RO integrity monitoring. In summary, Table 3-4 shows strontium – a divalent cation with an atomic radius of 0.21 nm –

as a potentially useful surrogate for enhancing RO LRV via DIT monitoring. With that said, it is key that a utility be mindful of the typical strontium RO feed concentrations and determine if it is suitable to demonstrate such log removal values using currently available methods. With this finding, further evaluation was made on strontium across membranes of different condition as well as across different monitoring locations (e.g., vessel, train, stage permeate).

**Table 3-4: Rejection of naturally occurring (ions/metals) constituents across an intact Stage 1 vessel fitted with aged ESPA2 LD elements**

| Constituent | LRV[1] |
|---|---|
| Strontium[2] | 3.3 |
| Sulfate | ≥ 2.7 |
| Magnesium | ≥ 2.6 |
| Orthophosphate-P | ≥ 2.1 |
| Total Organic Carbon | 2.0 |
| Strontium[3] | ≥ 2.0 |
| Calcium | ≥ 1.9 |
| Chloride | 1.9 |
| Conductivity | 1.7 |
| Sodium | 1.6 |
| Potassium | ≥ 1.4 |
| Fluoride | ≥ 1.1 |

1 – "≥" means the constituent was not detected in the permeate and only the lower limit on the LRV could be determined.

2 - EPA 200.8 (ICP-MS, MRL = 0.3 µg/L)

3 - EPA 200.7 (ICP-AES, MRL = 0.01 mg/L)

### 3.3.1. Strontium

Further evaluation was made to assess strontium as a surrogate for monitoring RO integrity. A total of eight sampling events took place across the three sets of membranes (aged and unused ESPA2 LD and TMG20D-400), where strontium samples were collected at different locations across the system. Sampling took place at ambient conditions, such that the LRVs achieved were from naturally occurring strontium concentrations. Figure 3-2 shows rejection of strontium at different locations across the investigated membranes. Unused ESPA2 LD is limited to vessel level data since only a single vessel was loaded with such membranes. Rejection of strontium appeared to be susceptible to membrane aging, such that rejection across Stage 2 was on the order of 1 log less than across Stage 1 when the system was fitted with aged ESPA2 LD elements. In contrast, log removals were on the same order (3.3 – 3.4 logs) when sampled across virgin Toray TMG20D-400. The susceptibility of strontium removal across aged

membranes may be explained by the increase in surface negativity as a function of membrane oxidation, resulting in charge attraction between the membrane surface and strontium, a divalent cation. The increase in surface negativity as a function of membrane aging has been reported in a number of RO autopsy investigations (Pype et al., 2016a; Do et al., 2012; Kwon & Leckie, 2006b; Simon et al, 2009). Such changes would increase the rate of diffusion of strontium across the membrane.

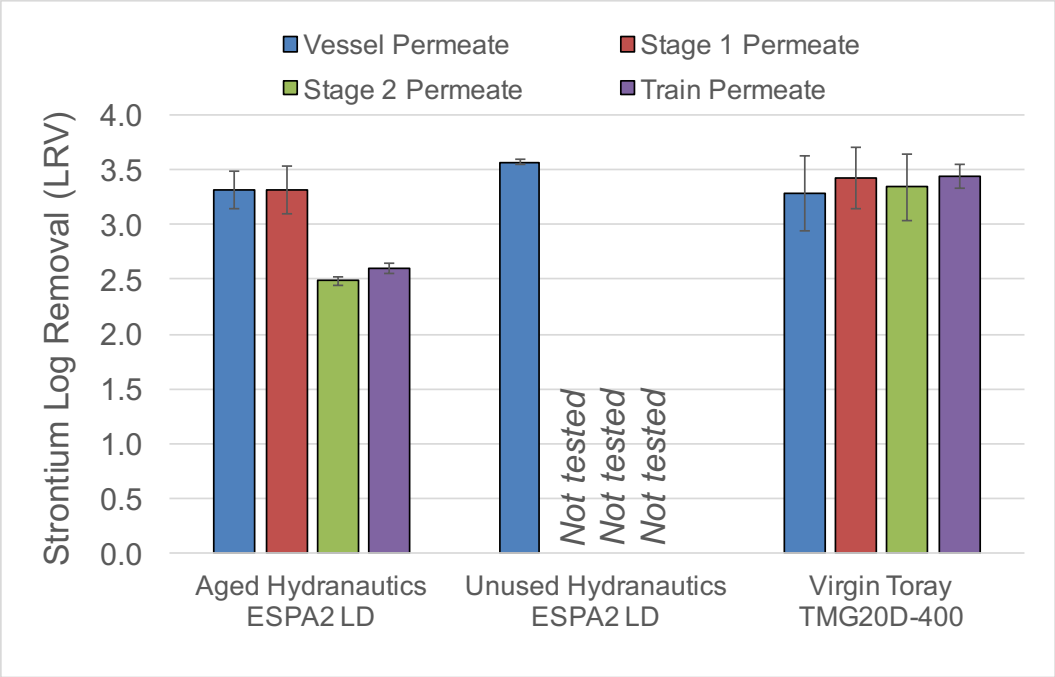


**Figure 3-2: Rejection of strontium at different sampling locations across the investigated membranes (unused ESPA2 LD data limited to vessel level since only a single vessel was loaded with such membranes)**

### 3.3.2. Effluent Organic Matter

Effluent organic matter (EfOM) was monitored by collecting data from excitation emission matrices (EEM). EEMs were performed for both RO feedwater and combined permeate (Train A permeate) to evaluate membrane integrity. Analysis of EEMs focused on the humic acid zone – emission: 391 nm to 580 nm, excitation: 240 nm to 300 nm – which have the highest fluorescence intensity of various fractions of EfOM detectable after ozone and biological activated carbon pre-treatment. An image of the RO feed and train permeate EEMs when fitted with Toray TMG20D-400 elements are shown in Figure 3-3 and Figure 3-4. The LRV for the integrated humic acid region was similar to that reported by Pype et al. (2013), calculated to be 2.3-logs considering the regional integrated normalized RO feed fluorescence intensity of ($\Phi_{f,n}$) of 4,907 and train permeate ($\Phi_{p,n}$) of 26. The measured humic acid EEM LRV was comparable to that of ambient TOC rejection across the same set of membranes. EEMs offer potential to monitor integrity at enhanced LRVs if channeled to target regions (or wavelength pairs) of higher expected rejection, such as one representing compounds of high molecular weight. As for FRI, it offers an opportunity to monitor RO integrity at levels that are comparable to TOC. However, thought should be given on implementing this method on a routine basis since running analysis and performing data analysis are laborious and can be time consuming. On the other hand, this analysis could be facilitated by the development of an on-line monitoring device designed to operate in an excitation/emission zone capturing the highest degree of ambient fluorescence removal - for example, excitation: 390-410 nm; emission: 345-355 nm.

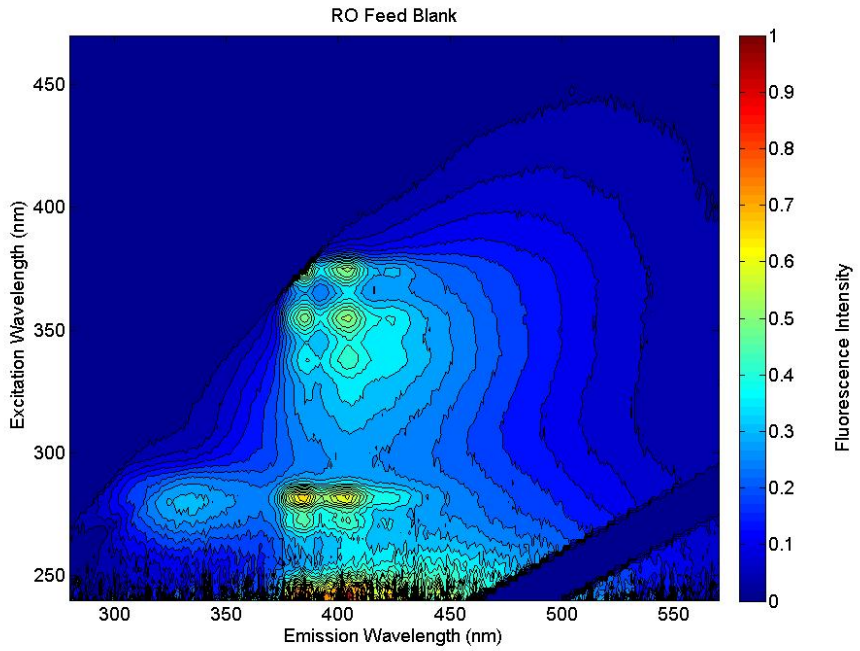


**Figure 3-3: Excitation emission matrix of a RO feed sample when fitted with TMG20D-400 elements**

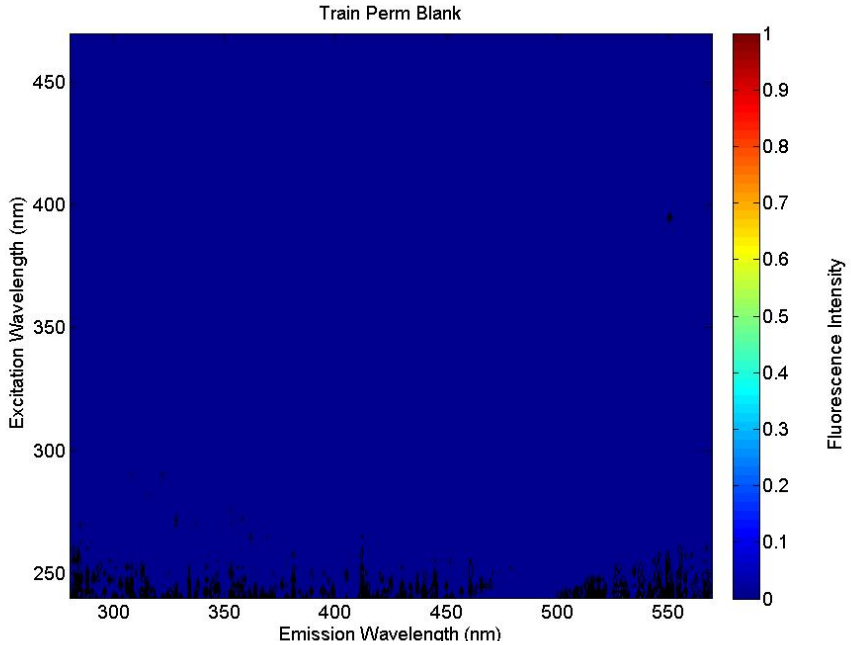


**Figure 3-4: Excitation emission matrix of a Train permeate sample when fitted with TMG20D-400 elements**

## 3.4. Integrity monitoring with spiked constituents

### 3.4.1. Rhodamine WT challenge testing

Two rounds of challenge testing were performed across aged Hydranautics ESPA2 LD elements using Rhodamine WT (R-WT). R-WT rejection was measured at the Vessel, Stage 1, and Train level by rerouting the sample line to the C3 fluorometer flow-through cell during the challenge test. R-WT was converted to a discrete concentration either via absorbance (Beer's law) or an in-house developed raw fluorescence unit calibration curve, as described in the methods section. Table 3-5 provides the R-WT LRVs achieved for the different locations during challenge testing.

**Table 3-5: Results from R-WT challenge testing across aged ESPA2 LD elements**

| Parameter | Round 1 | Round 2 |
|---|---|---|
| Feed R-WT (mg/L) | 1.5 – 8.0 | 3.2 – 4.2 |
| Vessel LRV | 3.8 | 3.7 |
| Stage 1 LRV | 4.0 | 4.2 |
| Train LRV | 4.2 | 3.2 |

Initial testing indicated R-WT as a strong candidate for demonstrating high LRV across RO systems, with 3.2 – 4.2 LRV across intact aged ESPA2 LD elements. Investigations also took place to investigate dye adsorption to membranes as this was a concern reported in literature (Lozier et al., 2003; Kitis et al., 2003a). This phenomenon was investigated by spiking RWT at a constant feed concentration and continuously monitoring permeate signal as raw fluorescence unit (rfu). Figure 3-5 provides results from this examination, showing how the steady-state permeate signal was not reached during the spike and how background fluorescence levels were not reestablished an hour after terminating the spike. These results suggest that aged ESPA2 LD membranes, when rinsed, are prone to R-WT adsorption. In terms of membrane integrity monitoring, this adsorption phenomenon would be problematic as it is difficult to ascertain a true R-WT LRV in the presence of a mechanism, like adsorption, which accomplishes removal by a mechanism other than passage through defects in the membrane. It is possible that adsorption sites are eventually exhausted, given sufficient R-WT exposure, but this would result in tracer breakthrough when tracer is no longer being added. After observing the adsorption phenomemon, a decision was made to cease evaluating R-WT as a potential surrogate for monitoring RO integrity.

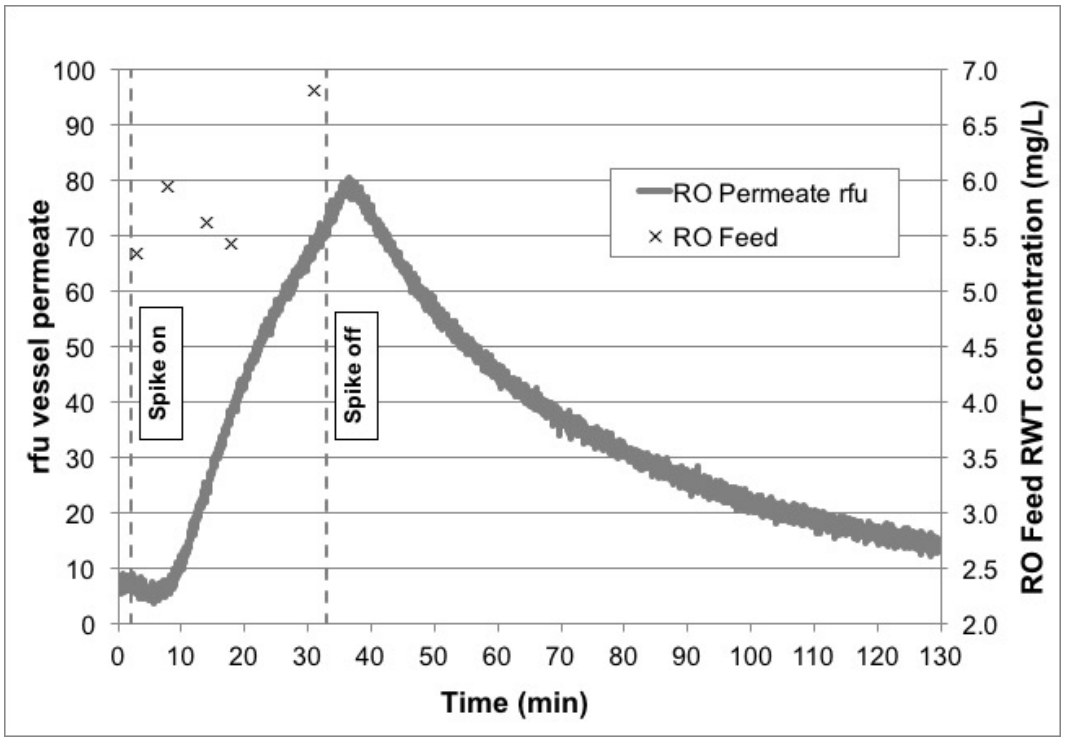


**Figure 3-5: R-WT permeate signal profile during and after spiking dye (investigation on membrane dye adsorption)**

### 3.4.2. 3D TRASAR trial and challenge testing

Figure 3-6 provides 3D TRASAR integrity monitoring – along with TOC and EC – during the 110-day trial across Toray TMG20D-400 membranes. The dashed bars indicate changes in TRASAR 23299 dye (10% active) feed concentration. Figure 3-6 shows that 3D TRASAR consistently demonstrated higher LRV at the train level (i.e., beyond 3-logs) in relation to other online methods (EC and TOC) that were monitored in parallel. Additionally, observed 3D TRASAR LRVs were stable across the different feed dye concentrations, tested to as low as 0.05 mg/L as active dye. Table 3-6 provides 3D TRASAR rejection across the different sampling locations across Toray TMG20D-400 membranes.

**Table 3-6: Rejection of 3D TRASAR across different locations when fitted with TMG20D-400 elements**

| Location | 3D TRASAR Log Removal Value |
|---|---|
| Vessel permeate | 3.6 ± 0.1 |
| Stage 1 permeate | 3.7 ± 0.1 |
| Stage 2 permeate | 3.4 ± 0.1 |
| Train permeate | 3.5 ± 0.1 |

Overall, 3D TRASAR showed potential in providing enhanced LRV for an RO system. In addition, real-time LRV monitoring would give instant feedback to operators on system compromises at an LRV superior to that of EC and TOC. Further testing indicated that neither dye adsorption nor desorption on the membrane appeared to be a factor. This is illustrated in Figure 3-7, tracer profiling at the initiation of a test, and Figure 3-8, tracer profiling when the tracer feed was terminated. The figures show that steady state conditions were achieved within the matter of minutes from when the spike was initiated and background fluorescence was reestablished shortly thereafter dye injection was terminated. Tests exploring successively lower feed concentrations demonstrated that a very low feed concentration of the proprietary 23299 TRASAR dye (i.e., 0.05 mg/L as active product) was necessary to consistently validate an LRV beyond 3-logs. Unfortunately, 3D TRASAR testing did not take place across aged ESPA2 LD membranes to assess the effect of dye rejection across relatively degraded membranes. Yet, a single study by others did assess TRASAR 23299 dye rejection across oxidized membranes and was reported to be negatively affected from approximately 4.2 logs across intact membranes to about 3.5 logs across oxidized membranes (Carollo Engineers, 2016). This observation is consistent with the expectation that, like most added surrogates, the TRASAR 23299 dye passes through the membrane primarily by diffusion. As a result, the LRV of the tracer will be able to demonstrate normal wear and tear that may not affect the passage of pathogens, which only pass through defects in the membrane system or the membrane themselves.

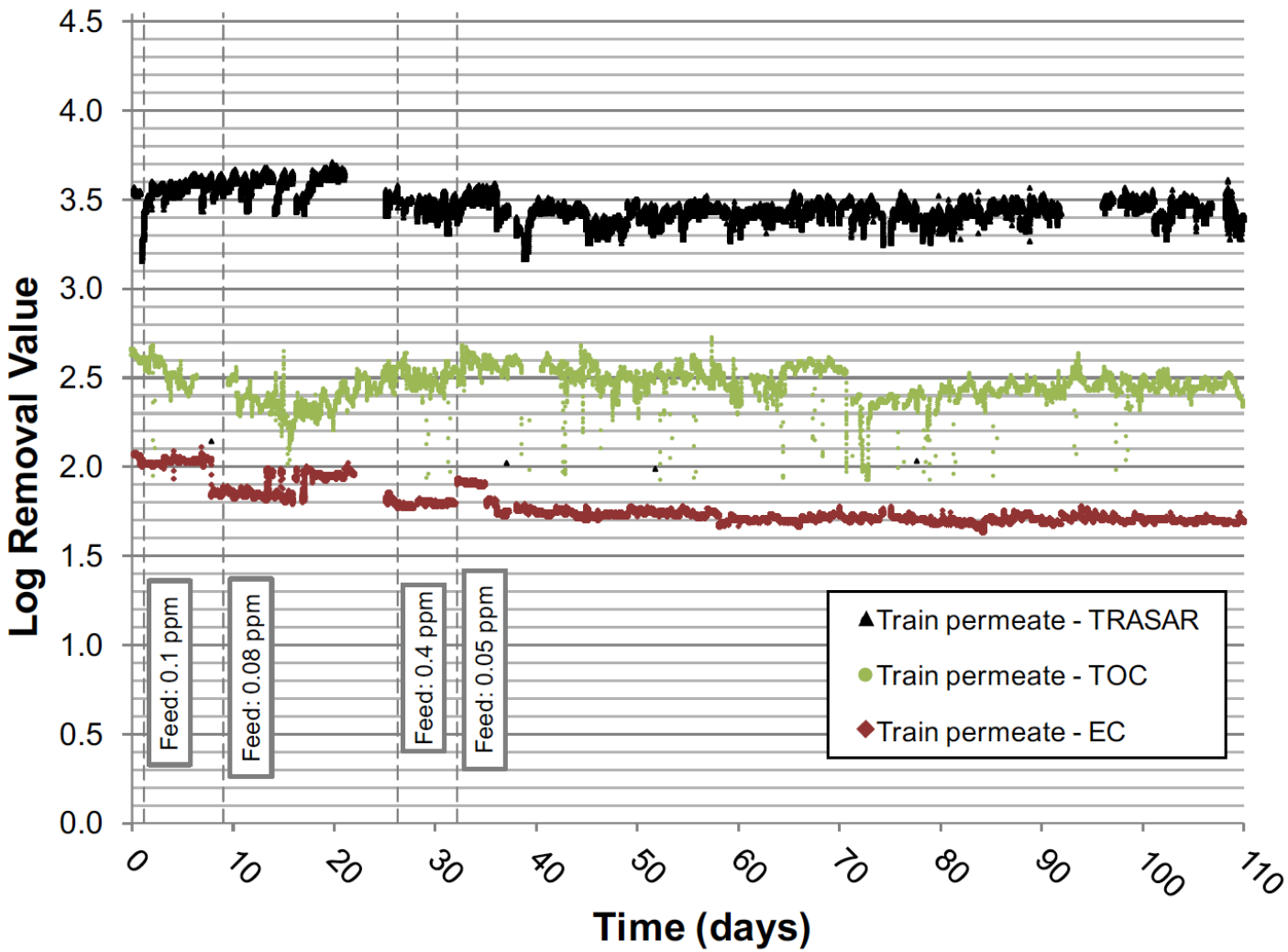


**Figure 3-6: 3D TRASAR, EC and TOC monitoring across TMG20D-400 elements**

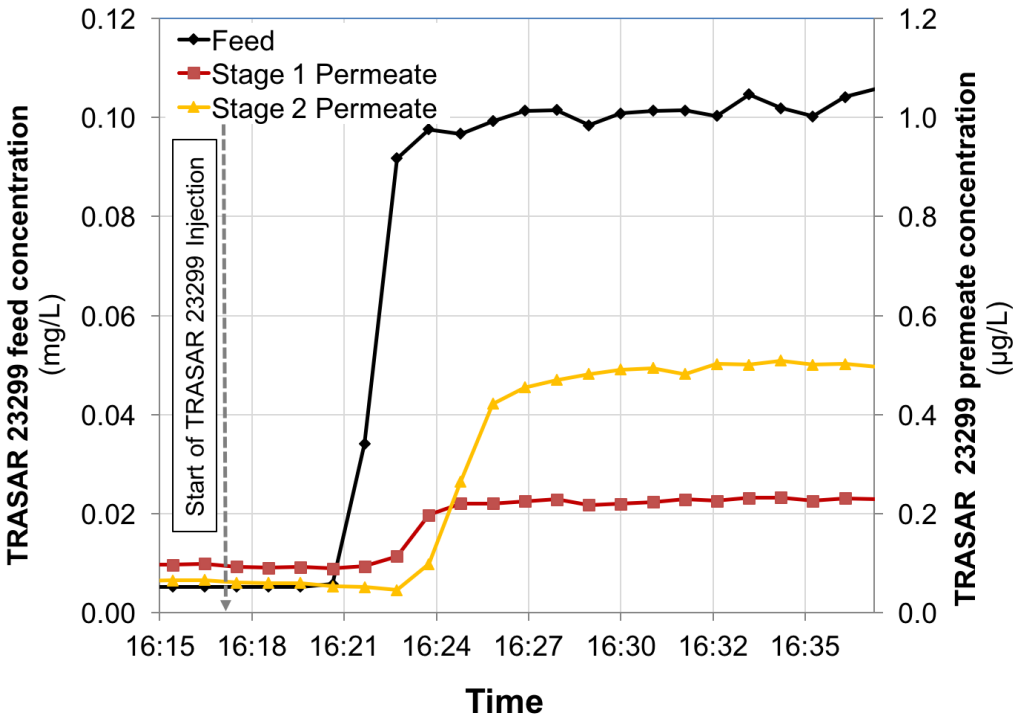


**Figure 3-7: TRASAR 23299 profiling at the start of dye injection**

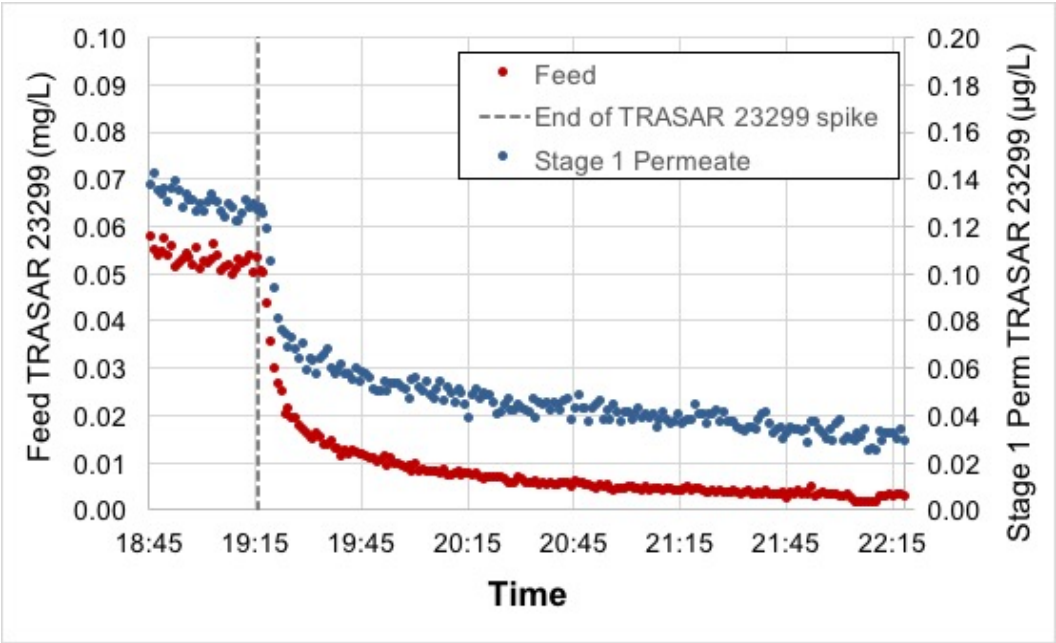


**Figure 3-8: TRASAR 23299 profiling as spike was terminated**

### 3.4.3. Sugar challenge testing

A total of eight sugar challenge tests were carried out throughout this project to evaluate sugar as a surrogate for RO integrity monitoring. Three rounds were performed for both aged and unused Hydranautics ESPA2 LD elements, while two rounds were performed across virgin Toray TMG20D-400 elements. It was necessary to spike the feed with 300 to 600 mg/L of sugar to differentiate it from the background TOC. Background TOC was accounted for in determining sugar-associated LRVs. Figure 3-9 shows the extent of spiked sugar removal across different locations for the investigated membranes. Only vessel level data is shown for the unused ESPA2 LD elements since this was the only location where such membranes were loaded. An LRV between 2.5 and 3.2 was achieved depending on sampling location and membrane. The lowest log removal (LRV = 2.4) was observed across Stage 2 when fitted with used ESPA2 LD elements. For the same location, an LRV of 3.0 was observed when fitted with virgin Toray TMG20D-400 elements. This indicates that membrane condition (e.g., used versus virgin elements) had an impact on the extent of spiked sugar removal. In addition, lower rejection achieved across trailing stages fitted with used ESPA2 LD elements further indicates that trailing stages are more prone to degradation than leading stages. This is also consistent with the lower salt rejection achieved across Stage 2 in comparison to Stage 1, as captured in Table 3-2. The slightly higher sugar rejection across a Stage 1 vessel with TMG20D-400 elements (LRV = 3.2) versus the rejection shown with unused ESPA2 LD elements (LRV = 3.0) may be attributed to the fact that the Toray elements are slightly tighter and thus more effective in rejecting bulk carbon. A similar difference was also observed for ambient TOC rejection, where 2.3 LRV was observed across the TMG20D-400 elements and 2.0 LRV for the unused ESPA2 LD elements (data not shown). All these behaviors indicate that most of the sugar passing through the membrane is due to molecular diffusion.

Overall, spiked sugar rejection via TOC was shown to be an effective method for demonstrating enhanced LRV across RO in comparison to TOC and EC. Additional instrumentation is often not necessary since TOC meters usually already exist as part of RO facility producing water for potable reuse. With a dedicated sugar injecting skid, integrity verification could be done with the system delivering product water – since only minor amounts of sugar would be found in the permeate (ppb range). In addition, sugar appeared to not adsorb to membranes since steady TOC values were observed as sugar was spiked followed by a drop to background TOC levels once the spike was terminated, as shown in Figure 3-10. One downside of this technique is that spiking of sugar must occur, which incurs additional cost and staff support. There is, however, an opportunity to optimize target feed concentration such that sugar usage can be diminished. This must be done on a case-by-case basis since the observed sugar LRV is linked to background TOC levels.

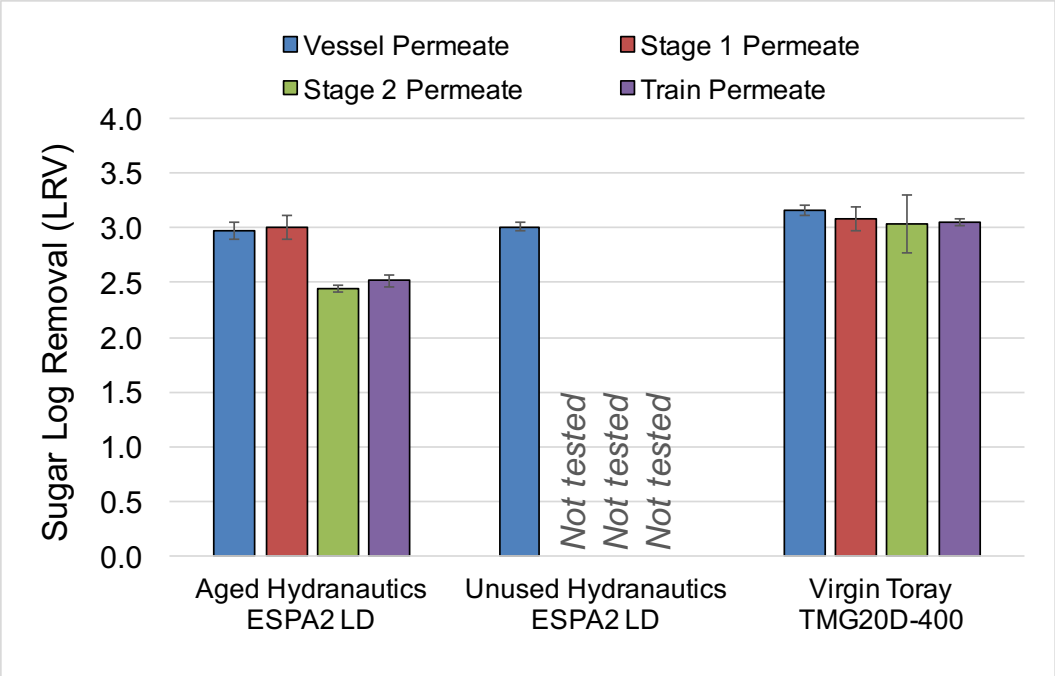


**Figure 3-9: Extent of sugar rejection during challenge testing across the investigated membranes (unused ESPA2 LD data limited to vessel level since only a single vessel was loaded with such membranes)**

**Figure 3-10: Train permeate online TOC monitoring during sugar spiking event**

#### *3.4.3.1. Sucralose challenge testing to crosscheck sugar rejection via TOC*

A challenge test was also carried out to measure sucralose rejection across the RO system fitted with aged and unused ESPA2 LD elements. Given their similar molecular weights, sucralose (397 Da) and sugar (342 Da) were expected to be rejected to a similar extent. Since sucralose was measured using an analytical method (SPE LS-MS/MS), sucralose rejection results were assessed to cross-check accuracy of the TOC-basis method to target sugar concentrations.
Figure 3-11 provides a side-by-side comparison of sugar and sucralose rejection across a Stage 1 vessel fitted with aged or unused ESPA2 LD elements. Sucralose was measured between 4.2 and 4.8 mg/L in feed, between 5.3 µg/L and 5.6 µg/L in the permeate across unused ESPA2 LD elements, and between 5.7 µg/L and 6.8 µg/L in the permeate across aged ESPA2 LD elements. The results show that rejection of sucralose was comparable to that of sugar, suggesting that TOC accurately captured sugar rejection across the RO system.

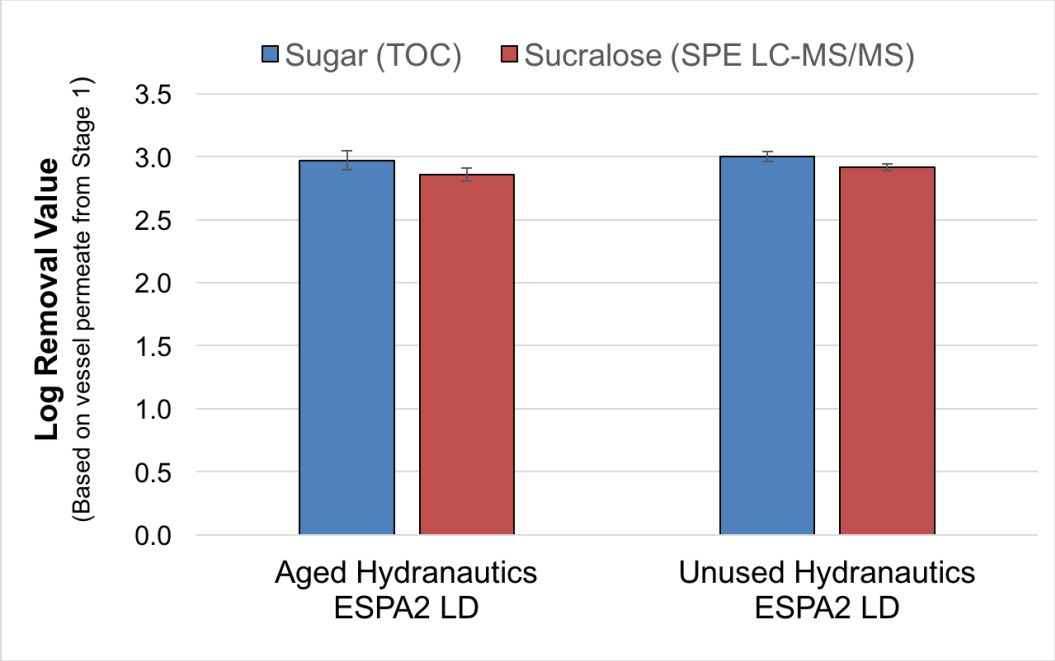


**Figure 3-11: Rejection of sugar and sucralose across aged and unused ESPA2 LD elements (vessel-level)**

## 3.5. Rejection of uncharged low molecular weight organics

Experience with sucrose and sucralose as tracers, as well as a general understanding of the relatively low removal of other constituents (e.g., boron, NDMA, 1,4-dioxane and silica), stimulated an interest in further exploring the removal of low molecular weight uncharged compounds. To simplify the exercise, organic compounds were spiked individually and removal was assessed by measuring the TOC of both the RO feed and permeate (as was done with sugar).

Figure 3-12 and Table 3-7 provide the observed rejection of the spiked uncharged low molecular weight organics as a function of molecular weight across aged and unused ESPA2 LD elements. Overall, rejection increased as a function of molecular weight. Xylose (150 Da) provided the highest rejection (99.6%) of the compounds spiked. Rejection beyond 90% appeared to happen at a molecular weight of 90-100 Da (i.e., glycerol). Molecular weight cut off (MWCO) is defined when rejection surpasses 90%, according to der Bruggen et al. (1999). As for the performance of aged versus unused ESPA2 LD elements, slightly higher rejection was observed across the unused elements for all of the spiked compounds.

It was not possible to measure ethanol and methanol rejection using the simplified TOC removal technique – in fact a negative rejection was observed (i.e., higher permeate TOC than feed TOC). One possibility is that the wastewater matrix (RO feed) may have interfered with the feed TOC measurements for the spiked compounds, but did not interfere in the permeate samples because the interfering constituents in the feed had been removed. This would result in an accurate measurement of permeate but inaccurate measurement of the feed concentration, resulting is a low calculation for rejection. In any case, the test does show that TOC measurement in the RO feed is sensitive to spiked organics such that it would detect unintentional chemical spills to the sewershed that ultimately reach RO permeate. In terms of integrity monitoring, uncharged low molecular weight organics would be unsuitable for verifying RO LRV as their rejection is typically limited to 1-log removal – due to molecular diffusion.

**Table 3-7: Vessel-level rejection of uncharged low molecular weight organics across aged and unused ESPA2 LD elements**

| Compound | Molecular Weight (Da) | Aged Hydranautics ESPA2 LD | Unused Hydranautics ESPA2 LD |
|---|---|---|---|
| Methanol | 32 | * | - |
| Ethanol | 46 | * | - |
| 2-propanol | 60 | 36% | 47% |
| Ethylene glycol | 62 | 15% | 32% |
| Boron (boric acid)* | 62 | 29% | 45% |
| 2-butanol | 74 | 8% | 69% |
| Glycerol | 92 | 86% | 94% |
| Xylose | 150 | 99.6% | - |

* negative rejection was observed

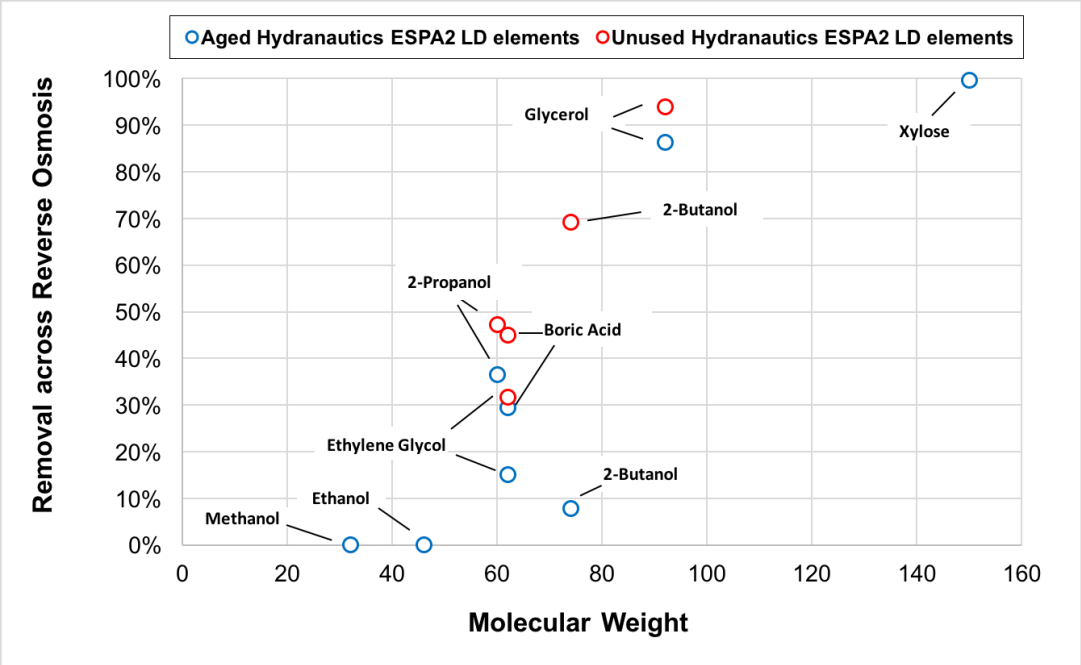


**Figure 3-12: Vessel-level rejection of uncharged low molecular weight organics across aged and unused ESPA2 LD elements**

## 3.6. Overview of evaluated surrogate rejection across intact RO elements

Figure 3-13 summarizes rejection of the evaluated integrity monitoring surrogates across the tested RO elements as observed across a Stage 1 vessel. The data shows that there are multiple alternative surrogates, both naturally occurring or spiked, that can offer higher LRV across RO compared to those commonly employed – TOC and EC. Both strontium and 3D TRASAR provided beyond 3-logs removal across the tested membranes at the vessel-level, making them the most noteworthy of the evaluated surrogates. The use of strontium is highly attractive since it was naturally occurring at high enough concentrations to demonstrate the greater than 3-log LRV. 3D TRASAR provided comparable LRV to strontium with the advantage of real-time monitoring. Sugar and sucralose also provided higher LRV than EC and TOC.

Although higher 3D TRASAR log removals have been reported in literature (MWH, 2007), most of these trials were for a short duration (i.e., a few days). The trial performed during this project was the longest and most representative of a full-scale facility to-date. Specifically for Stage 1 membranes, aging effects on only appeared to be pronounced for naturally occurring strontium (drop from 3.6 to 3.3 LRV) and electrical conductivity (drop from 1.9 to 1.7 LRV) when comparing aged to unused ESPA2 LD elements. This decrease may be attributed to an increase in surface charge negativity, characteristic of oxidized membranes

(Pype et al., 2016a; Do et al., 2012; Kwon & Leckie, 2006b; Simon et al, 2009), resulting in charge attraction for positively charged constituents.

Figure 3-14 provides a rejection comparison between Stage 1 and Stage 2 for selected surrogates across aged ESPA2 LD and virgin TMG20D-400 elements. Overall, the aged ESPA2 LD elements offered lower surrogate rejection across Stage 2 in comparison to Stage 1. This is consistent to membrane operational parameters listed in Table 3-2, and further indicates that Stage 2 membranes were further degraded than Stage 1 at the time of testing. The largest LRV loss across stages was for strontium, from 3.3 to 2.5 LRV. 3D TRASAR nor MS2 were inconveniently not sampled across the different stages to add to this comparison. With respect to 3D TRASAR, a previous study showed that dye removal was susceptible to oxidized membranes (Carollo Engineers, 2016), where less removal was observed across the oxidized membranes in comparison to non-oxidized ones. Regarding MS2, Pype et al. (2016a) observed that aged membranes still provided a barrier for viruses such that MS2 rejection remained higher than other monitoring surrogates, such as R-WT and sulfate. As for virgin TMG20D-400 elements, similar surrogate removal was achieved across both Stage 1 and Stage 2. Figure 3-15 shows how removal of surrogates (spiked sugar, strontium, and ambient TOC) was increased at the train level once aged ESPA2 LD membranes were replaced with virgin TMG20D-400. This is mostly attributed due to the increase in Stage 2 membrane performance when fitted with fresh membranes.

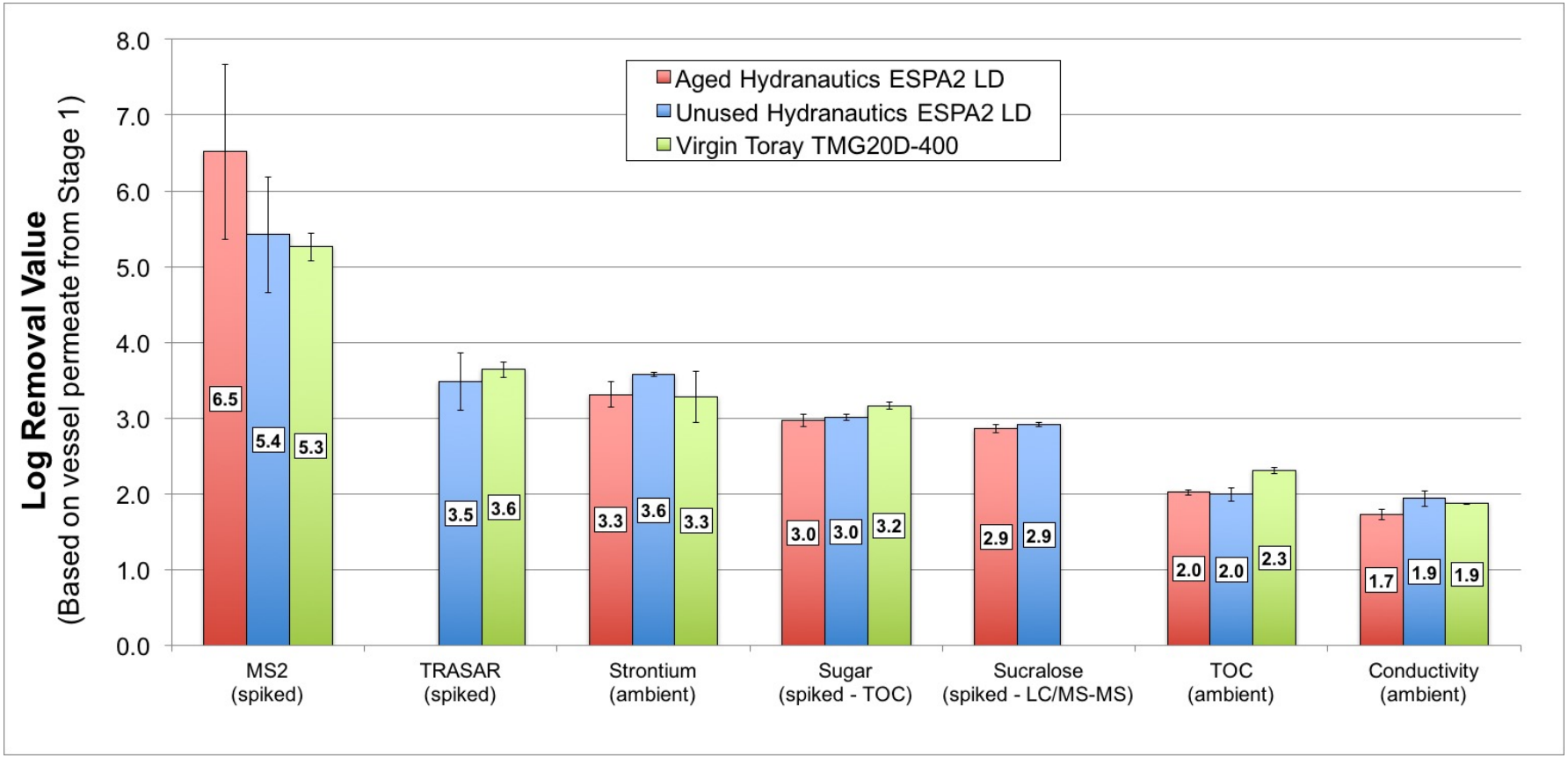


**Figure 3-13: Rejection of MS2 and selected RO integrity monitoring surrogates across a Stage 1 vessel fitted with tested RO elements.**

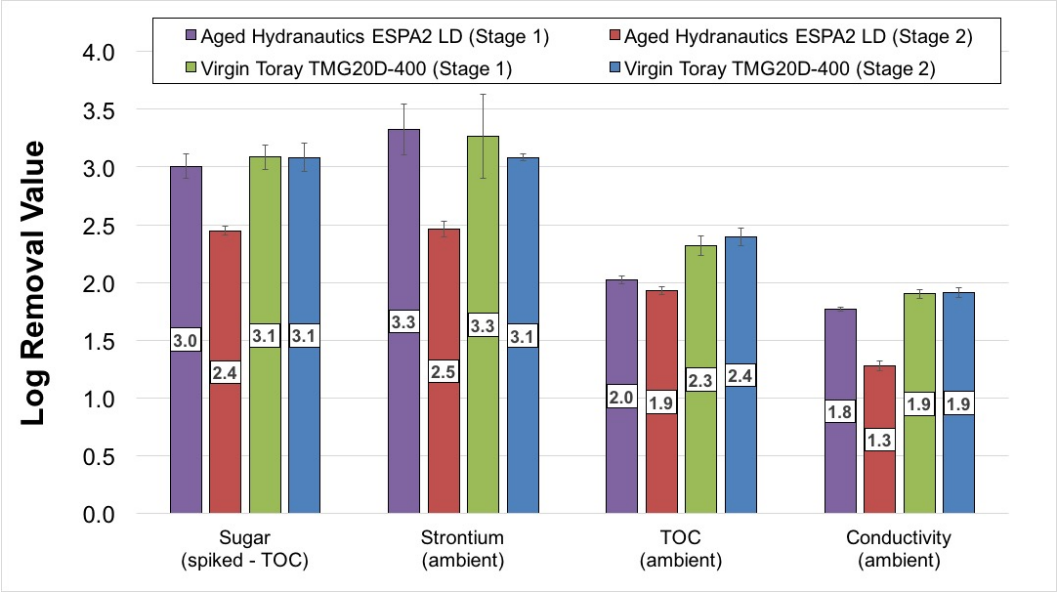


**Figure 3-14: Comparison of surrogate rejection between Stage1 & Stage 2 fitted with aged ESPA2LD and virgin TMG20D-400 elements**

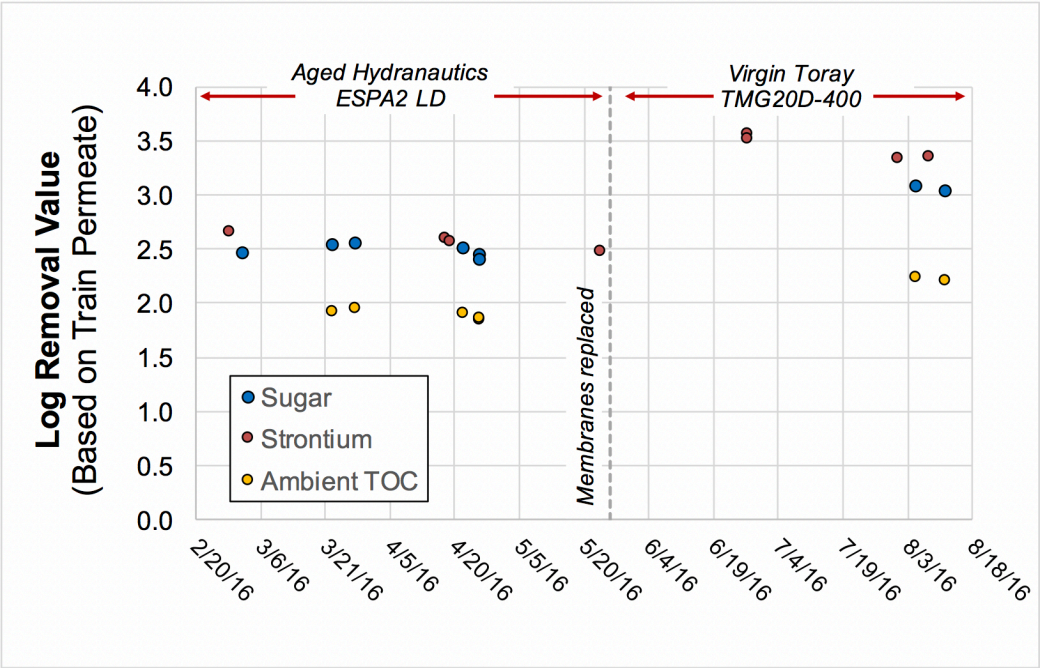


**Figure 3-15: Train level rejection for selected surrogates across ESPA2 LD followed by virgin TMG20D-400**

## 3.7. Establishing test conditions to represent multiple degrees of failure

Testing for this and other projects show that pathogens pass through RO systems as a result of defects which allow them to breach or bypass the membrane and enter the permeate. In order to better understand the impact of such defects on the performance of a full-scale RO system (i.e., multi-stage, fitted with 8-inch elements), an array of compromises was evaluated to determine meaningful conditions that could later be applied in surrogate and MS2 challenge testing. As described in the methods, compromises were performed by either cutting or removing O-rings from permeate interconnectors or vessel endcaps.

Table 3-8 describes the compromises that took place to determine meaningful conditions for further testing. This took place using aged ESPA2 LD elements and sampling for naturally occurring constituents in both the feed and permeate; including strontium, sulfate, conductivity, magnesium, etc. Figure 3-16 shows vessel-level LRVs achieved for each of the constituents as a function of the evaluated compromises.

Overall, Figure 3-16 shows how constituent removal was negligibly affected when permeate interconnector O-rings were compromised (Test 1 through 5). In contrast, a significant reduction in removal was observed when compromises were made to vessel endcap O-rings (Test 6 and Test 7). For these two conditions, LRVs were reduced to similar value for the measured constituents, indicating that a significant breach was caused.

**Table 3-8: Description of compromises evaluated to establish meaningful degrees of failure**

| Test # | Compromise description |
|---|---|
| Control | Control |
| Test 1 | Cut 2 O-rings from a single interconnector |
| Test 2 | Remove 2 O-rings from a single interconnector |
| Test 3 | Cut 8 O-rings from a total of two interconnectors |
| Test 4 | Remove 8 O-rings from a total of two interconnectors |
| Test 5 | Remove 16 O-rings from a total of four interconnectors |
| Test 6 | Remove all 28 O-rings from a total of six interconnectors, in addition to the four endcap O-rings from both feed and brine side |
| Test 7 | Remove 16 O-rings from a total of four interconnectors, in addition to the four endcap O-rings from both feed and brine side |

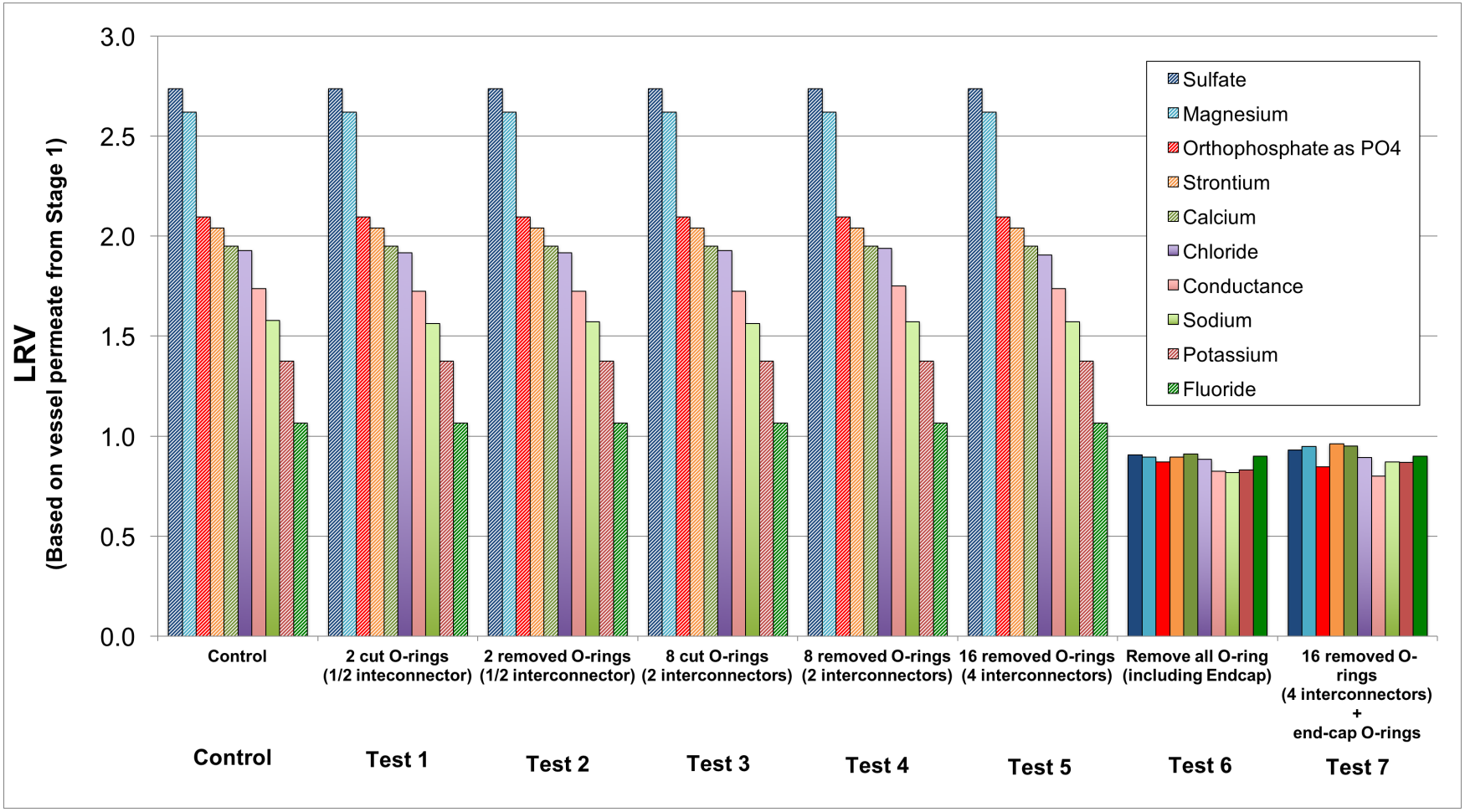


**Figure 3-16: Naturally occurring constituent vessel level LRV across intact and compromised ESPA2 LD elements**

**(Shaded bars indicate permeate samples were below MRL)**

Based on these results, three compromised conditions were selected to offer different degrees of failure in evaluating surrogates throughout the project. Table 3-9 provides a description of these compromises. Figure 2-14 shows how the compromises were carried out.

**Table 3-9: Compromises performed throughout the Project to evaluate surrogate across different degrees of failure**

| Condition | Compromise Description | Hypothetical degree of failure* |
|---|---|---|
| Control | No compromise, integral membrane. | None |
| Interconnector compromise | Removal of O-rings (4 total) from a single permeate interconnector from an element located in the middle of the pressure vessel (e.g., between 3rd and 4th element). | Low |
| Brine endcap compromise | Removal of O-rings (2 total) from endcap located on brine side of the pressure vessel. | Medium |
| Feed endcap compromise | Removal of O-rings (2 total) from endcap located on feed side of the pressure vessel. | Severe |

*Based on preliminary testing using ESPA2 LD elements

## 3.8. Surrogate and MS2 rejection across compromised membranes

Compromises described in Table 3-9 were carried out across both aged and unused ESPA2 LD and TMG20D-400 elements at the vessel level to evaluate surrogate response to a variety of failure scenarios. Figure 3-17 provides the progression of surrogate and MS2 LRVs in response to the compromises. Overall, the surrogates remained conservative to virus (i.e., MS2) removal for an intact system. When compromised, surrogate rejection was either less than or comparable to MS2. For the most severe compromise evaluated (i.e., feed endcap compromise), the removal of surrogates and MS2 was comparable, measured at an LRV of approximately 1. These observations suggest that the evaluated surrogates are suitable for demonstrating RO integrity, since they do not overestimate virus removal under both intact and compromised conditions.

Interestingly, the interconnector compromise results were inconsistent when fitted with membranes of different manufacturers. Specifically, the interconnector compromise rendered minor to no impact on the system's integrity when fitted with ESPA2 LD elements – as shown in Figure 3-16 and Figure 3-17. In contrast, the same compromise rendered a significant integrity breach when fitted with TMG20D-400 as captured in Figure 3-17. In such scenario, surrogate removal was limited to an LRV of approximately 1. The measured discrepancy may be a function of differences in the product design.

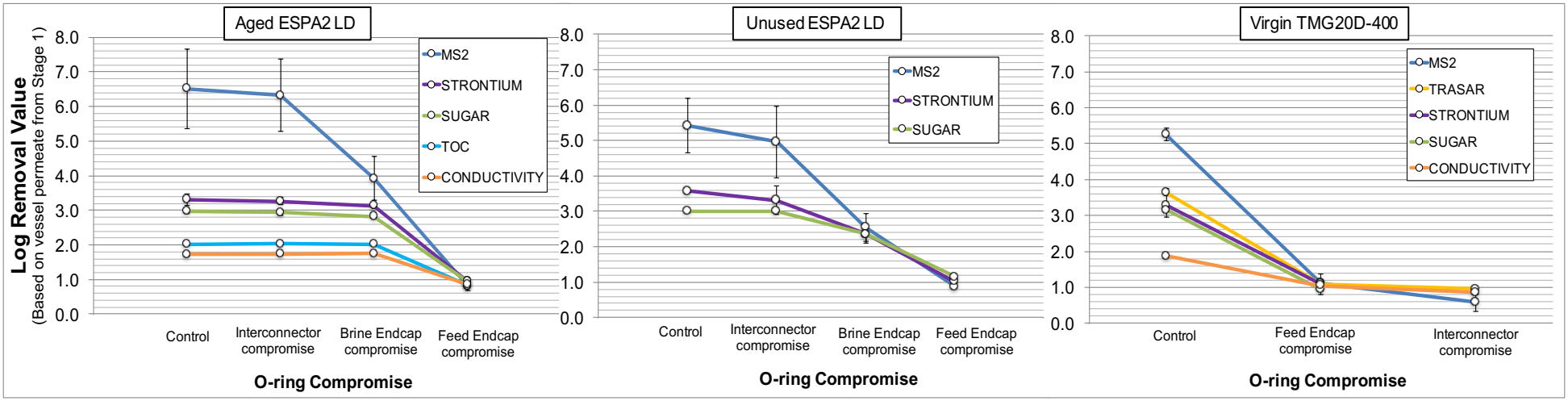


**Figure 3-17: MS2 and surrogate response as a result of O-ring compromises**

### 3.8.1. Identifying impact of element design on compromise response

Further testing was done to investigate the discrepancy in interconnector compromise response when fitted with elements from different manufacturers. A number of variables were evaluated, including swapping brine seals and interconnectors, as well as a perforated interconnector. A description of the tests performed is provided in Table 3-10. Results for this effort are provided in Figure 3-18, showing extent of conductivity rejection for the different test conditions at the vessel level.

Brine seals, interconnectors, and a perforated interconnector appeared not to affect system integrity when fitted with ESPA2 LD (Test A through C). An additional variable in element design – a notch on the face of the TMG20D-400 element as shown in Figure 2-4, was identified as the possible cause for the compromise response discrepancy. Testing for this variable occurred by placing a cut O-ring between two ESPA2 LD elements to space them from each other (Figure 3-19). This was done to identify if an ancillary seal between the face of two ESPA2 LD elements was being formed such that system integrity remained even in the absence of interconnector O-rings. A sharp decrease in conductivity was measured when the spacer was placed between two ESPA2 LD element with no interconnector O-rings (Test E). This suggests that the notch located on the face of the permeate channel of the tested Toray TMG20D-400 provided an opportunity for feed water to enter the permeate channel in the absence of interconnector O-rings.

**Table 3-10: Description of test conditions performed to evaluate element design in response to interconnector compromise**

| Test # | Description of compromise |
|---|---|
| Control | Control |
| Test A | Swap a single interconnector containing no O-rings |
| Test B | Swap brine seals from an entire vessel (7x) and remove O-rings from a single interconnector |
| Test C* | Replace intact interconnector with a perforated one containing no O-rings |
| Test D* | Place spacer (i.e. cut O-ring) between elements with an intact interconnector (with O-rings) |
| Test E* | Place spacer (i.e. cut O-ring) between elements with an interconnector containing no O-rings |

**only performed on ESPA2 LD elements*

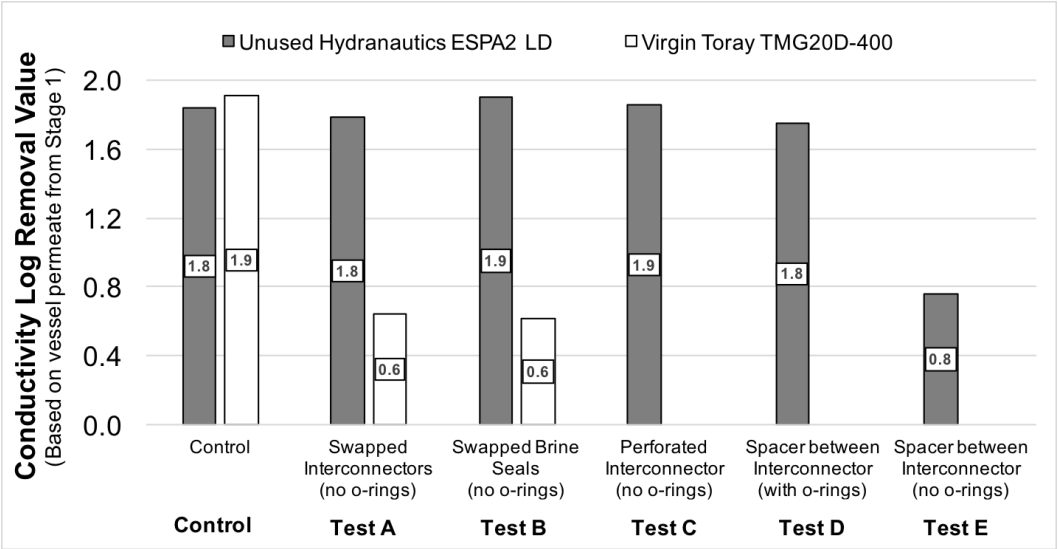


**Figure 3-18: Conductivity rejection across tested elements in response to interconnector compromise and other variables**

**Figure 3-19: Installed spacer on Hydranautics ESPA2 LD element with interconnector without O-rings (Test E).**

### 3.8.2. Resolution of failure analysis

Figure 3-20 provides rejection of conductivity, TOC, spiked sugar, and strontium at different locations (vessel, stage, and train permeate) across an intact and compromised system (i.e., feed endcap compromise) fitted with aged ESPA2 LD membranes. At the vessel level, all surrogates captured the compromise as shown by the decrease in LRV in relation to the control. This is most likely because the compromise being tested resulted in a significant breach, allowing flow to reach the permeate without passing through the membrane. At the train level, in contrast, the same compromise was nearly undistinguishable for conductivity when compared to the LRV achieved across intact membranes. For conductivity, the rejection at the train level was 1.5 and 1.4-logs across intact and compromised membranes, respectively. This indicates such surrogates, whose removal is relatively low across intact membranes, may not provide the sufficient resolution of failure to detect compromises when sampled at the train level given the amount of dilution throughout the system. In any case, it shall be noted that conductivity is a valuable tool in assessing membrane integrity when measuring smaller clusters (e.g., vessel level) since it is fairly simple and straightforward to carry out. TOC was slightly more sensitive at the train level, such that 1.9 and 1.5-logs were recorded for the intact and compromised condition, respectively.

On the other hand, both strontium and spiked sugar were successful at capturing the compromised membrane at the train level. For strontium, a decrease in 2.6 to 1.9-logs was measured at the train level for the intact and compromised condition, respectively. For spiked sugar, this LRV decrease was 2.5 to 1.9. This analysis shows that, in practice, surrogates offering higher LRV provide greater resolution in detecting failures that could otherwise not be identified by surrogates offering lower LRV. This is an important consideration when deciding which surrogate to implement for direct integrity testing (DIT), since such test is performed to identify and isolate integrity breaches.

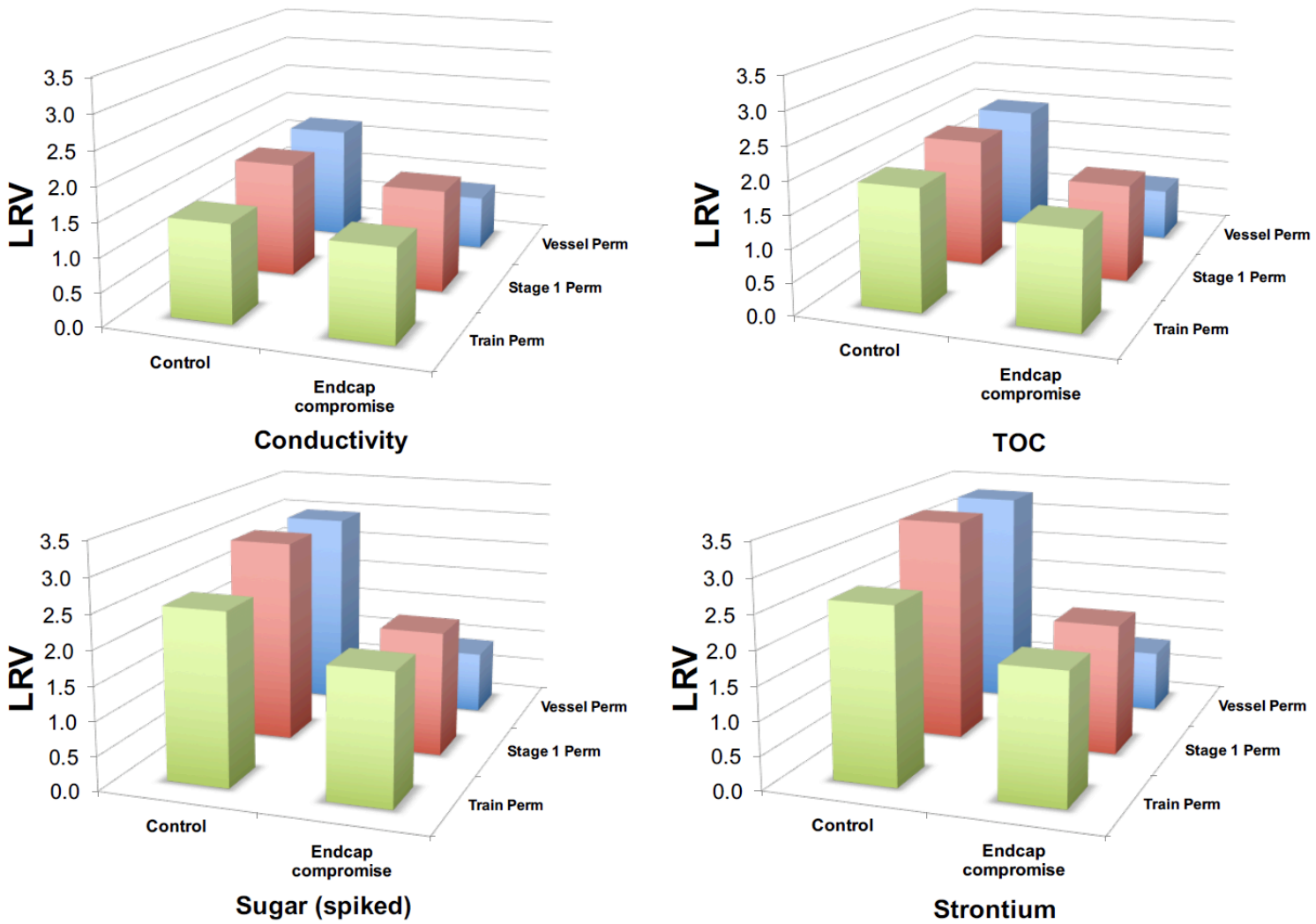


**Figure 3-20: Rejection of different surrogates at different locations in response to a compromised membrane. Testing performed across aged ESPA2 LD elements, compromise originated from a single vessel in Stage 1.**

## 3.9. Integrity verification program with alternative surrogates

In pursuing pathogen credit for an RO system, a utility shall, per the *Guidance Manual* (USEPA, 2005), develop an integrity verification program (IVP) consistent to available framework and regulations. It shall be noted that an RO system used for potable reuse applications will likely be regulated according to its significance on protecting public health. For example, an RO system used in an indirect potable reuse scheme (e.g., groundwater replenishment, surface water augmentation) may not be bound to the *Guidance Manual* regulatory aspects entirely given the relatively long response time to address failures. In contrast, regulatory framework laid in the *Guidance Manual* would be expected for a direct potable reuse application (e.g., *flange-to-flange*), since the consequences of failure are far greater in an application lacking an environmental buffer.

An IVP entails the adoption of on-going monitoring in the form of a CIIM and a more sensitive, yet less frequent, DIT to demonstrate integrity during system operation. This is done in recognition of the fact that membrane failures are not normally a sudden phenomenon, but rather a matter of gradual decline in performance. Provided that EC and TOC have been approved as the sole-basis for demonstrating RO integrity, this monitoring practice can be understood as a quasi CIIM / DIT coupling. As such, the use of EC or TOC will likely satisfy the CIIM component, which is convenient since EC and/or TOC meters are often implemented in the design of RO systems. The DIT, on the other hand, can be tailored to award higher pathogen removal credit for an RO system. To be compliant with available framework, the DIT shall be conducted on each membrane unit at a frequency no less than one day of operation, given there are no exceptions from by State in performing less frequent DIT. An additional periodic integrity verification – such as conductivity profiling – may also be implemented to offer further confidence that the RO system is operating with no faults. Practices like conductivity profiling are particularly valuable whenever new membranes are installed to ensure the integrity of the installation. Table 3-11 provides a conceptual IVP in the scheme of enhancing awarded pathogen credit across an RO system. It includes the different levels of monitoring, surrogate contenders for each, monitoring location, and frequency.

Of the alternative surrogates investigated, strontium showed great promise at the site where the study was conducted. As a naturally occurring constituent, high enough feed concentration made it possible to demonstrate an LRV of approximately 3.5-logs across membranes of adequate condition (e.g., virgin TMG20D-400). Implementing strontium as the DIT surrogate would provide a significant advantage over current methods (e.g., TOC and EC) often granting no more than 2-logs. The analysis of strontium would need to be completed within 24-hour period, requiring constant coordination of laboratory and operations. An on-line strontium analyzer may serve as an alternative, yet requires investigation.

One nuance is that strontium showed to be prone to membrane degradation (Figure 3-14). Given this experience, utilities would be pressured to change out aged membranes more frequently, particularly those in trailing stages, to match and maintain the highest removal as shown when membranes are commissioned.

3D TRASAR also offered a noteworthy LRV between 3.5-3.6 in this study across both ESPA2 LD and TMG20D-400 membranes. For this application, it is necessary to spike a proprietary dye and employ custom fluorescent meters. This makes 3D TRASAR a potentially costlier option when compared to a surrogate that is naturally occurring in feedwater that can provide a comparable LRV. Nevertheless, the capability to continuously monitor membrane integrity makes 3D TRASAR a valuable instrument in the realm of this topic and is expected to continue attracting interest amongst potable reuse RO applications. Because RO membrane performance is not prone to sudden decline, a more attractive alternative may be to feed the TRASAR dye for a short period each day (rather than continuously) to satisfy the DIT criteria.

**Table 3-11: Conceptual layers of monitoring for an integrity verification program**

| Parameter | Direct integrity testing (DIT) | Continuous indirect integrity monitoring (CIIM) | Periodic integrity verification[5] |
|---|---|---|---|
| Potential surrogates | 3D TRASAR (spiked), strontium[1] | Conductivity (or TOC) | Conductivity |
| Monitoring location | every membrane unit | system-wide | every vessel |
| Frequency | every 24 hours[2] | continuous[4] | quarterly |
| Expected LRV | at *least* 2.5[3] | Higher than 95% rejection (1.3 LRV) | Higher than 95% rejection (1.3 LRV) |

1 – other naturally occurring constituents may be considered given there is sufficient concentration in the feed and detection limit is low enough to provide an LRV > 3
2 – unless otherwise approved by the State if supported by demonstrated process reliability, the use of multiple barriers effective for the pathogen of concern, or reliable process safeguards
3 – based on rejection across aged trailing stage elements (*worst condition*)
4 – every 15 minutes
5 – not demanded by regulations. Serves as an additional process safeguard

# 4. Conclusions

The purpose of this project was to evaluate alternative surrogates to enhance pathogen removal credit awarded for RO systems. In pursuing this effort, the findings showed that there are several surrogates available (both naturally occurring and spiked) that can be used for this purpose. Spiked 3D TRASAR and naturally occurring strontium are amongst the most noteworthy of those evaluated. In evaluating surrogate rejection across membranes of different condition, it was found that rejection was reduced as membrane age increased. This trend appeared to be exacerbated in trailing stages, implying that utilities would ultimately need to make more frequent changes on trailing stage elements to maintain the highest possible awarded RO log removal credit. Nonetheless, the aged membranes maintained a strong barrier for viruses (i.e., MS2) for membranes that were tested and which is consistent to other studies.

As for the other evaluated surrogates in this study, all of them remained conservative or converged to MS2 rejection for severe compromises. Interestingly, a slight alteration in membrane shell design provided a noticeable difference in terms of surrogate response to a system compromise for the different membrane manufacturers that were evaluated.

Furthermore, a systematic investigation showed that surrogates offering higher LRV (> 3) provided enhanced resolution of failure in detecting integrity breaches across the system. This makes it highly encouraging to use surrogates that provide greater LRVs since they can identify breaches at locations beyond where a breach is originated (e.g., single vessel). The same resolution of failure was not achieved with electrical conductivity, since it inherently delivers lower LRV.

The use of TOC and EC will most likely continue as the means for continuous indirect integrity monitoring (CIIM), yet alternative surrogates such as strontium and 3D TRASAR show true potential in delivering higher pathogen removal credit for RO systems via direct integrity testing (DIT). Additonal safeguarding, such as process reliability, use of multiple barriers, and periodic vessel-level monitoring (e.g., conductivity profiling) are aspects that further instill confidence of an RO system seeking enhanced pathogen credit awardance. In implementing an integrity verification program (IVP) using alternative surrogates to pursue enhanced pathogen credit, utilities should be mindful of:

(i) Nuances of membrane filtration system framework and regulations under which the facility is ruled – e.g., Membrane Filtration System Guidance Manual and LT2ESWTR provide Federal standards for the agencies located in the United States, however additional requirements may be set by the local State.

(ii) Verifying that a potential naturally occuring surrogate has sufficient concentration in the feed and low enough detection limit to demonstrate the intended LRV.

(iii) Optimizing the feed concentration for spiked constituents (e.g., 3D TRASAR) such that it is at the lowest level necessary to verify the target awarded LRV to minimize chemical costs. The use of short pulses, rather than continuous monitoring, is also worth exploring.

(iv) Developing a database to evaluate statistical variance and establish control limits for detecting breaches for the various employed surrogate.

(v) Assessment and comparison of alternative surrogates and their potential benefits and drawbacks in pursuing enhanced RO pathogen removal credit in the context of the treatment train overall LRV.

To conclude, there continues to be the need for improving pathogen removal credit awarded for RO systems. With advancements in method development (e.g., lower detection limits), the ability to demonstrate RO performance closer to its true potential has become more accessible in terms of cost and logistics. The development of a site-specific comprehensive IVP incorporating ease of implementation and effectiveness to demonstrate ongoing integrity will be key in pursuing regulatory approval for utilities seeking to enhance RO pathogen removal credit.

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# Appendix A – Data Record

**MS2 ROUND 1 ON AGED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

BioVir Laboratories

EPA ID# 01401, CA-ELAP #179

685 Stone Road, Unit 6 • Benicia, CA 94510 • (707) 747-5906 • 1-800-GIARDIA • FAX (707) 747-1751 • WEB: www.biovir.com

**REPORT NO.:** 160541
**PAGE NO.:** 1 of 8
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

**ASSAY RESULTS:**

**Test:** **1602 Bacteriophage** **Method:** **EPA 1602 (821-R-01-029)**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-013B** | **Control Vessel Perm (1of3)B** | **Control Vessel Perm (1of3)** | **Male Specific Phage** | **<1** | **pfu/100 mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:00:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160541-014B** | **Control Vessel Perm (2of3)B** | **Control Vessel Perm (2of3)** | **Male Specific Phage** | **<1** | **pfu/100 mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:00:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160541-015B** | **Control Vessel Perm (3of3)B** | **Control Vessel Perm (3of3)** | **Male Specific Phage** | **<1** | **pfu/100 mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:00:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160541-022B** | **Test 3 Vessel 1 Perm (1of3)B** | **Test 3 Vessel 1 Perm (1of3)** | **Male Specific Phage** | **<1** | **pfu/100 mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:32:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

**REPORT NO.:** 160541
**PAGE NO.:** 2 of 8
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

### Test: 1602 Bacteriophage Method: EPA 1602 (821-R-01-029)

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160541-023B | Test 3 Vessel 1 Perm (2of3)B | Test 3 Vessel 1 Perm (2of3) | Male Specific Phage | <1 | pfu/100 mL |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:32:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160541-024B | Test 3 Vessel 1 Perm (3of3)B | Test 3 Vessel 1 Perm (3of3) | Male Specific Phage | <1 | pfu/100 mL |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:32:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

### Test: Bacteriophage Method: Adams 1959

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160541-001 | Control Ro Feed (1of3) | Control RO Feed (1of3) | Bacteriophage | 1.0e6 | PFU/mL |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:01:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160541-002 | Control RO Feed (2of3) | Control RO Feed (2of3) | Bacteriophage | 8.8e5 | PFU/mL |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:01:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

**REPORT NO.:** 160541
**PAGE NO.:** 3 of 8
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-003** | **Control RO Feed (3of3)** | **Control RO Feed (3of3)** | **Bacteriophage** | **8.6e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:01:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-004** | **Test 1 RO Feed (1of3)** | **Test 1 RO Feed (1of3)** | **Bacteriophage** | **9.7e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:25:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-005** | **Test 1 RO Feed (2of3)** | **Test 1 RO Feed (2of3)** | **Bacteriophage** | **8.8e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:25:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-006** | **Test 1 RO Feed (3of3)** | **Test 1 RO Feed (3of3)** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:25:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-007** | **Test 2 RO Feed (1of3)** | **Test 2 RO Feed (1of3)** | **Bacteriophage** | **9.6e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:00:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

**REPORT NO.:** 160541
**PAGE NO.:** 4 of 8
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-008** | **Test 2 RO Feed (2of3)** | **Test 2 RO Feed (2of3)** | **Bacteriophage** | **1.0e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:00:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160541-009** | **Test 2 RO Feed (3of3)** | **Test 2 RO Feed (3of3)** | **Bacteriophage** | **1.0e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:00:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160541-010** | **Test 3 RO Feed (1of3)** | **Test 3 RO Feed (1of3)** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:32:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160541-011** | **Test 3 RO Feed (2of3)** | **Test 3 RO Feed (2of3)** | **Bacteriophage** | **9.2e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:32:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160541-012** | **Test 3 RO Feed (3of3)** | **Test 3 RO Feed (3of3)** | **Bacteriophage** | **9.6e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:32:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-013A** | **Control Vessel Perm (1of3)A** | **Control Vessel Perm (1of3)** | **Bacteriophage** | **<10** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:00:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-014** | **Control Vessel Perm (2of3)** | **Control Vessel Perm (2of3)** | **Bacteriophage** | | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:00:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 1100ml Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-014A** | **Control Vessel Perm (2of3)A** | **Control Vessel Perm (2of3)** | **Bacteriophage** | **<10** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:00:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-015A** | **Control Vessel Perm (3of3)A** | **Control Vessel Perm (3of3)** | **Bacteriophage** | **<10** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:00:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-016** | **Test 1 Vessel 1 Perm (1of3)** | **Test 1 Vessel 1 Perm (1of3)** | **Bacteriophage** | **1.2e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:23:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-017** | **Test 1 Vessel 1 Perm (2of3)** | **Test 1 Vessel 1 Perm (2of3)** | **Bacteriophage** | **1.3e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:23:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-018** | **Test 1 Vessel 1 Perm (3of3)** | **Test 1 Vessel 1 Perm (3of3)** | **Bacteriophage** | **1.3e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:23:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/1/2016 Analysis Start Time: 1407
Analyst: KTucker Analysis End: 3/2/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-019** | **Test 2 Vessel 1 Perm (1of3)** | **Test 2 Vessel 1 Perm (1of3)** | **Bacteriophage** | **27** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:58:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-020** | **Test 2 Vessel 1 Perm (2of3)** | **Test 2 Vessel 1 Perm (2of3)** | **Bacteriophage** | **97** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:58:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

**REPORT NO.:** 160541
**PAGE NO.:** 7 of 8
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-021** | **Test 2 Vessel 1 Perm (3of3)** | **Test 2 Vessel 1 Perm (3of3)** | **Bacteriophage** | **4** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 11:58:00 AM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp 7.1C
Volume: 100 mL Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-022A** | **Test 3 Vessel 1 Perm (1of3)A** | **Test 3 Vessel 1 Perm (1of3)** | **Bacteriophage** | **<10** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:32:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-023A** | **Test 3 Vessel 1 Perm (2of3)A** | **Test 3 Vessel 1 Perm (2of3)** | **Bacteriophage** | **<10** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:32:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160541-024A** | **Test 3 Vessel 1 Perm (3of3)A** | **Test 3 Vessel 1 Perm (3of3)** | **Bacteriophage** | **10** | **PFU/mL** |

Collector: Elise Chen CollectDate: 2/29/2016 CollectTime: 12:32:00 PM
ReceiveDate 3/1/2016 9:23:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 3/2/2016 Analysis Start Time: 1630
Analyst: KTucker Analysis End: 3/3/2016

Comment

| | |
|---|---|
| **REPORT NO.:** | 160541 |
| **PAGE NO.:** | 8 of 8 |
| **CLIENT:** | Trussell Technologies |
| **ADDRESS** | 232 N. Lake Avenue, Suite 300 |
| | Pasadena, CA 91101 |
| **CLIENT NO** | TRU004 **CLIENT PO:** N/A |

**ASSAY RESULTS:**

SAMPLE EVALUATION PERFORMANCE CRITERIA: The precise rates of recovery of organisms from environmental samples cannot be determined. B ioVir Laboratories has analyzed your sample(s) in accordance with the method described with each analyte above, however, due to inherent limitations of these methods organisms may avoid detection. For additional information regarding the limitations of the method(s) referred to above please call us at 1-800-GIARDIA.
COMPANY IS NOT AN INSURER: BioVir Laboratories is not an insurer or guarantor of the quality and/or purity of water, wastewater, biosolid or other material from which the sample was taken. BioVir offers no express or implied warranties whatsoever concerning the quality or purity of any water, wastewater, biosolid or other material which is ultimately consumed, distributed, applied or disposed.
MAINTENANCE OF RECORDS: BioVir Laboratories, Inc. shall maintain records pertaining to the historical reconstruction of client's data for a minimum of five years from the date of issuance of the final report. Records m ay be destroyed after that date unless a written client's request for records transfer is received by BioVir which requests otherwise. Records transfer or storage charges may apply after the 5 year period. THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF BIOVIR LABORATORIES, INC.

3/14/2016

Date:

Signature

**Quality Checked** ElbaM

**MS2 ROUND 2 ON AGED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

BioVir Laboratories, Inc

NELAC #05234CA
EPA ID# 01401, CA-ELAP #179

685 Stone Road, Unit 6 • Benicia, CA 94510 • (707) 747-5906 • 1-800-GIARDIA • FAX (707) 747-1751 • WEB: www.biovir.com

**REPORT NO.:** 160846
**PAGE NO.:** 1 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

**ASSAY RESULTS:**

**Test:** **1601 Bacteriophage** **Method:** **EPA 1601 (821-R-01-030)**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-013** | **Control Vessqel Perm (1of3)** | **Control Vessel Perm (1of3)** | **Male Specific Phage** | **Present** | **P/A per L** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:24:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1300
Analyst: KTucker Analysis End: 4/22/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-014** | **Control Vessqel Perm (2of3)** | **Control Vessel Perm (2of3)** | **Male Specific Phage** | **Present** | **P/A per L** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:23:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1300
Analyst: KTucker Analysis End: 4/22/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-015** | **Control Vessqel Perm (3of3)** | **Control Vessel Perm (3of3)** | **Male Specific Phage** | **Present** | **P/A per L** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:23:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1300
Analyst: KTucker Analysis End: 4/22/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-022** | **Test 3 Vessel Perm (1of3)** | **Test 3 Vessel Perm (1of3)** | **Male Specific Phage** | **Present** | **P/A per L** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:13:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/19 Analysis Start Time: 1300
Analyst: KTucker Analysis End: 4/22/2016

Comment

**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

### Test: 1601 Bacteriophage Method: EPA 1601 (821-R-01-030)

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160846-023 | Test 3 Vessel Perm (2of3) | Test 3 Vessel Perm (2of3) | Male Specific Phage | Present | P/A per L |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:13:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1300
Analyst: KTucker Analysis End: 4/22/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160846-024 | Test 3 Vessel Perm (3of3) | Test 3 Vessel Perm (3of3) | Male Specific Phage | Present | P/A per L |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:13:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1300
Analyst: KTucker Analysis End: 4/22/2016

Comment

### Test: 1602 Bacteriophage Method: EPA 1602 (821-R-01-029)

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160846-013 | Control Vessqel Perm (1of3) | Control Vessel Perm (1of3) | Male Specific Phage | 10 | pfu/100 mL |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:24:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1650
Analyst: KTucker Analysis End: 4/21/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160846-014 | Control Vessqel Perm (2of3) | Control Vessel Perm (2of3) | Male Specific Phage | 4 | pfu/100 mL |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:23:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1650
Analyst: KTucker Analysis End: 4/21/2016

Comment

**REPORT NO.:** 160846
**PAGE NO.:** 3 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: 1602 Bacteriophage** **Method: EPA 1602 (821-R-01-029)**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-015** | **Control Vessqel Perm (3of3)** | **Control Vessel Perm (3of3)** | **Male Specific Phage** | **<1** | **pfu/100 mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:23:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1650
Analyst: KTucker Analysis End: 4/21/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-022** | **Test 3 Vessel Perm (1of3)** | **Test 3 Vessel Perm (1of3)** | **Male Specific Phage** | **11** | **pfu/100 mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:13:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/19 Analysis Start Time: 1650
Analyst: KTucker Analysis End: 4/21/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-023** | **Test 3 Vessel Perm (2of3)** | **Test 3 Vessel Perm (2of3)** | **Male Specific Phage** | **12** | **pfu/100 mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:13:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1650
Analyst: KTucker Analysis End: 4/21/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-024** | **Test 3 Vessel Perm (3of3)** | **Test 3 Vessel Perm (3of3)** | **Male Specific Phage** | **2** | **pfu/100 mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:13:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/20/16 Analysis Start Time: 1650
Analyst: KTucker Analysis End: 4/21/2016

Comment

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|

**REPORT NO.:** 160846
**PAGE NO.:** 4 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-001** | **Control RO Feed (1of3)** | **Control RO Feed (1of3)** | **Bacteriophage** | **8.6e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:24:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-002** | **Control RO Feed (2of3)** | **Control RO Feed (2of3))** | **Bacteriophage** | **8.2e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:24:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-003** | **Control RO Feed (3of3)** | **Control RO Feed (3of3)** | **Bacteriophage** | **7.3e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:24:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-004** | **Test 1 RO Feed (1of3)** | **Test 1 RO Feed (1of3)** | **Bacteriophage** | **8.9e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:56:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-005** | **Test 1 RO Feed (2of3)** | **Test 1 RO Feed (2of3)** | **Bacteriophage** | **7.1e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:56:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

**REPORT NO.:** 160846
**PAGE NO.:** 5 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-006** | **Test 1 RO Feed (3of3)** | **Test 1 RO Feed (3of3)** | **Bacteriophage** | **6.6e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:57:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-007** | **Test 2 RO Feed (1of3)** | **Test 2 RO Feed (1of3)** | **Bacteriophage** | **9.0e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 5:39:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-008** | **Test 2 RO Feed (2of3)** | **Test 2 RO Feed (2of3)** | **Bacteriophage** | **6.3e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 5:39:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-009** | **Test 2 RO Feed (3of3)** | **Test 2 RO Feed (3of3)** | **Bacteriophage** | **6.0e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 5:39:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-010** | **Test 3 RO Feed (1of3)** | **Test 3 RO Feed (1of3)** | **Bacteriophage** | **5.8e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:14:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-011** | **Test 3 RO Feed (2of3)** | **Test 3 RO Feed (2of3)** | **Bacteriophage** | **7.4e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:14:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-012** | **Test 3 RO Feed (3of3)** | **Test 3 RO Feed (3of3)** | **Bacteriophage** | **7.1e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:14:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-013** | **Control Vessqel Perm (1of3)** | **Control Vessel Perm (1of3)** | **Bacteriophage** | **<1.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:24:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-014** | **Control Vessqel Perm (2of3)** | **Control Vessel Perm (2of3)** | **Bacteriophage** | **<1.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:23:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-015** | **Control Vessqel Perm (3of3)** | **Control Vessel Perm (3of3)** | **Bacteriophage** | **<1.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:23:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

**REPORT NO.:** 160846
**PAGE NO.:** 7 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-016** | **Test 1 Vessel Perm (1of3)** | **Test 1 Vessel Perm (1of 3)** | **Bacteriophage** | **1.3e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:54:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-017** | **Test 1 Vessel Perm (2of3)** | **Test 1 Vessel Perm (2of 3)** | **Bacteriophage** | **1.7e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:55:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-018** | **Test 1 Vessel Perm (3of3)** | **Test 1 Vessel Perm (3of 3)** | **Bacteriophage** | **1.2e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 4:54:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-019** | **Test 2 Vessel Perm (1of3)** | **Test 2 Vessel Perm (1of3)** | **Bacteriophage** | **1.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 5:38:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160846-020** | **Test 2 Vessel Perm (2of3)** | **Test 2 Vessel Perm (2of3)** | **Bacteriophage** | **3.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 5:38:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

**REPORT NO.:** 160846
**PAGE NO.:** 8 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

---

**ASSAY RESULTS:**

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-021** | **Test 2 Vessel Perm (3of3)** | **Test 2 Vessel Perm (3of3)** | **Bacteriophage** | **<1.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 5:38:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-022** | **Test 3 Vessel Perm (1of3)** | **Test 3 Vessel Perm (1of3)** | **Bacteriophage** | **<1.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:13:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-023** | **Test 3 Vessel Perm (2of3)** | **Test 3 Vessel Perm (2of3)** | **Bacteriophage** | **<1.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:13:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160846-024** | **Test 3 Vessel Perm (3of3)** | **Test 3 Vessel Perm (3of3)** | **Bacteriophage** | **<1.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/18/2016 CollectTime: 6:13:00 PM
ReceiveDate 4/19/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 5.3C
Volume: 1100 mL Analysis Start Date: 4/19/16 Analysis Start Time: 1316
Analyst: KTucker Analysis End: 4/20/2016

Comment

| | |
|---|---|
| **REPORT NO.:** | 160846 |
| **PAGE NO.:** | 9 of 9 |
| **CLIENT:** | Trussell Technologies |
| **ADDRESS** | 232 N. Lake Avenue, Suite 300 |
| | Pasadena, CA 91101 |
| **CLIENT NO** | TRU004 **CLIENT PO:** N/A |

**ASSAY RESULTS:**

SAMPLE EVALUATION PERFORMANCE CRITERIA: The precise rates of recovery of organisms from environmental samples cannot be determined. B ioVir Laboratories has analyzed your sample(s) in accordance with the method described with each analyte above, however, due to inherent limitations of these methods organisms may avoid detection. For additional information regarding the limitations of the method(s) referred to above please call us at 1-800-GIARDIA.
COMPANY IS NOT AN INSURER: BioVir Laboratories is not an insurer or guarantor of the quality and/or purity of water, wastewater, biosolid or other material from which the sample was taken. BioVir offers no express or implied warranties whatsoever concerning the quality or purity of any water, wastewater, biosolid or other material which is ultimately consumed, distributed, applied or disposed.
MAINTENANCE OF RECORDS: BioVir Laboratories, Inc. shall maintain records pertaining to the historical reconstruction of client's data for a minimum of five years from the date of issuance of the final report. Records m ay be destroyed after that date unless a written client's request for records transfer is received by BioVir which requests otherwise. Records transfer or storage charges may apply after the 5 year period. THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF BIOVIR LABORATORIES, INC.

5/18/2016

Date:

Signature

**Quality Checked** ElbaM

**MS2 ROUND 3 ON AGED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

BioVir Laboratories, Inc

NELAC #05234CA
EPA ID# 01401, CA-ELAP #179

685 Stone Road, Unit 6 • Benicia, CA 94510 • (707) 747-5906 • 1-800-GIARDIA • FAX (707) 747-1751 • WEB: www.biovir.com

**REPORT NO.:** 160854
**PAGE NO.:** 1 of 7
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** Gulf Coast

## ASSAY RESULTS:

**Test: 1601 Bacteriophage** **Method: EPA 1601 (821-R-01-030)**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160854-023 | Test 3 Vessel Perm (2of 3) | Test 3 Vessel Perm (2of3) | Male Specific Phage | Present | P/A per L |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 1:55:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: JTruscott Analysis End: 4/23/2016

Comment

**Test: 1602 Bacteriophage** **Method: EPA 1602 (821-R-01-029)**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 160854-023 | Test 3 Vessel Perm (2of 3) | Test 3 Vessel Perm (2of3) | Male Specific Phage | <1 | pfu/100 mL |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 1:55:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: JTruscott Analysis End: 4/23/2016

Comment

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|

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**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** Gulf Coast

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160854-001** | **Control RO Feed (1of3)** | **Control RO Feed (1of3)** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 2:49:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-002** | **Control RO Feed (2of3)** | **Control RO Feed (2of3)** | **Bacteriophage** | **1.0e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 2:49:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-003** | **Control RO Feed (3of3)** | **Control RO Feed (3of3)** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 2:49:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-004** | **Test 1 RO Feed (1of3)** | **Test 1 RO Feed (1of3)** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 3:28:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-005** | **Test 1 RO Feed (2of3)** | **Test 1 RO Feed (2of3)** | **Bacteriophage** | **8.1e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 3:28:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

**REPORT NO.:** 160854
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**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** Gulf Coast

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160854-006** | **Test 1 RO Feed (3of3)** | **Test 1 RO Feed (3of3)** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 3:28:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-007** | **Test 2 RO Feed (1of3)** | **Test 2 RO Feed (1of3)** | **Bacteriophage** | **1.2e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 4:00:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-008** | **Test 2 RO Feed (2of3)** | **Test 2 RO Feed (2of3)** | **Bacteriophage** | **1.3e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 4:00:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-009** | **Test 2 RO Feed (3of3)** | **Test 2 RO Feed (3of3)** | **Bacteriophage** | **1.0e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 4:00:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-010** | **Test 3 RO Feed (1of3)** | **Test 3 RO Feed (1of3)** | **Bacteriophage** | **1.4e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 1:58:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

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Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** Gulf Coast

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160854-011** | **Test 3 RO Feed (2of3)** | **Test 3 RO Feed (2of3)** | **Bacteriophage** | **1.8e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 1:59:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-012** | **Test 3 RO Feed (3of3)** | **Test 3 RO Feed (3of3)** | **Bacteriophage** | **1.2e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 1:59:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-013** | **Control Vessel Perm(1of 3)** | **Control Vessel Perm (1of3)** | **Bacteriophage** | **2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 2:46:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-014** | **Control Vessel Perm(2of 3)** | **Control Vessel Perm (2of3)** | **Bacteriophage** | **3** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 2:48:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-015** | **Control Vessel Perm(3of 3)** | **Control Vessel Perm (3of3)** | **Bacteriophage** | **2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 2:47:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

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**CLIENT NO** TRU004 **CLIENT PO:** Gulf Coast

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160854-016** | **Test 1 Vessel Perm (1of3)** | **Test 1 Vessel Perm (1of 3)** | **Bacteriophage** | **1.9e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 3:27:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-017** | **Test 1 Vessel Perm (2of3)** | **Test 1 Vessel Perm (2of 3)** | **Bacteriophage** | **1.8e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 3:27:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-018** | **Test 1 Vessel Perm (3of3)** | **Test 1 Vessel Perm (3of 3)** | **Bacteriophage** | **1.7e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 3:27:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-019** | **Test 2 Vessel Perm (1of 3)** | **Test 2 Vessel Perm (1of3)** | **Bacteriophage** | **3.3e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 3:59:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-020** | **Test 2 Vessel Perm (2of 3)** | **Test 2 Vessel Perm (2of3)** | **Bacteriophage** | **4.2e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 3:57:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

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Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** Gulf Coast

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **160854-021** | **Test 2 Vessel Perm (3of 3)** | **Test 2 Vessel Perm (3of3)** | **Bacteriophage** | **5.0e2** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 3:56:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-022** | **Test 3 Vessel Perm (1of 3)** | **Test 3 Vessel Perm (1of3)** | **Bacteriophage** | **3** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 1:54:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-023** | **Test 3 Vessel Perm (2of 3)** | **Test 3 Vessel Perm (2of3)** | **Bacteriophage** | **<1** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 1:55:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **160854-024** | **Test 3 Vessel Perm (3of 3)** | **Test 3 Vessel Perm (3of3)** | **Bacteriophage** | **3** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 4/19/2016 CollectTime: 1:56:00 PM
ReceiveDate 4/20/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 3.8C
Volume: 1100 mL Analysis Start Date: 4/20/2016 Analysis Start Time: 1430
Analyst: KTucker Analysis End: 4/21/2016

Comment

| | |
|---|---|
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| **CLIENT:** | Trussell Technologies |
| **ADDRESS** | 232 N. Lake Avenue, Suite 300 |
| | Pasadena, CA 91101 |
| **CLIENT NO** | TRU004 **CLIENT PO:** Gulf Coast |

**ASSAY RESULTS:**

SAMPLE EVALUATION PERFORMANCE CRITERIA: The precise rates of recovery of organisms from environmental samples cannot be determined. B ioVir Laboratories has analyzed your sample(s) in accordance with the method described with each analyte above, however, due to inherent limitations of these methods organisms may avoid detection. For additional information regarding the limitations of the method(s) referred to above please call us at 1-800-GIARDIA.
COMPANY IS NOT AN INSURER: BioVir Laboratories is not an insurer or guarantor of the quality and/or purity of water, wastewater, biosolid or other material from which the sample was taken. BioVir offers no express or implied warranties whatsoever concerning the quality or purity of any water, wastewater, biosolid or other material which is ultimately consumed, distributed, applied or disposed.
MAINTENANCE OF RECORDS: BioVir Laboratories, Inc. shall maintain records pertaining to the historical reconstruction of client's data for a minimum of five years from the date of issuance of the final report. Records m ay be destroyed after that date unless a written client's request for records transfer is received by BioVir which requests otherwise. Records transfer or storage charges may apply after the 5 year period. THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF BIOVIR LABORATORIES, INC.

5/9/2016

Date:

Signature

**Quality Checked** ElbaM

**MS2 ROUND 1 ON UNUSED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

BioVir Laboratories, Inc

NELAC #05234CA
EPA ID# 01401, CA-ELAP #179

685 Stone Road, Unit 6 • Benicia, CA 94510 • (707) 747-5906 • 1-800-GIARDIA • FAX (707) 747-1751 • WEB: www.biovir.com

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**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: 1602 Bacteriophage** **Method: EPA 1602 (821-R-01-029)**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-020** | **Test 3 Vessel Perm (2of3)** | **Test 3 Vessel Perm (2of3)** | **Male Specific Phage** | **7.5e2** | **pfu/100 mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 4:45:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: MPiper Analysis End: 5/27/2016

Comment

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-001** | **Control RO Feed (1of3)** | **Control RO Feed (1of3)** | **Bacteriophage** | **8.8e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 2:50:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161068-002** | **Control RO Feed (2of3)** | **Control RO Feed (2of3)** | **Bacteriophage** | **9.3e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 2:50:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

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## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-003** | **Control RO Feed (3of3)** | **Control RO Feed (3of3)** | **Bacteriophage** | **6.3e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 2:50:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-004** | **Test 1 RO Feed (1of3)** | **Test 1 RO Feed (1of3)** | **Bacteriophage** | **6.8e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:20:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-005** | **Test 1 RO Feed (2of3)** | **Test 1 RO Feed (2of3)** | **Bacteriophage** | **6.9e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:20:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-006** | **Test 1 RO Feed (3of3)** | **Test 1 RO Feed (3of3)** | **Bacteriophage** | **5.7e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:20:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-007** | **Test 2 RO Feed (1of3)** | **Test 2 RO Feed (1of3)** | **Bacteriophage** | **6.2e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:55:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

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**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-008** | **Test 2 RO Feed (2of3)** | **Test 2 RO Feed (2of3)** | **Bacteriophage** | **6.8e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:55:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-009** | **Test 2 RO Feed (3of3)** | **Test 2 RO Feed (3of3)** | **Bacteriophage** | **7.1e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:55:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-010** | **Test 3 RO Feed (1of3)** | **Test 3 RO Feed (1of3)** | **Bacteriophage** | **7.4e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 4:45:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-011** | **Test 3 RO Feed (2of3)** | **Test 3 RO Feed (2of3)** | **Bacteriophage** | **6.8e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 4:45:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-012** | **Test 3 RO Feed (3of3)** | **Test 3 RO Feed (3of3)** | **Bacteriophage** | **8.7e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 4:45:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: MPiper Analysis End: 5/26/2016

Comment

**REPORT NO.:** 161068
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Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-013** | **Control Vessel Perm (1of3)** | **Control Vessel Perm (1of3)** | **Bacteriophage** | **1.0e2** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 2:42:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-014** | **Control Vessel Perm (2of3)** | **Control Vessel Perm (2of3)** | **Bacteriophage** | **8** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 2:42:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/27/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-015** | **Control Vessel Perm (3of3)** | **Control Vessel Perm (3of3)** | **Bacteriophage** | **10** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 2:42:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-016** | **Test 2 Vessel Perm (1of3)** | **Test 2 Vessel Perm (1of3)** | **Bacteriophage** | **5.0e3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:52:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-017** | **Test 2 Vessel Perm (2of3)** | **Test 2 Vessel Perm (2of3)** | **Bacteriophage** | **7.0e3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:52:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

**REPORT NO.:** 161068
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**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-018** | **Test 2 Vessel Perm (3of3)** | **Test 2 Vessel Perm (3of3)** | **Bacteriophage** | **5.0e3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:52:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-019** | **Test 3 Vessel Perm (1of3)** | **Test 3 Vessel Perm (1of3)** | **Bacteriophage** | **20** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 4:45:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-020** | **Test 3 Vessel Perm (2of3)** | **Test 3 Vessel Perm (2of3)** | **Bacteriophage** | **<10** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 4:45:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-021** | **Test 3 Vessel Perm (3of3)** | **Test 3 Vessel Perm (3of3)** | **Bacteriophage** | **20** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 4:45:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 1100 mL Analysis Start Date: 5/25/2016 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-022** | **Test 1 Vessel Perm (1of3)** | **Test 1 Vessel Perm (1of 3)** | **Bacteriophage** | **8.5e4** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:15:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/16 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

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**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-023** | **Test 1 Vessel Perm (2of3)** | **Test 1 Vessel Perm (2of 3)** | **Bacteriophage** | **9.3e4** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:15:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/16 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161068-024** | **Test 1 Vessel Perm (3of3)** | **Test 1 Vessel Perm (3of 3)** | **Bacteriophage** | **1.2e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 5/24/2016 CollectTime: 3:15:00 PM
ReceiveDate 5/25/2016 9:15:00 AM Matrix: Water, Reagent Grade Temp 7.9C
Volume: 100 mL Analysis Start Date: 5/25/16 Analysis Start Time: 1440
Analyst: KTucker Analysis End: 5/26/2016

Comment

SAMPLE EVALUATION PERFORMANCE CRITERIA: The precise rates of recovery of organisms from environmental samples cannot be determined. B ioVir Laboratories has analyzed your sample(s) in accordance with the method described with each analyte above, however, due to inherent limitations of these methods organisms may avoid detection. For additional information regarding the limitations of the method(s) referred to above please call us at 1-800-GIARDIA.
COMPANY IS NOT AN INSURER: BioVir Laboratories is not an insurer or guarantor of the quality and/or purity of water, wastewater, biosolid or other material from which the sample was taken. BioVir offers no express or implied warranties whatsoever concerning the quality or purity of any water, wastewater, biosolid or other material which is ultimately consumed, distributed, applied or disposed.
MAINTENANCE OF RECORDS: BioVir Laboratories, Inc. shall maintain records pertaining to the historical reconstruction of client's data for a minimum of five years from the date of issuance of the final report. Records m ay be destroyed after that date unless a written client's request for records transfer is received by BioVir which requests otherwise. Records transfer or storage charges may apply after the 5 year period. THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF BIOVIR LABORATORIES, INC.

6/2/2016
Date:

Signature

**Quality Checked** ElbaM

**MS2 ROUND 2 & 3 ON UNUSED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**


IEH-BioVir Laboratories

EPA ID# 01401, CA-ELAP #179

685 Stone Road, Unit 6 • Benicia, CA 94510 • (707) 747-5906 • 1-800-GIARDIA • FAX (707) 747-1751 • WEB: www.biovir.com


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**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:**

## ASSAY RESULTS:

**Test: 1601 Bacteriophage** **Method: EPA 1601 (821-R-01-030)**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161071-043 | Test 3 Vessel Perm (1of3) | Test 3 Vessel Perm (1of3) | Male Specific Phage | Absent | P/A per L |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 2:45:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/29/2016 Analysis Start Time: 1250
Analyst: KTucker Analysis End: 7/1/2016

Comment

**Test: 1602 Bacteriophage** **Method: EPA 1602 (821-R-01-029)**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161071-043 | Test 3 Vessel Perm (1of3) | Test 3 Vessel Perm (1of3) | Male Specific Phage | 2.1e2 | pfu/100 mL |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 2:45:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/29/2016 Analysis Start Time: 1555
Analyst: KTucker Analysis End: 7/1/2016

Comment

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|

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**CLIENT NO** TRU004 **CLIENT PO:**

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**ASSAY RESULTS:**

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-001** | **Control RO Feed (1of3)** | **Control RO Feed (1of3)** | **Bacteriophage** | **1.4e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 10:55:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-002** | **Control RO Feed (2of3)** | **Control RO Feed (2of3)** | **Bacteriophage** | **1.2e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 10:55:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-003** | **Control RO Feed (3of3)** | **Control RO Feed (3of3)** | **Bacteriophage** | **1.2e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 10:55:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-004** | **Test 1 RO Feed (1of3)** | **Test 1 RO Feed (1of3)** | **Bacteriophage** | **1.3e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 11:32:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-005** | **Test 1 RO Feed (2of3)** | **Test 1 RO Feed (2of3)** | **Bacteriophage** | **1.3e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 11:32:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

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## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-006** | **Test 1 RO Feed (3of3)** | **Test 1 RO Feed (3of3)** | **Bacteriophage** | **1.0e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 11:32:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-007** | **Test 2 RO Feed (1of3)** | **Test 2 RO Feed (1of3)** | **Bacteriophage** | **1.3e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:20:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-008** | **Test 2 RO Feed (2of3)** | **Test 2 RO Feed (2of3)** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:20:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-009** | **Test 2 RO Feed (3of3)** | **Test 2 RO Feed (3of3)** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:20:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-010** | **Test 3 RO Feed (1of3)** | **Test 3 RO Feed (1of3)** | **Bacteriophage** | **1.3e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

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Pasadena, CA 91101
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## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-011** | **Test 3 RO Feed (2of3)** | **Test 3 RO Feed (2of3)** | **Bacteriophage** | **1.3e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1410
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-013** | **Control Vessel Perm (1of3)** | **Control Vessel Perm (1of3)** | **Bacteriophage** | **2** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 10:55:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 1100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-014** | **Control Vessel Perm (2of3)** | **Control Vessel Perm (2of3)** | **Bacteriophage** | **1** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 10:55:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 1100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-015** | **Control Vessel Perm (3of3)** | **Control Vessel Perm (3of3)** | **Bacteriophage** | **1** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 10:55:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 1100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-016** | **Test 2 Vessel Perm (1of3)** | **Test 2 Vessel Perm (1of3)** | **Bacteriophage** | **1.7e3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:20:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

**CLIENT:** Trussell Technologies
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Pasadena, CA 91101
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## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-017** | **Test 2 Vessel Perm (2of3)** | **Test 2 Vessel Perm (2of3)** | **Bacteriophage** | **1.9e3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:20:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-018** | **Test 2 Vessel Perm (3of3)** | **Test 2 Vessel Perm (3of3)** | **Bacteriophage** | **1.9e3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:20:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-019** | **Test 3 Vessel Perm (1of3)** | **Test 3 Vessel Perm (1of3)** | **Bacteriophage** | **8** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 1100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-020** | **Test 3 Vessel Perm (2of3)** | **Test 3 Vessel Perm (2of3)** | **Bacteriophage** | **5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 1100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-021** | **Test 3 Vessel Perm (3of3)** | **Test 3 Vessel Perm (3of3)** | **Bacteriophage** | **4** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 12:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 1100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

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**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:**

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-022** | **Test 1 Vessel Perm (1of3)** | **Test 1 Vessel Perm (1of 3)** | **Bacteriophage** | **2.0e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 11:32:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-023** | **Test 1 Vessel Perm (2of3)** | **Test 1 Vessel Perm (2of 3)** | **Bacteriophage** | **1.8e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 11:32:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-024** | **Test 1 Vessel Perm (3of3)** | **Test 1 Vessel Perm (3of 3)** | **Bacteriophage** | **1.0e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 11:32:00 AM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-025** | **Control RO Feed (1of3)** | **Control RO Feed (1of3)** | **Bacteriophage** | **9.5e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 4:25:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-026** | **Control RO Feed (2of3)** | **Control RO Feed (2of3)** | **Bacteriophage** | **1.6e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 4:25:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

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**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:**

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-027** | **Control RO Feed (3of3)** | **Control RO Feed (3of3)** | **Bacteriophage** | **1.2e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 4:25:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-028** | **Test 1 RO Feed (1of3)** | **Test 1 RO Feed (1of3)** | **Bacteriophage** | **1.4e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:22:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-029** | **Test 1 RO Feed (2of3)** | **Test 1 RO Feed (2of3)** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:22:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-030** | **Test 1 RO Feed (3of3)** | **Test 1 RO Feed (3of3)** | **Bacteriophage** | **1.6e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:22:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-031** | **Test 2 RO Feed (1of3)** | **Test 2 RO Feed (1of3)** | **Bacteriophage** | **1.5e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

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**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:**

---

**ASSAY RESULTS:**

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-032** | **Test 2 RO Feed (2of3)** | **Test 2 RO Feed (2of3)** | **Bacteriophage** | **1.4e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-033** | **Test 2 RO Feed (3of3)** | **Test 2 RO Feed (3of3)** | **Bacteriophage** | **1.4e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-034** | **Test 3 RO Feed (1of3)** | **Test 3 RO Feed (1of3)** | **Bacteriophage** | **1.2e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 2:45:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-035** | **Test 3 RO Feed (2of3)** | **Test 3 RO Feed (2of3)** | **Bacteriophage** | **2.0e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 2:45:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-036** | **Test 3 RO Feed (3of3)** | **Test 3 RO Feed (3of3)** | **Bacteriophage** | **1.5e6** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 2:45:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

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**ADDRESS** 232 N. Lake Avenue, Suite 300
Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:**

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-037** | **Control Vessel Perm (1of3)** | **Control Vessel Perm (1of3)** | **Bacteriophage** | **2** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 4:25:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-038** | **Control Vessel Perm (2of3)** | **Control Vessel Perm (2of3)** | **Bacteriophage** | **3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 4:25:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-039** | **Control Vessel Perm (3of3)** | **Control Vessel Perm (3of3)** | **Bacteriophage** | **3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 4:25:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-040** | **Test 2 Vessel Perm (1of3)** | **Test 2 Vessel Perm (1of3)** | **Bacteriophage** | **2.9e3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-041** | **Test 2 Vessel Perm (2of3)** | **Test 2 Vessel Perm (2of3)** | **Bacteriophage** | **2.6e3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

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**CLIENT NO** TRU004 **CLIENT PO:**

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-042** | **Test 2 Vessel Perm (3of3)** | **Test 2 Vessel Perm (3of3)** | **Bacteriophage** | **2.5e3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:55:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-043** | **Test 3 Vessel Perm (1of3)** | **Test 3 Vessel Perm (1of3)** | **Bacteriophage** | **<1** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 2:45:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-044** | **Test 3 Vessel Perm (2of3)** | **Test 3 Vessel Perm (2of3)** | **Bacteriophage** | **5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 2:45:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-045** | **Test 3 Vessel Perm (3of3)** | **Test 3 Vessel Perm (3of3)** | **Bacteriophage** | **3** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 2:45:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| | | | | | |
|---|---|---|---|---|---|
| **161071-046** | **Test 1 Vessel Perm (1of3)** | **Test 1 Vessel Perm (1of 3)** | **Bacteriophage** | **2.1e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:22:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp 5.7
Volume: 100 mL Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

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**CLIENT NO** TRU004 **CLIENT PO:**

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-047** | **Test 1 Vessel Perm (2of3)** | **Test 1 Vessel Perm (2of 3)** | **Bacteriophage** | **1.7e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:22:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161071-048** | **Test 1 Vessel Perm (3of3)** | **Test 1 Vessel Perm (3of 3)** | **Bacteriophage** | **1.8e5** | **PFU/mL** |

Collector: Elise Chen CollectDate: 6/27/2016 CollectTime: 3:22:00 PM
ReceiveDate 6/28/2016 9:20:00 AM Matrix: Water, Reagent Grade Temp
Volume: Analysis Start Date: 6/28/2016 Analysis Start Time: 1730
Analyst: KTucker Analysis End: 7/1/2016

Comment

SAMPLE EVALUATION PERFORMANCE CRITERIA: The precise rates of recovery of organisms from environmental samples cannot be determined. B ioVir Laboratories has analyzed your sample(s) in accordance with the method described with each analyte above, however, due to inherent limitations of these methods organisms may avoid detection. For additional information regarding the limitations of the method(s) referred to above please call us at 1-800-GIARDIA.
COMPANY IS NOT AN INSURER: BioVir Laboratories is not an insurer or guarantor of the quality and/or purity of water, wastewater, biosolid or other material from which the sample was taken. BioVir offers no express or implied warranties whatsoever concerning the quality or purity of any water, wastewater, biosolid or other material which is ultimately consumed, distributed, applied or disposed.
MAINTENANCE OF RECORDS: BioVir Laboratories, Inc. shall maintain records pertaining to the historical reconstruction of client's data for a minimum of five years from the date of issuance of the final report. Records m ay be destroyed after that date unless a written client's request for records transfer is received by BioVir which requests otherwise. Records transfer or storage charges may apply after the 5 year period. THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF BIOVIR LABORATORIES, INC.

8/18/2016
Date:

Signature

**Quality Checked** ElbaM

**MS2 ROUND 1 ON VIRGIN TORAY TMG20D-400 ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**


IEH-BioVir Laboratories

EPA ID# 01401, CA-ELAP #1795

685 Stone Road, Unit 6 • Benicia, CA 94510 • (707) 747-5906 • 1-800-GIARDIA • FAX (707) 747-1751 • WEB: www.biovir.com


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**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

**ASSAY RESULTS:**

**Test:** **Bacteriophage Male-Specific** **Method:** **Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-001** | **Control RO Feed (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **6.8e5** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:37:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161483-002** | **Control RO Feed (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.5e6** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:37:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/5/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161483-003** | **Control RO Feed (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.2e6** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:37:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161483-004** | **Control Stage 2 Feed (1of1)** | **None Given** | **Bacteriophage, Male Specific** | **2.0e6** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:37:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

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**CLIENT NO** TRU004 **CLIENT PO:** N/A

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**ASSAY RESULTS:**

**Test: Bacteriophage Male-Specific** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-005** | **Test 1 RO Feed (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **9.3e5** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-006** | **Test 1 RO Feed (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.1e6** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-007** | **Test 1 RO Feed (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **6.7e5** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-008** | **Test 1 Stage 2 Feed (1of1)** | **None Given** | **Bacteriophage, Male Specific** | **1.6e6** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-009** | **Test 3 RO Feed (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **7.5e5** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:12:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

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## ASSAY RESULTS:

**Test: Bacteriophage Male-Specific** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-010** | **Test 3 RO Feed (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **6.6e5** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:12:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-011** | **Test 3 RO Feed (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **5.3e5** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:12:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-012** | **Test 3 Stage 2 Feed (1of1)** | **None Given** | **Bacteriophage, Male Specific** | **1.3e6** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:12:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-013** | **Control Vessel Perm (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **<10** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:25:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: PBianchi Analysis End: 8/25/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-014** | **Control Vessel Perm (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **3** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:25:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/5/2016

Comment:

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## ASSAY RESULTS:

**Test: Bacteriophage Male-Specific** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-015** | **Control Vessell Perm (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:25:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/5/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-016** | **Control Stage 1 Perm (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.3e3** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:30:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/5/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-017** | **Control Stage 1 Perm (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.6e3** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:30:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/5/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-018** | **Control Stage 1 Perm (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.6e3** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:30:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/5/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-019** | **Control Stage 2 Perm (1of1)** | **None Given** | **Bacteriophage, Male Specific** | **<1.0e2** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:31:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

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**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage Male-Specific** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-020** | **Control Train Perm (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **3** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:33:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/5/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-021** | **Control Train Perm (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **1** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:33:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 30 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/5/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-022** | **Control Train Perm (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **<1.0e2** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 11:33:00 AM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: PBianchi Analysis End: 8/25/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-023** | **Test 1 Vessel Perm (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **5.8e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-024** | **Test 1 Vessel Perm (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **6.9e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage Male-Specific** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-025** | **Test 1 Vessel Perm (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **5.5e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-026** | **Test 1 Stage 1 Perm (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **6.5e3** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-027** | **Test 1 Stage 1 Perm (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **5.0e3** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 30 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-028** | **Test 1 Stage 1 Perm (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.3e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-029** | **Test 1 Stage 2 Perm (1of1)** | **None Given** | **Bacteriophage, Male Specific** | **<1.0e3** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

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**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

---

**ASSAY RESULTS:**

**Test: Bacteriophage Male-Specific** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-030** | **Test 1 Train Perm (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.1e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-031** | **Test 1 Train Perm (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.2e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-032** | **Test 1 Train Perm (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **1.1e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 12:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-033** | **Test 3 Vessel Perm (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **3.3e5** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:00:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-034** | **Test 3 Vessel Perm (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **3.5e5** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:00:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

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**ADDRESS** 232 N. Lake Avenue, Suite 300

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**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage Male-Specific** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-035** | **Test 3 Vessel Perm (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **3.4e5** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:00:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-036** | **Test 3 Stage 1 Perm (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **3.6e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:04:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-037** | **Test 3 Stage 1 Perm (2of3)** | **None Given** | **Bacteriophage, Male Specific** | **3.9e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:04:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-038** | **Test 3 Stage 1 Perm (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **4.1e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:04:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-039** | **Test 3 Stage 2 Perm (1of1)** | **None Given** | **Bacteriophage, Male Specific** | **<1.0e3** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

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Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage Male-Specific** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161483-040** | **Test 3 Train Perm (1of3)** | **None Given** | **Bacteriophage, Male Specific** | **2.5e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161483-041** | **Test 3 Train Perm (2of3)A** | **None Given** | **Bacteriophage, Male Specific** | **2.6e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161483-042** | **Test 3 Train Perm (3of3)** | **None Given** | **Bacteriophage, Male Specific** | **2.4e4** | **pfu/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/1/2016 CollectTime: 2:10:00 PM
ReceiveDate: 8/2/2016 8:49:00 AM Matrix: Water, not otherwise specified Temp 5.7
Volume: 100 mL Analysis Start Date: 8/2/16 Analysis Start Time: 1510
Analyst: KTucker Analysis End: 8/3/2016

Comment:

SAMPLE EVALUATION PERFORMANCE CRITERIA: The precise rates of recovery of organisms from environmental samples cannot be determined. B ioVir Laboratories has analyzed your sample(s) in accordance with the method described with each analyte above, however, due to inherent limitations of these methods organisms may avoid detection. For additional information regarding the limitations of the method(s) referred above please call us at 1-800-GIARDIA.
COMPANY IS NOT AN INSURER: BioVir Laboratories is not an insurer or guarantor of the quality and/or purity of water, wastewater, biosolid or otl material from which the sample was taken. BioVir offers no express or implied warranties whatsoever concerning the quality or purity of any water, wastewater, biosolid or other material which is ultimately consumed, distributed, applied or disposed.
MAINTENANCE OF RECORDS: BioVir Laboratories, Inc. shall maintain records pertaining to the historical reconstruction of client's data for a minimum of five years from the date of issuance of the final report. Records m ay be destroyed after that date unless a written client's request for records transfer is received by BioVir which requests otherwise. Records transfer or storage charges may apply after the 5 year period. THIS REP SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF BIOVIR LABORATORIES, INC.

10/19/2016
Date:

Signature

**Quality Checked** ElbaM

**MS2 ROUND 2 ON VIRGIN TORAY TMG20D-400 ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**


IEH-BioVir Laboratories

EPA ID# 01401, CA-ELAP #1795

685 Stone Road, Unit 6 • Benicia, CA 94510 • (707) 747-5906 • 1-800-GIARDIA • FAX (707) 747-1751 • WEB: www.biovir.com


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**CLIENT NO** TRU004 **CLIENT PO:** N/A

**ASSAY RESULTS:**

**Test:** **Bacteriophage** **Method:** **Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-001** | **Control RO Feed (1of3)** | **None Given** | **Bacteriophage** | **1.1e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:35:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161484-002** | **Control RO Feed (2of3)** | **None Given** | **Bacteriophage** | **9.2e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:35:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161484-003** | **Control RO Feed (3of3)** | **None Given** | **Bacteriophage** | **1.3e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:35:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161484-004** | **Control Stage 2 Feed (1of1)** | **None Given** | **Bacteriophage** | **3.0e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:35:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

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---

**ASSAY RESULTS:**

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-005** | **Test 1 RO Feed (1of 3)** | **None Given** | **Bacteriophage** | **1.2e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-006** | **Test 1 RO Feed (2of 3)** | **None Given** | **Bacteriophage** | **1.0e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-007** | **Test 1 RO Feed (3of 3)** | **None Given** | **Bacteriophage** | **1.0e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-008** | **Test 1 Stage 2 Feed (1of1)** | **None Given** | **Bacteriophage** | **2.1e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-009** | **Test 3 RO Feed (1of3)** | **None Given** | **Bacteriophage** | **1.6e6** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:25:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

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## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-010 | Test 3 RO Feed (2of3) | None Given | Bacteriophage | 1.4e6 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:25:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-011 | Test 3 RO Feed (3of3) | None Given | Bacteriophage | 1.6e6 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:25:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-012 | Test 3 Stage 2 Feed (1of1) | None Given | Bacteriophage | 3.6e6 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:25:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-013 | Control Vessel Perm (1of3) | None Given | Bacteriophage | 47 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-014 | Control Vessel Perm (1of3) | None Given | Bacteriophage | 9 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

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## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-015 | Control Vessel Perm (1of3) | None Given | Bacteriophage | 9 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-016 | Control Stage 1 Perm (1of3) | None Given | Bacteriophage | 26 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-017 | Control Stage 1 Perm (2of3) | None Given | Bacteriophage | 27 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-018 | Control Stage 1 Perm (3of3) | None Given | Bacteriophage | 20 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-019 | Control Stage 2 Perm (1of1) | None Given | Bacteriophage | 76 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

**REPORT NO.:** 161484
**PAGE NO.:** 5 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-020 | Control Train Perm (1of3) | None Given | Bacteriophage | 54 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| 161484-021 | Control Train Perm (2of3) | None Given | Bacteriophage | 42 | PFU/mL |
|---|---|---|---|---|---|

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| 161484-022 | Control Train Perm (3of3) | None Given | Bacteriophage | 50 | PFU/mL |
|---|---|---|---|---|---|

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 12:30:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| 161484-023 | Test 1 Vessel Perm (1of3) | None Given | Bacteriophage | 6.0e4 | PFU/mL |
|---|---|---|---|---|---|

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| 161484-024 | Test 1 Vessel Perm (2of3) | None Given | Bacteriophage | 1.6e5 | PFU/mL |
|---|---|---|---|---|---|

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

**REPORT NO.:** 161484
**PAGE NO.:** 6 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

---

**ASSAY RESULTS:**

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-025** | **Test 1 Vessel Perm (3of3)** | **None Given** | **Bacteriophage** | **1.0e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-026** | **Test 1 Stage 1 Perm (1of3)** | **None Given** | **Bacteriophage** | **1.0e4** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-027** | **Test 1 Stage 1 Perm (2of3)** | **None Given** | **Bacteriophage** | **1.0e4** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-028** | **Test 1 Stage 1 Perm (3of3)** | **None Given** | **Bacteriophage** | **1.0e4** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-029** | **Test 1 Stage 2 Perm (1of1)** | **None Given** | **Bacteriophage** | **79** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

**REPORT NO.:** 161484
**PAGE NO.:** 7 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

---

**ASSAY RESULTS:**

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-030** | **Test 1 Train Perm (1of3)** | **None Given** | **Bacteriophage** | **1.0e4** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-031** | **Test 1 Train Perm (2of3)** | **None Given** | **Bacteriophage** | **2.0e4** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-032** | **Test 1 Train Perm (3of3)** | **None Given** | **Bacteriophage** | **4.0e4** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 3:05:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-033** | **Test 3 Vessel Perm (1of3)** | **None Given** | **Bacteriophage** | **1.6e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-034** | **Test 3 Vessel Perm (2of3)** | **None Given** | **Bacteriophage** | **2.5e5** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

**REPORT NO.:** 161484
**PAGE NO.:** 8 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-035 | Test 3 Vessel Perm (3of3) | None Given | Bacteriophage | 2.2e5 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-036 | Test 3 Stage 1 Perm (1of3) | None Given | Bacteriophage | 3.0e4 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-037 | Test 3 Stage 1 Perm (2of3) | None Given | Bacteriophage | 2.0e4 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-038 | Test 3 Stage 1 Perm (3of3) | None Given | Bacteriophage | 3.0e4 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| 161484-039 | Test 3 Stage 2 Perm (1of1) | None Given | Bacteriophage | 90 | PFU/mL |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

**REPORT NO.:** 161484
**PAGE NO.:** 9 of 9
**CLIENT:** Trussell Technologies
**ADDRESS** 232 N. Lake Avenue, Suite 300

Pasadena, CA 91101
**CLIENT NO** TRU004 **CLIENT PO:** N/A

## ASSAY RESULTS:

**Test: Bacteriophage** **Method: Adams 1959**

| BioVir # | Sample ID | Site | Analyte | Result | Units |
|---|---|---|---|---|---|
| **161484-040** | **Test 3 Train Perm (1of3)** | **None Given** | **Bacteriophage** | **2.0e4** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161484-041** | **Test 3 Train Perm (2of3)** | **None Given** | **Bacteriophage** | **2.0e4** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

| | | | | | |
|---|---|---|---|---|---|
| **161484-042** | **Test 3 Train Perm (3of3)** | **None Given** | **Bacteriophage** | **3.0e4** | **PFU/mL** |

Collector: Rodrigo Tackeert CollectDate: 8/8/2016 CollectTime: 2:20:00 PM
ReceiveDate: 8/9/2016 9:55:00 AM Matrix: Water, Reagent Grade Temp 6.5
Volume: 100 mL Analysis Start Date: 8/9/2016 Analysis Start Time: 1340
Analyst: KTucker Analysis End: 8/12/2016

Comment:

SAMPLE EVALUATION PERFORMANCE CRITERIA: The precise rates of recovery of organisms from environmental samples cannot be determined. B ioVir Laboratories has analyzed your sample(s) in accordance with the method described with each analyte above, however, due to inherent limitations of these methods organisms may avoid detection. For additional information regarding the limitations of the method(s) referred above please call us at 1-800-GIARDIA.
COMPANY IS NOT AN INSURER: BioVir Laboratories is not an insurer or guarantor of the quality and/or purity of water, wastewater, biosolid or otl material from which the sample was taken. BioVir offers no express or implied warranties whatsoever concerning the quality or purity of any water, wastewater, biosolid or other material which is ultimately consumed, distributed, applied or disposed.
MAINTENANCE OF RECORDS: BioVir Laboratories, Inc. shall maintain records pertaining to the historical reconstruction of client's data for a minimum of five years from the date of issuance of the final report. Records m ay be destroyed after that date unless a written client's request for records transfer is received by BioVir which requests otherwise. Records transfer or storage charges may apply after the 5 year period. THIS REP SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF BIOVIR LABORATORIES, INC.

10/19/2016
Date:

Signature

**Quality Checked** ElbaM

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Fax: (626) 386-1101
1 800 566 LABS (1 800 566 5227)

ilac-MRA

ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

# PRELIMINARY TESTING ON AGED HYDRANAUTICS ESPA2 LD ELEMENTS

**TEST 1: 2 CUT O-RINGS**
**TEST 2: 2 REMOVED O-RINGS**
**TEST 3: 4 CUT O-RINGS**
**TEST 4: 4 REMOVED O-RINGS**
**TEST 5: 8 CUT O-RINGS**
**TEST 6: 8 REMOVED O-RINGS**
**TEST 7: 16 REMOVED O-RINGS**
**TEST 8: 16 REMOVED O-RINGS + ENDCAP O-RINGS**

## Laboratory Report

**TEST 9: REMOVAL OF ALL O-RINGS**
**TEST 10: 16 REMOVED O-RINGS + REMOVAL OF SMALL ENDCAP O-RINGS**
**TEST 11: CONTROL**

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**12/10/2015**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 562542
Project: SANDIEGO
Group: Challenge Test 111215
PO#: 67.004-5

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
* Following the cover page are State Certification List, ISO 17025 Accredited Method List, Acknowledgement of Samples Received, Comments, Hits Report, Data Report, QC Summary, QC Report and Regulatory Forms, as applicable.
* Test results relate only to the sample(s) tested.
* This report shall not be reproduced except in full, without the written approval of the laboratory.

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Fax: (626) 386-1101
1 800 566 LABS (1 800 566 5227)

**Laboratory Hits**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201511130509** | **Control Test 0 Vessel Permeate** | | | | |
| 11/14/2015 01:04 | Chloride | | 3.7 | 250 | mg/L | 1 |
| 11/18/2015 20:51 | Sodium Total ICAP | | 5.9 | | mg/L | 1 |
| 11/17/2015 02:21 | Specific Conductance, 25 C | | 33 | | umho/cm | 2 |
| | **201511130510** | **Control Test 0 Stage Permeate** | | | | |
| 11/14/2015 01:17 | Chloride | | 3.7 | 250 | mg/L | 1 |
| 11/18/2015 20:12 | Sodium Total ICAP | | 6.0 | | mg/L | 1 |
| 11/17/2015 07:21 | Specific Conductance, 25 C | | 34 | | umho/cm | 2 |
| | **201511130511** | **Control Test 0 RO Feed** | | | | |
| 11/18/2015 20:16 | Calcium Total ICAP | | 87 | | mg/L | 2 |
| 11/14/2015 01:30 | Chloride | | 310 | 250 | mg/L | 10 |
| 11/17/2015 17:17 | Fluoride | | 0.58 | 4 | mg/L | 0.05 |
| 11/18/2015 20:16 | Magnesium Total ICAP | | 40 | | mg/L | 0.2 |
| 11/13/2015 19:05 | Orthophosphate as P | | 0.97 | | mg/L | 0.01 |
| 11/14/2015 15:04 | Orthophosphate as Phosphate | | 3.0 | | mg/L | 0.031 |
| 11/18/2015 20:16 | Potassium Total ICAP | | 24 | | mg/L | 2 |
| 11/18/2015 20:16 | Sodium Total ICAP | | 220 | | mg/L | 2 |
| 11/17/2015 07:13 | Specific Conductance, 25 C | | 1800 | | umho/cm | 2 |
| 11/18/2015 20:16 | Strontium ICAP | | 1.0 | | mg/L | 0.02 |
| 11/14/2015 01:30 | Sulfate | | 260 | 250 | mg/L | 5 |
| | **201511130512** | **Control Test 0 Train Permeate** | | | | |
| 11/14/2015 01:43 | Chloride | | 8.6 | 250 | mg/L | 1 |
| 11/18/2015 20:21 | Potassium Total ICAP | | 1.0 | | mg/L | 1 |
| 11/18/2015 20:21 | Sodium Total ICAP | | 11 | | mg/L | 1 |
| 11/17/2015 01:28 | Specific Conductance, 25 C | | 63 | | umho/cm | 2 |
| 11/14/2015 01:43 | Sulfate | | 0.98 | 250 | mg/L | 0.5 |
| | **201511130513** | **Test 2 Train Permeate** | | | | |
| 11/14/2015 01:56 | Chloride | | 8.6 | 250 | mg/L | 1 |
| 11/18/2015 21:16 | Potassium Total ICAP | | 1.1 | | mg/L | 1 |
| 11/18/2015 21:16 | Sodium Total ICAP | | 11 | | mg/L | 1 |
| 12/01/2015 01:07 | Specific Conductance, 25 C | | 64 | | umho/cm | 2 |
| 11/14/2015 01:56 | Sulfate | | 1.0 | 250 | mg/L | 0.5 |
| | **201511130514** | **Test 2 Stage Permeate** | | | | |
| 11/14/2015 02:08 | Chloride | | 3.7 | 250 | mg/L | 1 |
| 11/18/2015 20:55 | Sodium Total ICAP | | 6.0 | | mg/L | 1 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 11/16/2015 23:59 | Specific Conductance, 25 C | | 33 | | umho/cm | 2 |
| | **201511130515** | **Test 2 Vessel Permeate** | | | | |
| 11/14/2015 04:17 | Chloride | | 3.8 | 250 | mg/L | 1 |
| 11/18/2015 20:59 | Sodium Total ICAP | | 6.0 | | mg/L | 1 |
| 11/17/2015 07:29 | Specific Conductance, 25 C | | 34 | | umho/cm | 2 |
| | **201511130516** | **Test 5 Train Permeate** | | | | |
| 11/14/2015 04:56 | Chloride | | 8.5 | 250 | mg/L | 1 |
| 11/18/2015 20:38 | Potassium Total ICAP | | 1.1 | | mg/L | 1 |
| 11/18/2015 20:38 | Sodium Total ICAP | | 11 | | mg/L | 1 |
| 11/17/2015 06:48 | Specific Conductance, 25 C | | 65 | | umho/cm | 2 |
| 11/14/2015 04:56 | Sulfate | | 1.0 | 250 | mg/L | 0.5 |
| | **201511130517** | **Test 5 Stage Permeate** | | | | |
| 11/14/2015 05:09 | Chloride | | 3.6 | 250 | mg/L | 1 |
| 11/18/2015 20:42 | Sodium Total ICAP | | 6.0 | | mg/L | 1 |
| 11/17/2015 06:32 | Specific Conductance, 25 C | | 34 | | umho/cm | 2 |
| | **201511130518** | **Test 5 Vessel Permeate** | | | | |
| 11/14/2015 05:22 | Chloride | | 3.7 | 250 | mg/L | 1 |
| 11/18/2015 21:03 | Sodium Total ICAP | | 6.1 | | mg/L | 1 |
| 11/17/2015 06:56 | Specific Conductance, 25 C | | 34 | | umho/cm | 2 |
| | **201511130519** | **Test 1 Vessel Permeate** | | | | |
| 11/14/2015 05:35 | Chloride | | 3.8 | 250 | mg/L | 1 |
| 11/18/2015 20:46 | Sodium Total ICAP | | 6.1 | | mg/L | 1 |
| 11/17/2015 07:04 | Specific Conductance, 25 C | | 34 | | umho/cm | 2 |
| | **201511130520** | **Test 1 Stage Permeate** | | | | |
| 11/14/2015 05:48 | Chloride | | 3.7 | 250 | mg/L | 1 |
| 11/18/2015 21:28 | Sodium Total ICAP | | 5.9 | | mg/L | 1 |
| 11/17/2015 06:40 | Specific Conductance, 25 C | | 33 | | umho/cm | 2 |
| | **201511130521** | **Test 1 Train Permeate** | | | | |
| 11/14/2015 06:01 | Chloride | | 8.5 | 250 | mg/L | 1 |
| 11/13/2015 19:48 | Orthophosphate as P | | 0.010 | | mg/L | 0.01 |
| 11/14/2015 15:04 | Orthophosphate as Phosphate | | 0.031 | | mg/L | 0.031 |
| 11/18/2015 21:32 | Potassium Total ICAP | | 1.0 | | mg/L | 1 |
| 11/18/2015 21:32 | Sodium Total ICAP | | 11 | | mg/L | 1 |
| 11/17/2015 01:52 | Specific Conductance, 25 C | | 64 | | umho/cm | 2 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 11/14/2015 06:01 | Sulfate | | 1.0 | 250 | mg/L | 0.5 |
| | **201511130522** | **Test 6 Vessel Permeate** | | | | |
| 11/14/2015 06:14 | Chloride | | 3.6 | 250 | mg/L | 1 |
| 11/18/2015 21:37 | Sodium Total ICAP | | 6.0 | | mg/L | 1 |
| 11/17/2015 01:35 | Specific Conductance, 25 C | | 32 | | umho/cm | 2 |
| | **201511130523** | **Test 6 Stage Permeate** | | | | |
| 11/14/2015 06:26 | Chloride | | 3.6 | 250 | mg/L | 1 |
| 11/18/2015 21:41 | Sodium Total ICAP | | 5.9 | | mg/L | 1 |
| 11/17/2015 01:44 | Specific Conductance, 25 C | | 32 | | umho/cm | 2 |
| | **201511130524** | **Test 6 Train Permeate** | | | | |
| 11/14/2015 06:39 | Chloride | | 8.3 | 250 | mg/L | 1 |
| 11/18/2015 21:45 | Potassium Total ICAP | | 1.1 | | mg/L | 1 |
| 11/18/2015 21:45 | Sodium Total ICAP | | 11 | | mg/L | 1 |
| 11/17/2015 06:24 | Specific Conductance, 25 C | | 64 | | umho/cm | 2 |
| 11/14/2015 06:39 | Sulfate | | 1.0 | 250 | mg/L | 0.5 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Data**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Control Test 0 Vessel Permeate (201511130509)** | | | | | | **Sampled on 11/12/2015 0935** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 20:51 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:51 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:51 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:51 874172 | (EPA 200.7) | Sodium Total ICAP | 5.9 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:51 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 01:04 873360 | (EPA 300.0) | Chloride | 3.7 | mg/L | 1 | 1 |
| | 11/14/2015 | 01:04 873360 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 17:34 873856 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 02:21 873687 | (SM2510B) | Specific Conductance, 25 C | 33 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:55 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |
| **Control Test 0 Stage Permeate (201511130510)** | | | | | | **Sampled on 11/12/2015 0937** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 20:12 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:12 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:12 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:12 874172 | (EPA 200.7) | Sodium Total ICAP | 6.0 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:12 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 01:17 873360 | (EPA 300.0) | Chloride | 3.7 | mg/L | 1 | 1 |
| | 11/14/2015 | 01:17 873360 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 17:20 873856 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 07:21 873691 | (SM2510B) | Specific Conductance, 25 C | 34 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:44 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Control Test 0 RO Feed (201511130511)** | | | | | | **Sampled on 11/12/2015 0936** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 20:16 874172 | (EPA 200.7) | Calcium Total ICAP | 87 | mg/L | 2 | 2 |
| 11/16/2015 | 11/18/2015 | 20:16 874172 | (EPA 200.7) | Magnesium Total ICAP | 40 | mg/L | 0.2 | 2 |
| 11/16/2015 | 11/18/2015 | 20:16 874172 | (EPA 200.7) | Potassium Total ICAP | 24 | mg/L | 2 | 2 |
| 11/16/2015 | 11/18/2015 | 20:16 874172 | (EPA 200.7) | Sodium Total ICAP | 220 | mg/L | 2 | 2 |
| 11/16/2015 | 11/18/2015 | 20:16 874172 | (EPA 200.7) | Strontium ICAP | 1.0 | mg/L | 0.02 | 2 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 01:30 873360 | (EPA 300.0) | Chloride | 310 | mg/L | 10 | 10 |
| | 11/14/2015 | 01:30 873360 | (EPA 300.0) | Sulfate | 260 | mg/L | 5 | 10 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 17:17 873856 | (SM 4500F-C) | Fluoride | 0.58 | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | 3.0 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 07:13 873691 | (SM2510B) | Specific Conductance, 25 C | 1800 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:05 873237 | (4500P-E/365.1) | Orthophosphate as P | 0.97 | mg/L | 0.01 | 1 |
| **Control Test 0 Train Permeate (201511130512)** | | | | | | **Sampled on 11/12/2015 0939** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 20:21 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:21 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:21 874172 | (EPA 200.7) | Potassium Total ICAP | 1.0 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:21 874172 | (EPA 200.7) | Sodium Total ICAP | 11 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:21 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 01:43 873360 | (EPA 300.0) | Chloride | 8.6 | mg/L | 1 | 1 |
| | 11/14/2015 | 01:43 873360 | (EPA 300.0) | Sulfate | 0.98 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 22:12 873868 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 01:28 873687 | (SM2510B) | Specific Conductance, 25 C | 63 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:41 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

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**Laboratory Data**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
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Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 2 Train Permeate (201511130513)** | | | | | | **Sampled on 11/12/2015 1046** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 21:16 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:16 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:16 874172 | (EPA 200.7) | Potassium Total ICAP | 1.1 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:16 874172 | (EPA 200.7) | Sodium Total ICAP | 11 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:16 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 01:56 873360 | (EPA 300.0) | Chloride | 8.6 | mg/L | 1 | 1 |
| | 11/14/2015 | 01:56 873360 | (EPA 300.0) | Sulfate | 1.0 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 17:30 873856 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 12/01/2015 | 01:07 876191 | (SM2510B) | Specific Conductance, 25 C | 64 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:47 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |
| **Test 2 Stage Permeate (201511130514)** | | | | | | **Sampled on 11/12/2015 1048** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 20:55 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:55 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:55 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:55 874172 | (EPA 200.7) | Sodium Total ICAP | 6.0 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:55 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 02:08 873360 | (EPA 300.0) | Chloride | 3.7 | mg/L | 1 | 1 |
| | 11/14/2015 | 02:08 873360 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 22:07 873868 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/16/2015 | 23:59 873670 | (SM2510B) | Specific Conductance, 25 C | 33 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:46 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
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Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 2 Vessel Permeate (201511130515)** | | | | | | **Sampled on 11/12/2015 1048** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 20:59 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:59 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:59 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:59 874172 | (EPA 200.7) | Sodium Total ICAP | 6.0 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:59 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 04:17 873388 | (EPA 300.0) | Chloride | 3.8 | mg/L | 1 | 1 |
| | 11/14/2015 | 04:17 873388 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 22:02 873868 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 07:29 873691 | (SM2510B) | Specific Conductance, 25 C | 34 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:45 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |
| **Test 5 Train Permeate (201511130516)** | | | | | | **Sampled on 11/12/2015 1326** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 20:38 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:38 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:38 874172 | (EPA 200.7) | Potassium Total ICAP | 1.1 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:38 874172 | (EPA 200.7) | Sodium Total ICAP | 11 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:38 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 04:56 873388 | (EPA 300.0) | Chloride | 8.5 | mg/L | 1 | 1 |
| | 11/14/2015 | 04:56 873388 | (EPA 300.0) | Sulfate | 1.0 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 22:17 873868 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 06:48 873691 | (SM2510B) | Specific Conductance, 25 C | 65 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:03 873237 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

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(c) - indicates calculated results

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**Laboratory Data**
**Report: 562542**

**Trussell Technologies, Inc.**
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Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 5 Stage Permeate (201511130517)** | | | | | | **Sampled on 11/12/2015 1328** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 20:42 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:42 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:42 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:42 874172 | (EPA 200.7) | Sodium Total ICAP | 6.0 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:42 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 05:09 873388 | (EPA 300.0) | Chloride | 3.6 | mg/L | 1 | 1 |
| | 11/14/2015 | 05:09 873388 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 23:19 873868 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 06:32 873691 | (SM2510B) | Specific Conductance, 25 C | 34 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:52 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |
| **Test 5 Vessel Permeate (201511130518)** | | | | | | **Sampled on 11/12/2015 1329** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 21:03 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:03 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:03 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:03 874172 | (EPA 200.7) | Sodium Total ICAP | 6.1 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:03 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 05:22 873388 | (EPA 300.0) | Chloride | 3.7 | mg/L | 1 | 1 |
| | 11/14/2015 | 05:22 873388 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 23:09 873868 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 06:56 873691 | (SM2510B) | Specific Conductance, 25 C | 34 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:07 873237 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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Tel: (626) 386-1100
Fax: (626) 386-1101
1 800 566 LABS (1 800 566 5227)

**Laboratory Data**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 1 Vessel Permeate (201511130519)** | | | | | | **Sampled on 11/12/2015 1414** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 20:46 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:46 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:46 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:46 874172 | (EPA 200.7) | Sodium Total ICAP | 6.1 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 20:46 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 05:35 873388 | (EPA 300.0) | Chloride | 3.8 | mg/L | 1 | 1 |
| | 11/14/2015 | 05:35 873388 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 23:24 873868 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 07:04 873691 | (SM2510B) | Specific Conductance, 25 C | 34 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:49 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |
| **Test 1 Stage Permeate (201511130520)** | | | | | | **Sampled on 11/12/2015 1410** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 21:28 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:28 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:28 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:28 874172 | (EPA 200.7) | Sodium Total ICAP | 5.9 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:28 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 05:48 873388 | (EPA 300.0) | Chloride | 3.7 | mg/L | 1 | 1 |
| | 11/14/2015 | 05:48 873388 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 17:55 874765 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 06:40 873691 | (SM2510B) | Specific Conductance, 25 C | 33 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:06 873237 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 1 Train Permeate (201511130521)** | | | | | | **Sampled on 11/12/2015 1412** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 21:32 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:32 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:32 874172 | (EPA 200.7) | Potassium Total ICAP | 1.0 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:32 874172 | (EPA 200.7) | Sodium Total ICAP | 11 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:32 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 06:01 873388 | (EPA 300.0) | Chloride | 8.5 | mg/L | 1 | 1 |
| | 11/14/2015 | 06:01 873388 | (EPA 300.0) | Sulfate | 1.0 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 17:49 873856 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | 0.031 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 01:52 873687 | (SM2510B) | Specific Conductance, 25 C | 64 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:48 873376 | (4500P-E/365.1) | Orthophosphate as P | 0.010 | mg/L | 0.01 | 1 |
| **Test 6 Vessel Permeate (201511130522)** | | | | | | **Sampled on 11/12/2015 0800** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 21:37 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:37 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:37 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:37 874172 | (EPA 200.7) | Sodium Total ICAP | 6.0 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:37 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 06:14 873388 | (EPA 300.0) | Chloride | 3.6 | mg/L | 1 | 1 |
| | 11/14/2015 | 06:14 873388 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 17:49 874765 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 01:35 873687 | (SM2510B) | Specific Conductance, 25 C | 32 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:50 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562542**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/13/2015 17:49

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 6 Stage Permeate (201511130523)** | | | | | | **Sampled on 11/12/2015 0800** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 21:41 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:41 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:41 874172 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:41 874172 | (EPA 200.7) | Sodium Total ICAP | 5.9 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:41 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 06:26 873388 | (EPA 300.0) | Chloride | 3.6 | mg/L | 1 | 1 |
| | 11/14/2015 | 06:26 873388 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 18:00 874765 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 01:44 873687 | (SM2510B) | Specific Conductance, 25 C | 32 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:04 873237 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |
| **Test 6 Train Permeate (201511130524)** | | | | | | **Sampled on 11/12/2015 0800** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/16/2015 | 11/18/2015 | 21:45 874172 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:45 874172 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:45 874172 | (EPA 200.7) | Potassium Total ICAP | 1.1 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:45 874172 | (EPA 200.7) | Sodium Total ICAP | 11 | mg/L | 1 | 1 |
| 11/16/2015 | 11/18/2015 | 21:45 874172 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/14/2015 | 06:39 873388 | (EPA 300.0) | Chloride | 8.3 | mg/L | 1 | 1 |
| | 11/14/2015 | 06:39 873388 | (EPA 300.0) | Sulfate | 1.0 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/17/2015 | 23:14 873868 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/14/2015 | 15:04 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/17/2015 | 06:24 873691 | (SM2510B) | Specific Conductance, 25 C | 64 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/13/2015 | 19:51 873376 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

**PRELIMINARY TESTING ON AGED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: 2 CUT O-RINGS**
**TEST 2: 2 REMOVED O-RINGS**
**TEST 3: 4 CUT O-RINGS**
**TEST 4: 4 REMOVED O-RINGS**
**TEST 5: 8 CUT O-RINGS**
**TEST 6: 8 REMOVED O-RINGS**
**TEST 7: 16 REMOVED O-RINGS**
**TEST 8: 16 REMOVED O-RINGS + ENDCAP O-RINGS**

# Laboratory Report

**TEST 9: REMOVAL OF ALL O-RINGS**
**TEST 10: 16 REMOVED O-RINGS + REMOVAL OF SMALL ENDCAP O-RINGS**
**TEST 11: CONTROL**

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**12/10/2015**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 562916
Project: SANDIEGO
Group: Challenge Test 111215
PO#: 67.004-5

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
* Following the cover page are State Certification List, ISO 17025 Accredited Method List, Acknowledgement of Samples Received, Comments, Hits Report, Data Report, QC Summary, QC Report and Regulatory Forms, as applicable.
* Test results relate only to the sample(s) tested.
* This report shall not be reproduced except in full, without the written approval of the laboratory.

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**Laboratory Hits**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201511170442** | **Test 7 Vessel Permeate** | | | | |
| 11/18/2015 03:48 | Chloride | | 3.9 | 250 | mg/L | 1 |
| 11/20/2015 21:20 | Sodium Total ICAP | | 6.0 | | mg/L | 1 |
| 11/23/2015 23:09 | Specific Conductance, 25 C | | 33 | | umho/cm | 2 |
| | **201511170443** | **Test 7 Stage Permeate** | | | | |
| 11/18/2015 04:27 | Chloride | | 3.8 | 250 | mg/L | 1 |
| 11/20/2015 21:32 | Sodium Total ICAP | | 5.8 | | mg/L | 1 |
| 12/01/2015 01:40 | Specific Conductance, 25 C | | 32 | | umho/cm | 2 |
| | **201511170444** | **Test 7 RO Feed** | | | | |
| 11/19/2015 22:23 | Calcium Total ICAP | | 89 | | mg/L | 1 |
| 11/18/2015 04:40 | Chloride | | 320 | 250 | mg/L | 10 |
| 11/20/2015 20:49 | Fluoride | | 0.61 | 4 | mg/L | 0.05 |
| 11/19/2015 22:23 | Magnesium Total ICAP | | 42 | | mg/L | 0.1 |
| 11/24/2015 20:10 | Orthophosphate as P | | 1.4 | | mg/L | 0.05 |
| 11/18/2015 13:17 | Orthophosphate as Phosphate | | 4.3 | | mg/L | 0.031 |
| 11/19/2015 22:23 | Potassium Total ICAP | | 23 | | mg/L | 1 |
| 11/19/2015 22:23 | Sodium Total ICAP | | 220 | | mg/L | 1 |
| 11/24/2015 00:03 | Specific Conductance, 25 C | | 1800 | | umho/cm | 2 |
| 11/19/2015 22:23 | Strontium ICAP | | 1.1 | | mg/L | 0.01 |
| 11/18/2015 04:40 | Sulfate | | 280 | 250 | mg/L | 5 |
| | **201511170445** | **Test 7 Train Permeate** | | | | |
| 11/18/2015 04:53 | Chloride | | 8.5 | 250 | mg/L | 1 |
| 11/19/2015 22:28 | Magnesium Total ICAP | | 0.10 | | mg/L | 0.1 |
| 11/19/2015 22:28 | Potassium Total ICAP | | 1.0 | | mg/L | 1 |
| 11/19/2015 22:28 | Sodium Total ICAP | | 11 | | mg/L | 1 |
| 12/01/2015 05:15 | Specific Conductance, 25 C | | 61 | | umho/cm | 2 |
| 11/18/2015 04:53 | Sulfate | | 1.2 | 250 | mg/L | 0.5 |
| | **201511170446** | **Test 10 Vessel Permeate** | | | | |
| 11/19/2015 22:32 | Calcium Total ICAP | | 10 | | mg/L | 1 |
| 11/18/2015 05:05 | Chloride | | 40 | 250 | mg/L | 2 |
| 11/20/2015 19:51 | Fluoride | | 0.073 | 4 | mg/L | 0.05 |
| 11/19/2015 22:32 | Magnesium Total ICAP | | 4.7 | | mg/L | 0.1 |
| 11/17/2015 20:05 | Orthophosphate as P | | 0.18 | | mg/L | 0.01 |
| 11/18/2015 13:17 | Orthophosphate as Phosphate | | 0.55 | | mg/L | 0.031 |
| 11/19/2015 22:32 | Potassium Total ICAP | | 3.2 | | mg/L | 1 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 11/19/2015 22:32 | Sodium Total ICAP | | 30 | | mg/L | 1 |
| 12/01/2015 01:15 | Specific Conductance, 25 C | | 270 | | umho/cm | 2 |
| 11/19/2015 22:32 | Strontium ICAP | | 0.12 | | mg/L | 0.01 |
| 11/18/2015 05:05 | Sulfate | | 32 | 250 | mg/L | 1 |
| | **201511170447** | **Test 10 Train Permeate** | | | | |
| 11/18/2015 05:18 | Chloride | | 11 | 250 | mg/L | 1 |
| 11/19/2015 22:36 | Magnesium Total ICAP | | 0.46 | | mg/L | 0.1 |
| 11/17/2015 19:59 | Orthophosphate as P | | 0.019 | | mg/L | 0.01 |
| 11/18/2015 13:17 | Orthophosphate as Phosphate | | 0.058 | | mg/L | 0.031 |
| 11/19/2015 22:36 | Potassium Total ICAP | | 1.2 | | mg/L | 1 |
| 11/19/2015 22:36 | Sodium Total ICAP | | 12 | | mg/L | 1 |
| 12/01/2015 05:07 | Specific Conductance, 25 C | | 75 | | umho/cm | 2 |
| 11/19/2015 22:36 | Strontium ICAP | | 0.012 | | mg/L | 0.01 |
| 11/18/2015 05:18 | Sulfate | | 3.5 | 250 | mg/L | 0.5 |
| | **201511170448** | **Test 10 RO Permeate** | | | | |
| 11/18/2015 05:31 | Chloride | | 7.0 | 250 | mg/L | 1 |
| 11/19/2015 22:40 | Magnesium Total ICAP | | 0.46 | | mg/L | 0.1 |
| 11/17/2015 20:06 | Orthophosphate as P | | 0.022 | | mg/L | 0.01 |
| 11/18/2015 13:17 | Orthophosphate as Phosphate | | 0.067 | | mg/L | 0.031 |
| 11/19/2015 22:40 | Sodium Total ICAP | | 7.9 | | mg/L | 1 |
| 12/01/2015 01:23 | Specific Conductance, 25 C | | 53 | | umho/cm | 2 |
| 11/19/2015 22:40 | Strontium ICAP | | 0.012 | | mg/L | 0.01 |
| 11/18/2015 05:31 | Sulfate | | 3.4 | 250 | mg/L | 0.5 |
| | **201511170449** | **Test 9 Vessel Permeate** | | | | |
| 11/19/2015 22:55 | Calcium Total ICAP | | 11 | | mg/L | 1 |
| 11/18/2015 05:44 | Chloride | | 41 | 250 | mg/L | 2 |
| 11/20/2015 21:03 | Fluoride | | 0.073 | 4 | mg/L | 0.05 |
| 11/19/2015 22:55 | Magnesium Total ICAP | | 5.3 | | mg/L | 0.1 |
| 11/17/2015 20:01 | Orthophosphate as P | | 0.17 | | mg/L | 0.01 |
| 11/18/2015 13:17 | Orthophosphate as Phosphate | | 0.52 | | mg/L | 0.031 |
| 11/19/2015 22:55 | Potassium Total ICAP | | 3.5 | | mg/L | 1 |
| 11/19/2015 22:55 | Sodium Total ICAP | | 34 | | mg/L | 1 |
| 11/23/2015 23:37 | Specific Conductance, 25 C | | 270 | | umho/cm | 2 |
| 11/19/2015 22:55 | Strontium ICAP | | 0.14 | | mg/L | 0.01 |
| 11/18/2015 05:44 | Sulfate | | 34 | 250 | mg/L | 1 |
| | **201511170450** | **Test 9 Stage Permeate** | | | | |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 11/19/2015 22:59 | Calcium Total ICAP | | 1.1 | | mg/L | 1 |
| 11/18/2015 05:57 | Chloride | | 6.9 | 250 | mg/L | 1 |
| 11/19/2015 22:59 | Magnesium Total ICAP | | 0.51 | | mg/L | 0.1 |
| 11/17/2015 19:22 | Orthophosphate as P | | 0.023 | | mg/L | 0.01 |
| 11/18/2015 13:17 | Orthophosphate as Phosphate | | 0.070 | | mg/L | 0.031 |
| 11/19/2015 22:59 | Sodium Total ICAP | | 8.1 | | mg/L | 1 |
| 11/23/2015 23:54 | Specific Conductance, 25 C | | 53 | | umho/cm | 2 |
| 11/19/2015 22:59 | Strontium ICAP | | 0.014 | | mg/L | 0.01 |
| 11/18/2015 05:57 | Sulfate | | 3.4 | 250 | mg/L | 0.5 |
| | **201511170451** | **Test 9 Train Permeate** | | | | |
| 11/19/2015 23:03 | Calcium Total ICAP | | 1.0 | | mg/L | 1 |
| 11/18/2015 06:10 | Chloride | | 11 | 250 | mg/L | 1 |
| 11/19/2015 23:03 | Magnesium Total ICAP | | 0.48 | | mg/L | 0.1 |
| 11/17/2015 19:21 | Orthophosphate as P | | 0.021 | | mg/L | 0.01 |
| 11/18/2015 13:17 | Orthophosphate as Phosphate | | 0.064 | | mg/L | 0.031 |
| 11/19/2015 23:03 | Potassium Total ICAP | | 1.2 | | mg/L | 1 |
| 11/19/2015 23:03 | Sodium Total ICAP | | 12 | | mg/L | 1 |
| 11/23/2015 23:45 | Specific Conductance, 25 C | | 76 | | umho/cm | 2 |
| 11/19/2015 23:03 | Strontium ICAP | | 0.013 | | mg/L | 0.01 |
| 11/18/2015 06:10 | Sulfate | | 3.6 | 250 | mg/L | 0.5 |
| | **201511170452** | **Test 11 RO Feed** | | | | |
| 11/19/2015 23:21 | Calcium Total ICAP | | 92 | | mg/L | 1 |
| 11/18/2015 06:49 | Chloride | | 310 | 250 | mg/L | 10 |
| 11/20/2015 19:54 | Fluoride | | 0.55 | 4 | mg/L | 0.05 |
| 11/19/2015 23:21 | Magnesium Total ICAP | | 43 | | mg/L | 0.1 |
| 11/24/2015 20:11 | Orthophosphate as P | | 1.4 | | mg/L | 0.05 |
| 11/18/2015 13:17 | Orthophosphate as Phosphate | | 4.3 | | mg/L | 0.031 |
| 11/19/2015 23:21 | Potassium Total ICAP | | 24 | | mg/L | 1 |
| 11/19/2015 23:21 | Sodium Total ICAP | | 230 | | mg/L | 1 |
| 11/23/2015 23:28 | Specific Conductance, 25 C | | 1800 | | umho/cm | 2 |
| 11/19/2015 23:21 | Strontium ICAP | | 1.2 | | mg/L | 0.01 |
| 11/18/2015 06:49 | Sulfate | | 280 | 250 | mg/L | 5 |
| | **201511170453** | **Test 11 Vessel Permeate** | | | | |
| 11/18/2015 07:02 | Chloride | | 3.6 | 250 | mg/L | 1 |
| 11/17/2015 19:20 | Orthophosphate as P | | 0.015 | | mg/L | 0.01 |
| 11/18/2015 13:17 | Orthophosphate as Phosphate | | 0.046 | | mg/L | 0.031 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 11/20/2015 21:36 | Sodium Total ICAP | | 5.6 | | mg/L | 1 |
| 11/23/2015 23:01 | Specific Conductance, 25 C | | 31 | | umho/cm | 2 |
| | **201511170454** | **Test 11 Stage Permeate** | | | | |
| 11/18/2015 07:14 | Chloride | | 3.6 | 250 | mg/L | 1 |
| 11/20/2015 21:40 | Sodium Total ICAP | | 5.5 | | mg/L | 1 |
| 11/24/2015 00:11 | Specific Conductance, 25 C | | 31 | | umho/cm | 2 |
| | **201511170455** | **Test 11 Train Permeate** | | | | |
| 11/18/2015 07:27 | Chloride | | 8.4 | 250 | mg/L | 1 |
| 11/19/2015 23:34 | Magnesium Total ICAP | | 0.10 | | mg/L | 0.1 |
| 11/19/2015 23:34 | Potassium Total ICAP | | 1.0 | | mg/L | 1 |
| 11/19/2015 23:34 | Sodium Total ICAP | | 11 | | mg/L | 1 |
| 12/01/2015 01:32 | Specific Conductance, 25 C | | 59 | | umho/cm | 2 |
| 11/18/2015 07:27 | Sulfate | | 1.3 | 250 | mg/L | 0.5 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Data**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 7 Vessel Permeate (201511170442)** | | | | | | **Sampled on 11/16/2015 1021** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 22:05 874478 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:05 874478 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:05 874478 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/20/2015 | 21:20 874827 | (EPA 200.7) | Sodium Total ICAP | 6.0 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:05 874478 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 03:48 873902 | (EPA 300.0) | Chloride | 3.9 | mg/L | 1 | 1 |
| | 11/18/2015 | 03:48 873902 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 18:34 874765 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/23/2015 | 23:09 875146 | (SM2510B) | Specific Conductance, 25 C | 33 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 19:23 873813 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |
| **Test 7 Stage Permeate (201511170443)** | | | | | | **Sampled on 11/16/2015 1016** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 22:18 874478 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:18 874478 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:18 874478 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/20/2015 | 21:32 874827 | (EPA 200.7) | Sodium Total ICAP | 5.8 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:18 874478 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 04:27 873902 | (EPA 300.0) | Chloride | 3.8 | mg/L | 1 | 1 |
| | 11/18/2015 | 04:27 873902 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 19:58 874769 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 12/01/2015 | 01:40 876191 | (SM2510B) | Specific Conductance, 25 C | 32 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 19:19 873813 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 7 RO Feed (201511170444)** | | | | | | **Sampled on 11/16/2015 1019** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 22:23 874478 | (EPA 200.7) | Calcium Total ICAP | 89 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:23 874478 | (EPA 200.7) | Magnesium Total ICAP | 42 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:23 874478 | (EPA 200.7) | Potassium Total ICAP | 23 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:23 874478 | (EPA 200.7) | Sodium Total ICAP | 220 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:23 874478 | (EPA 200.7) | Strontium ICAP | 1.1 | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 04:40 873902 | (EPA 300.0) | Chloride | 320 | mg/L | 10 | 10 |
| | 11/18/2015 | 04:40 873902 | (EPA 300.0) | Sulfate | 280 | mg/L | 5 | 10 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 20:49 874769 | (SM 4500F-C) | Fluoride | 0.61 | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | 4.3 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/24/2015 | 00:03 875146 | (SM2510B) | Specific Conductance, 25 C | 1800 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/24/2015 | 20:10 875332 | (4500P-E/365.1) | Orthophosphate as P | 1.4 (HA) | mg/L | 0.05 | 5 |
| **Test 7 Train Permeate (201511170445)** | | | | | | **Sampled on 11/16/2015 1022** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 22:28 874478 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:28 874478 | (EPA 200.7) | Magnesium Total ICAP | 0.10 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:28 874478 | (EPA 200.7) | Potassium Total ICAP | 1.0 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:28 874478 | (EPA 200.7) | Sodium Total ICAP | 11 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:28 874478 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 04:53 873902 | (EPA 300.0) | Chloride | 8.5 | mg/L | 1 | 1 |
| | 11/18/2015 | 04:53 873902 | (EPA 300.0) | Sulfate | 1.2 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 20:17 874769 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 12/01/2015 | 05:15 876195 | (SM2510B) | Specific Conductance, 25 C | 61 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 20:00 873894 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
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Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 10 Vessel Permeate (201511170446)** | | | | | | **Sampled on 11/16/2015 1100** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 22:32 874478 | (EPA 200.7) | Calcium Total ICAP | 10 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:32 874478 | (EPA 200.7) | Magnesium Total ICAP | 4.7 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:32 874478 | (EPA 200.7) | Potassium Total ICAP | 3.2 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:32 874478 | (EPA 200.7) | Sodium Total ICAP | 30 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:32 874478 | (EPA 200.7) | Strontium ICAP | 0.12 | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 05:05 873902 | (EPA 300.0) | Chloride | 40 | mg/L | 2 | 2 |
| | 11/18/2015 | 05:05 873902 | (EPA 300.0) | Sulfate | 32 | mg/L | 1 | 2 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 19:51 874769 | (SM 4500F-C) | Fluoride | 0.073 | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | 0.55 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 12/01/2015 | 01:15 876191 | (SM2510B) | Specific Conductance, 25 C | 270 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 20:05 873894 | (4500P-E/365.1) | Orthophosphate as P | 0.18 | mg/L | 0.01 | 1 |
| **Test 10 Train Permeate (201511170447)** | | | | | | **Sampled on 11/16/2015 1058** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 22:36 874478 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:36 874478 | (EPA 200.7) | Magnesium Total ICAP | 0.46 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:36 874478 | (EPA 200.7) | Potassium Total ICAP | 1.2 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:36 874478 | (EPA 200.7) | Sodium Total ICAP | 12 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:36 874478 | (EPA 200.7) | Strontium ICAP | 0.012 | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 05:18 873902 | (EPA 300.0) | Chloride | 11 | mg/L | 1 | 1 |
| | 11/18/2015 | 05:18 873902 | (EPA 300.0) | Sulfate | 3.5 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 18:43 874765 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | 0.058 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 12/01/2015 | 05:07 876195 | (SM2510B) | Specific Conductance, 25 C | 75 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 19:59 873894 | (4500P-E/365.1) | Orthophosphate as P | 0.019 | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 10 RO Permeate (201511170448)** | | | | | | **Sampled on 11/16/2015 1056** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 22:40 874478 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:40 874478 | (EPA 200.7) | Magnesium Total ICAP | 0.46 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:40 874478 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:40 874478 | (EPA 200.7) | Sodium Total ICAP | 7.9 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:40 874478 | (EPA 200.7) | Strontium ICAP | 0.012 | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 05:31 873902 | (EPA 300.0) | Chloride | 7.0 | mg/L | 1 | 1 |
| | 11/18/2015 | 05:31 873902 | (EPA 300.0) | Sulfate | 3.4 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 19:37 874769 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | 0.067 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 12/01/2015 | 01:23 876191 | (SM2510B) | Specific Conductance, 25 C | 53 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 20:06 873894 | (4500P-E/365.1) | Orthophosphate as P | 0.022 | mg/L | 0.01 | 1 |
| **Test 9 Vessel Permeate (201511170449)** | | | | | | **Sampled on 11/16/2015 1218** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 22:55 874478 | (EPA 200.7) | Calcium Total ICAP | 11 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:55 874478 | (EPA 200.7) | Magnesium Total ICAP | 5.3 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:55 874478 | (EPA 200.7) | Potassium Total ICAP | 3.5 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:55 874478 | (EPA 200.7) | Sodium Total ICAP | 34 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:55 874478 | (EPA 200.7) | Strontium ICAP | 0.14 | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 05:44 873902 | (EPA 300.0) | Chloride | 41 | mg/L | 2 | 2 |
| | 11/18/2015 | 05:44 873902 | (EPA 300.0) | Sulfate | 34 | mg/L | 1 | 2 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 21:03 874769 | (SM 4500F-C) | Fluoride | 0.073 | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | 0.52 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/23/2015 | 23:37 875146 | (SM2510B) | Specific Conductance, 25 C | 270 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 20:01 873894 | (4500P-E/365.1) | Orthophosphate as P | 0.17 | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562916**

**Trussell Technologies, Inc.**
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Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 9 Stage Permeate (201511170450)** | | | | | | **Sampled on 11/16/2015 1220** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 22:59 874478 | (EPA 200.7) | Calcium Total ICAP | 1.1 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:59 874478 | (EPA 200.7) | Magnesium Total ICAP | 0.51 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:59 874478 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:59 874478 | (EPA 200.7) | Sodium Total ICAP | 8.1 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 22:59 874478 | (EPA 200.7) | Strontium ICAP | 0.014 | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 05:57 873902 | (EPA 300.0) | Chloride | 6.9 | mg/L | 1 | 1 |
| | 11/18/2015 | 05:57 873902 | (EPA 300.0) | Sulfate | 3.4 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 20:38 874769 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | 0.070 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/23/2015 | 23:54 875146 | (SM2510B) | Specific Conductance, 25 C | 53 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 19:22 873813 | (4500P-E/365.1) | Orthophosphate as P | 0.023 | mg/L | 0.01 | 1 |
| **Test 9 Train Permeate (201511170451)** | | | | | | **Sampled on 11/16/2015 1222** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 23:03 874478 | (EPA 200.7) | Calcium Total ICAP | 1.0 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:03 874478 | (EPA 200.7) | Magnesium Total ICAP | 0.48 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:03 874478 | (EPA 200.7) | Potassium Total ICAP | 1.2 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:03 874478 | (EPA 200.7) | Sodium Total ICAP | 12 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:03 874478 | (EPA 200.7) | Strontium ICAP | 0.013 | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 06:10 873902 | (EPA 300.0) | Chloride | 11 | mg/L | 1 | 1 |
| | 11/18/2015 | 06:10 873902 | (EPA 300.0) | Sulfate | 3.6 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 20:12 874769 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | 0.064 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/23/2015 | 23:45 875146 | (SM2510B) | Specific Conductance, 25 C | 76 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 19:21 873813 | (4500P-E/365.1) | Orthophosphate as P | 0.021 | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 11 RO Feed (201511170452)** | | | | | | **Sampled on 11/16/2015 1406** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 23:21 874478 | (EPA 200.7) | Calcium Total ICAP | 92 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:21 874478 | (EPA 200.7) | Magnesium Total ICAP | 43 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:21 874478 | (EPA 200.7) | Potassium Total ICAP | 24 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:21 874478 | (EPA 200.7) | Sodium Total ICAP | 230 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:21 874478 | (EPA 200.7) | Strontium ICAP | 1.2 | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 06:49 873902 | (EPA 300.0) | Chloride | 310 | mg/L | 10 | 10 |
| | 11/18/2015 | 06:49 873902 | (EPA 300.0) | Sulfate | 280 | mg/L | 5 | 10 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 19:54 874769 | (SM 4500F-C) | Fluoride | 0.55 | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | 4.3 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/23/2015 | 23:28 875146 | (SM2510B) | Specific Conductance, 25 C | 1800 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/24/2015 | 20:11 875332 | (4500P-E/365.1) | Orthophosphate as P | 1.4 (HA) | mg/L | 0.05 | 5 |
| **Test 11 Vessel Permeate (201511170453)** | | | | | | **Sampled on 11/16/2015 1404** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 23:26 874478 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:26 874478 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:26 874478 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/20/2015 | 21:36 874827 | (EPA 200.7) | Sodium Total ICAP | 5.6 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:26 874478 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 07:02 873902 | (EPA 300.0) | Chloride | 3.6 | mg/L | 1 | 1 |
| | 11/18/2015 | 07:02 873902 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 20:53 874769 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | 0.046 | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/23/2015 | 23:01 875146 | (SM2510B) | Specific Conductance, 25 C | 31 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 19:20 873813 | (4500P-E/365.1) | Orthophosphate as P | 0.015 | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 562916**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
11/17/2015 1611

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **Test 11 Stage Permeate (201511170454)** | | | | | | **Sampled on 11/16/2015 1400** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 23:30 874478 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:30 874478 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:30 874478 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/20/2015 | 21:40 874827 | (EPA 200.7) | Sodium Total ICAP | 5.5 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:30 874478 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 07:14 873902 | (EPA 300.0) | Chloride | 3.6 | mg/L | 1 | 1 |
| | 11/18/2015 | 07:14 873902 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 20:08 874769 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 11/24/2015 | 00:11 875146 | (SM2510B) | Specific Conductance, 25 C | 31 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 20:03 873894 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |
| **Test 11 Train Permeate (201511170455)** | | | | | | **Sampled on 11/16/2015 1402** | | |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 11/18/2015 | 11/19/2015 | 23:34 874478 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:34 874478 | (EPA 200.7) | Magnesium Total ICAP | 0.10 | mg/L | 0.1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:34 874478 | (EPA 200.7) | Potassium Total ICAP | 1.0 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:34 874478 | (EPA 200.7) | Sodium Total ICAP | 11 | mg/L | 1 | 1 |
| 11/18/2015 | 11/19/2015 | 23:34 874478 | (EPA 200.7) | Strontium ICAP | ND | mg/L | 0.01 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 11/18/2015 | 07:27 873902 | (EPA 300.0) | Chloride | 8.4 | mg/L | 1 | 1 |
| | 11/18/2015 | 07:27 873902 | (EPA 300.0) | Sulfate | 1.3 | mg/L | 0.5 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 11/20/2015 | 20:03 874769 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as Phosphate (CAL)** | | | | | | |
| | 11/18/2015 | 13:17 | (4500P-E/365.1) | Orthophosphate as Phosphate | ND | mg/L | 0.031 | 1 |
| | | **SM2510B - Specific Conductance** | | | | | | |
| | 12/01/2015 | 01:32 876191 | (SM2510B) | Specific Conductance, 25 C | 59 | umho/cm | 2 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 11/17/2015 | 20:02 873894 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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AT-1807

**STRONTIUM ROUND 1 ON AGED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

# Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**03/09/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 578201
Project: SANDIEGO
Group: Ions and Metals
PO#: 24.010-2

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
* Following the cover page are State Certification List, ISO 17025 Accredited Method List, Acknowledgement of Samples Received, Comments, Hits Report, Data Report, QC Summary, QC Report and Regulatory Forms, as applicable.
* Test results relate only to the sample(s) tested.
* This report shall not be reproduced except in full, without the written approval of the laboratory.

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**Laboratory Hits**
**Report: 578201**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
03/01/2016 1653

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201603010743** | **Control RO Feed** | | | | |
| 03/04/2016 18:33 | Magnesium Total ICAP | | 42 | | mg/L | 0.1 |
| 03/01/2016 21:09 | Orthophosphate as P | | 1.2 | | mg/L | 0.05 |
| 03/02/2016 13:06 | Orthophosphate as PO4 | | 3.7 | | mg/L | 0.031 |
| 03/03/2016 14:26 | Strontium | | 1000 | | ug/L | 0.3 |
| 03/03/2016 14:38 | Sulfate | | 290 | 250 | mg/L | 2.5 |
| | **201603010744** | **Control Vessel Permeate** | | | | |
| 03/03/2016 14:34 | Strontium | | 0.31 | | ug/L | 0.3 |
| | **201603010746** | **Control Train Permeate** | | | | |
| 03/03/2016 14:39 | Strontium | | 2.2 | | ug/L | 0.3 |
| 03/03/2016 15:17 | Sulfate | | 0.98 | 250 | mg/L | 0.5 |
| | **201603010747** | **Test 1 RO Feed** | | | | |
| 03/04/2016 1:51 | Magnesium Total ICAP | | 42 | | mg/L | 0.1 |
| 03/01/2016 21:10 | Orthophosphate as P | | 1.1 | | mg/L | 0.05 |
| 03/02/2016 13:06 | Orthophosphate as PO4 | | 3.4 | | mg/L | 0.031 |
| 03/03/2016 14:42 | Strontium | | 990 | | ug/L | 0.3 |
| 03/03/2016 15:30 | Sulfate | | 290 | 250 | mg/L | 2.5 |
| | **201603010748** | **Test 1 Vessel Permeate** | | | | |
| 03/04/2016 1:56 | Magnesium Total ICAP | | 5.0 | | mg/L | 0.1 |
| 03/01/2016 21:01 | Orthophosphate as P | | 0.13 | | mg/L | 0.01 |
| 03/02/2016 13:26 | Orthophosphate as PO4 | | 0.40 | | mg/L | 0.031 |
| 03/03/2016 14:44 | Strontium | | 120 | | ug/L | 0.3 |
| 03/03/2016 17:27 | Sulfate | | 35 | 250 | mg/L | 0.5 |
| | **201603010749** | **Test 1 Stage Permeate** | | | | |
| 03/04/2016 12:43 | Magnesium Total ICAP | | 0.52 | | mg/L | 0.1 |
| 03/01/2016 21:06 | Orthophosphate as P | | 0.015 | | mg/L | 0.01 |
| 03/02/2016 13:26 | Orthophosphate as PO4 | | 0.046 | | mg/L | 0.031 |
| 03/03/2016 14:47 | Strontium | | 12 | | ug/L | 0.3 |
| 03/07/2016 19:38 | Sulfate | | 3.4 | 250 | mg/L | 0.5 |
| | **201603010750** | **Test 1 Train Permeate** | | | | |
| 03/04/2016 12:48 | Magnesium Total ICAP | | 0.48 | | mg/L | 0.1 |
| 03/01/2016 21:02 | Orthophosphate as P | | 0.015 | | mg/L | 0.01 |
| 03/02/2016 13:26 | Orthophosphate as PO4 | | 0.046 | | mg/L | 0.031 |
| 03/03/2016 15:01 | Strontium | | 12 | | ug/L | 0.3 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 578201**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
03/01/2016 1653

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 03/07/2016 19:51 | Sulfate | | 3.7 | 250 | mg/L | 0.5 |
| | **201603010751** | **Test 2 RO Feed** | | | | |
| 03/04/2016 12:52 | Magnesium Total ICAP | | 40 | | mg/L | 0.1 |
| 03/01/2016 21:12 | Orthophosphate as P | | 1.1 | | mg/L | 0.05 |
| 03/02/2016 13:26 | Orthophosphate as PO4 | | 3.4 | | mg/L | 0.031 |
| 03/03/2016 15:03 | Strontium | | 1000 | | ug/L | 0.3 |
| 03/07/2016 20:04 | Sulfate | | 290 | 250 | mg/L | 2.5 |
| | **201603010752** | **Test 2 Vessel Permeate** | | | | |
| 03/03/2016 15:06 | Strontium | | 0.62 | | ug/L | 0.3 |
| | **201603010753** | **Test 2 Stage Permeate** | | | | |
| 03/03/2016 15:14 | Strontium | | 0.32 | | ug/L | 0.3 |
| | **201603010754** | **Test 2 Train Permeate** | | | | |
| 03/04/2016 1:30 | Magnesium Total ICAP | | 0.10 | | mg/L | 0.1 |
| 03/03/2016 15:17 | Strontium | | 2.4 | | ug/L | 0.3 |
| 03/08/2016 13:28 | Sulfate | | 1.1 | 250 | mg/L | 0.5 |
| | **201603010755** | **Test 3 RO Feed** | | | | |
| 03/04/2016 2:36 | Magnesium Total ICAP | | 40 | | mg/L | 0.1 |
| 03/01/2016 21:13 | Orthophosphate as P | | 1.1 | | mg/L | 0.05 |
| 03/02/2016 13:26 | Orthophosphate as PO4 | | 3.4 | | mg/L | 0.031 |
| 03/03/2016 15:20 | Strontium | | 1000 | | ug/L | 0.3 |
| 03/08/2016 13:40 | Sulfate | | 280 | 250 | mg/L | 2.5 |
| | **201603010756** | **Test 3 Vessel Permeate** | | | | |
| 03/03/2016 15:22 | Strontium | | 0.42 | | ug/L | 0.3 |
| | **201603010757** | **Test 3 Stage Permeate** | | | | |
| 03/03/2016 15:25 | Strontium | | 0.30 | | ug/L | 0.3 |
| | **201603010758** | **Test 3 Train Permeate** | | | | |
| 03/04/2016 1:34 | Magnesium Total ICAP | | 0.11 | | mg/L | 0.1 |
| 03/01/2016 19:29 | Orthophosphate as P | | 0.011 | | mg/L | 0.01 |
| 03/02/2016 13:06 | Orthophosphate as PO4 | | 0.034 | | mg/L | 0.031 |
| 03/03/2016 15:33 | Strontium | | 2.4 | | ug/L | 0.3 |
| 03/08/2016 14:19 | Sulfate | | 1.1 | 250 | mg/L | 0.5 |

**SUMMARY OF POSITIVE DATA ONLY**

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AT-1807

**STRONTIUM ROUND 2 ON AGED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

# Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**05/27/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 583062
Project: SANDIEGO
Group: Strontium
PO#: 24.010-1

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
* Following the cover page are State Certification List, ISO 17025 Accredited Method List, Acknowledgement of Samples Received, Comments, Hits Report, Data Report, QC Summary, QC Report and Regulatory Forms, as applicable.
* Test results relate only to the sample(s) tested.
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**Laboratory Hits**
**Report: 583062**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
04/21/2016 19:06

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201604040395** | **Control RO Feed** | | | | |
| 04/25/2016 18:53 | Strontium | | 900 | | ug/L | 1.5 |
| | **201604040396** | **Control Vessel Permeate** | | | | |
| 04/25/2016 17:45 | Strontium | | 0.52 | | ug/L | 0.3 |
| | **201604040397** | **Control Stage 1 Permeate** | | | | |
| 04/25/2016 17:46 | Strontium | | 0.73 | | ug/L | 0.3 |
| | **201604040398** | **Control Stage 2 Feed** | | | | |
| 04/26/2016 11:39 | Strontium | | 2400 | | ug/L | 0.3 |
| | **201604040399** | **Control Stage 2 Permeate** | | | | |
| 04/25/2016 17:47 | Strontium | | 7.5 | | ug/L | 0.3 |
| | **201604040400** | **Control Train Permeate** | | | | |
| 04/25/2016 17:48 | Strontium | | 2.3 | | ug/L | 0.3 |
| | **201604040401** | **Test 1 RO Feed** | | | | |
| 04/25/2016 18:54 | Strontium | | 980 | | ug/L | 1.5 |
| | **201604040402** | **Test 1 Vessel Permeate** | | | | |
| 04/25/2016 17:51 | Strontium | | 110 | | ug/L | 0.3 |
| | **201604040403** | **Test 1 Stage 1 Permeate** | | | | |
| 04/25/2016 17:52 | Strontium | | 11 | | ug/L | 0.3 |
| | **201604040404** | **Test 1 Stage 2 Feed** | | | | |
| 04/25/2016 18:55 | Strontium | | 2200 | | ug/L | 3 |
| | **201604040405** | **Test 1 Stage 2 Permeate** | | | | |
| 04/25/2016 17:54 | Strontium | | 8.2 | | ug/L | 0.3 |
| | **201604040406** | **Test 1 Train Permeate** | | | | |
| 04/25/2016 17:55 | Strontium | | 11 | | ug/L | 0.3 |
| | **201604040407** | **Test 2 RO Feed** | | | | |
| 04/25/2016 19:12 | Strontium | | 1000 | | ug/L | 1.5 |
| | **201604040408** | **Test 2 Vessel Permeate** | | | | |
| 04/25/2016 17:59 | Strontium | | 0.85 | | ug/L | 0.3 |
| | **201604040409** | **Test 2 Stage 1 Permeate** | | | | |
| 04/25/2016 18:00 | Strontium | | 0.44 | | ug/L | 0.3 |
| | **201604040410** | **Test 2 Stage 2 Feed** | | | | |

**SUMMARY OF POSITIVE DATA ONLY**

eurofins | Eaton Analytical

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**Laboratory Hits**
**Report: 583062**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
04/21/2016 19:06

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 04/25/2016 19:15 | Strontium | | 2300 | | ug/L | 3 |
| | **201604040411** | **Test 2 Stage 2 Permeate** | | | | |
| 04/25/2016 18:03 | Strontium | | 8.6 | | ug/L | 0.3 |
| | **201604040412** | **Test 2 Train Permeate** | | | | |
| 04/25/2016 18:04 | Strontium | | 2.8 | | ug/L | 0.3 |
| | **201604040413** | **Test 3 RO Feed** | | | | |
| 04/25/2016 19:16 | Strontium | | 1000 | | ug/L | 1.5 |
| | **201604040414** | **Test 3 Vessel Permeate** | | | | |
| 04/25/2016 18:06 | Strontium | | 0.68 | | ug/L | 0.3 |
| | **201604040415** | **Test 3 Stage 1 Permeate** | | | | |
| 04/25/2016 18:07 | Strontium | | 0.51 | | ug/L | 0.3 |
| | **201604040416** | **Test 3 Stage 2 Feed** | | | | |
| 04/25/2016 19:17 | Strontium | | 2100 | | ug/L | 3 |
| | **201604040417** | **Test 3 Stage 2 Permeate** | | | | |
| 04/25/2016 18:16 | Strontium | | 8.8 | | ug/L | 0.3 |
| | **201604040418** | **Test 3 Train Permeate** | | | | |
| 04/25/2016 18:17 | Strontium | | 2.8 | | ug/L | 0.3 |

**SUMMARY OF POSITIVE DATA ONLY**

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

**STRONTIUM ROUND 3 ON AGED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

# Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**05/27/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 583063
Project: SANDIEGO
Group: Strontium
PO#: 24.010-1

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
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**Laboratory Hits**
**Report: 583063**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
04/21/2016 1755

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201604040419** | **Control RO Feed** | | | | |
| 04/25/2016 19:20 | Strontium | | 980 | | ug/L | 1.5 |
| | **201604040420** | **Control Vessel Permeate** | | | | |
| 04/25/2016 18:19 | Strontium | | 0.63 | | ug/L | 0.3 |
| | **201604040421** | **Control Stage 1 Permeate** | | | | |
| 04/25/2016 18:20 | Strontium | | 0.43 | | ug/L | 0.3 |
| | **201604040422** | **Control Stage 2 Feed** | | | | |
| 04/25/2016 19:20 | Strontium | | 2400 | | ug/L | 3 |
| | **201604040423** | **Control Stage 2 Permeate** | | | | |
| 04/25/2016 18:22 | Strontium | | 8.6 | | ug/L | 0.3 |
| | **201604040424** | **Control Train Permeate** | | | | |
| 04/25/2016 18:25 | Strontium | | 2.7 | | ug/L | 0.3 |
| | **201604040425** | **Test 1 RO Feed** | | | | |
| 04/25/2016 19:21 | Strontium | | 960 | | ug/L | 1.5 |
| | **201604040426** | **Test 1 Vessel Permeate** | | | | |
| 04/25/2016 18:26 | Strontium | | 110 | | ug/L | 0.3 |
| | **201604040427** | **Test 1 Stage 1 Permeate** | | | | |
| 04/25/2016 18:29 | Strontium | | 9.7 | | ug/L | 0.3 |
| | **201604040428** | **Test 1 Stage 2 Feed** | | | | |
| 04/25/2016 18:30 | Strontium | | 8.7 | | ug/L | 0.3 |
| | **201604040429** | **Test 1 Stage 2 Permeate** | | | | |
| 04/25/2016 18:31 | Strontium | | 8.4 | | ug/L | 0.3 |
| | **201604040430** | **Test 1 Train Permeate** | | | | |
| 04/25/2016 18:32 | Strontium | | 12 | | ug/L | 0.3 |
| | **201604040431** | **Test 2 RO Feed** | | | | |
| 04/25/2016 19:22 | Strontium | | 1000 | | ug/L | 1.5 |
| | **201604040432** | **Test 2 Vessel Permeate** | | | | |
| 04/25/2016 18:36 | Strontium | | 0.80 | | ug/L | 0.3 |
| | **201604040433** | **Test 2 Stage 1 Permeate** | | | | |
| 04/25/2016 18:37 | Strontium | | 0.81 | | ug/L | 0.3 |
| | **201604040434** | **Test 2 Stage 2 Feed** | | | | |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 583063**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
04/21/2016 1755

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 04/25/2016 19:23 | Strontium | | 2400 | | ug/L | 3 |
| | **201604040435** | **Test 2 Stage 2 Permeate** | | | | |
| 04/25/2016 18:38 | Strontium | | 8.6 | | ug/L | 0.3 |
| | **201604040436** | **Test 2 Train Permeate** | | | | |
| 04/25/2016 19:25 | Strontium | | 2.8 | | ug/L | 0.3 |
| | **201604040437** | **Test 3 RO Feed** | | | | |
| 04/25/2016 19:24 | Strontium | | 970 | | ug/L | 1.5 |
| | **201604040438** | **Test 3 Vessel Permeate** | | | | |
| 04/25/2016 18:49 | Strontium | | 0.55 | | ug/L | 0.3 |
| | **201604040439** | **Test 3 Stage 1 Permeate** | | | | |
| 04/25/2016 18:50 | Strontium | | 0.42 | | ug/L | 0.3 |
| | **201604040440** | **Test 3 Stage 2 Feed** | | | | |
| 04/25/2016 19:28 | Strontium | | 2300 | | ug/L | 3 |
| | **201604040441** | **Test 3 Stage 2 Permeate** | | | | |
| 04/25/2016 18:51 | Strontium | | 7.9 | | ug/L | 0.3 |
| | **201604040442** | **Test 3 Train Permeate** | | | | |
| 04/25/2016 18:52 | Strontium | | 2.6 | | ug/L | 0.3 |

**SUMMARY OF POSITIVE DATA ONLY**

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

**STRONTIUM ROUND 1 ON UNUSED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

# Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**06/05/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 588278
Project: SANDIEGO
Group: Strontium
PO#: 24.010-1

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
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**Laboratory Hits**
**Report: 588278**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201605030787** | **Control RO Feed** | | | | |
| 05/31/2016 10:34 | Strontium | | 1100 | | ug/L | 0.3 |
| | **201605030788** | **Control Vessel Permeate** | | | | |
| 05/31/2016 10:27 | Strontium | | 0.31 | | ug/L | 0.3 |
| | **201605030789** | **Control Stage 1 Permeate** | | | | |
| 05/31/2016 10:36 | Strontium | | 0.76 | | ug/L | 0.3 |
| | **201605030790** | **Control Stage 2 Feed** | | | | |
| 05/31/2016 10:42 | Strontium | | 2800 | | ug/L | 0.3 |
| | **201605030791** | **Control Stage 2 Permeate** | | | | |
| 05/31/2016 10:44 | Strontium | | 12 | | ug/L | 0.3 |
| | **201605030792** | **Control Train Permeate** | | | | |
| 05/31/2016 10:54 | Strontium | | 3.7 | | ug/L | 0.3 |
| | **201605030793** | **Test 1 RO Feed** | | | | |
| 05/31/2016 10:56 | Strontium | | 1000 | | ug/L | 0.3 |
| | **201605030794** | **Test 1 Vessel Permeate** | | | | |
| 05/31/2016 10:58 | Strontium | | 86 | | ug/L | 0.3 |
| | **201605030795** | **Test 1 Stage 1 Permeate** | | | | |
| 05/31/2016 11:00 | Strontium | | 10 | | ug/L | 0.3 |
| | **201605030796** | **Test 1 Stage 2 Feed** | | | | |
| 05/31/2016 11:06 | Strontium | | 2800 | | ug/L | 0.3 |
| | **201605030797** | **Test 1 Stage 2 Permeate** | | | | |
| 05/31/2016 11:12 | Strontium | | 12 | | ug/L | 0.3 |
| | **201605030798** | **Test 1 Train Permeate** | | | | |
| 05/31/2016 12:15 | Strontium | | 12 | | ug/L | 0.3 |
| | **201605030799** | **Test 2 RO Feed** | | | | |
| 05/31/2016 12:17 | Strontium | | 1100 | | ug/L | 0.3 |
| | **201605030800** | **Test 2 Vessel Permeate** | | | | |
| 05/31/2016 12:19 | Strontium | | 8.5 | | ug/L | 0.3 |
| | **201605030801** | **Test 2 Stage 1 Permeate** | | | | |
| 05/31/2016 12:21 | Strontium | | 1.3 | | ug/L | 0.3 |
| | **201605030802** | **Test 2 Stage 2 Feed** | | | | |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 588278**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 05/31/2016 12:27 | Strontium | | 2900 | | ug/L | 0.3 |
| | **201605030803** | **Test 2 Stage 2 Permeate** | | | | |
| 05/31/2016 12:29 | Strontium | | 14 | | ug/L | 0.3 |
| | **201605030804** | **Test 2 Train Permeate** | | | | |
| 05/31/2016 12:35 | Strontium | | 4.2 | | ug/L | 0.3 |
| | **201605030805** | **Test 3 RO Feed** | | | | |
| 05/31/2016 12:41 | Strontium | | 1100 | | ug/L | 0.3 |
| | **201605030806** | **Test 3 Vessel Permeate** | | | | |
| 05/31/2016 12:43 | Strontium | | 1.6 | | ug/L | 0.3 |
| | **201605030807** | **Test 3 Stage 1 Permeate** | | | | |
| 05/31/2016 13:06 | Strontium | | 0.62 | | ug/L | 0.3 |
| | **201605030808** | **Test 3 Stage 2 Feed** | | | | |
| 05/31/2016 13:16 | Strontium | | 2900 | | ug/L | 0.3 |
| | **201605030809** | **Test 3 Stage 2 Permeate** | | | | |
| 05/31/2016 13:18 | Strontium | | 15 | | ug/L | 0.3 |
| | **201605030810** | **Test 3 Train Permeate** | | | | |
| 05/31/2016 13:28 | Strontium | | 3.8 | | ug/L | 0.3 |

**SUMMARY OF POSITIVE DATA ONLY**

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

**STRONTIUM ROUND 2 ON UNUSED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

# Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**07/08/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 588279
Project: SANDIEGO
Group: Strontium
PO#: 24.010-1

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**Laboratory Hits**
**Report: 588279**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
06/29/2016 1502

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201605030811** | **Control RO Feed** | | | | |
| 06/30/2016 12:56 | Strontium | | 1200 | | ug/L | 0.3 |
| | **201605030814** | **Control Stage 2 Feed** | | | | |
| 06/30/2016 12:59 | Strontium | | 2700 | | ug/L | 0.3 |
| | **201605030815** | **Control Stage 2 Permeate** | | | | |
| 06/30/2016 13:01 | Strontium | | 0.66 | | ug/L | 0.3 |
| | **201605030816** | **Control Train Permeate** | | | | |
| 06/30/2016 13:02 | Strontium | | 0.33 | | ug/L | 0.3 |
| | **201605030817** | **Test 1 RO Feed** | | | | |
| 06/30/2016 13:04 | Strontium | | 1200 | | ug/L | 0.3 |
| | **201605030818** | **Test 1 Vessel Permeate** | | | | |
| 06/30/2016 13:12 | Strontium | | 120 | | ug/L | 0.3 |
| | **201605030819** | **Test 1 Stage 1 Permeate** | | | | |
| 06/30/2016 13:13 | Strontium | | 11 | | ug/L | 0.3 |
| | **201605030820** | **Test 1 Stage 2 Feed** | | | | |
| 06/30/2016 13:15 | Strontium | | 2800 | | ug/L | 0.3 |
| | **201605030821** | **Test 1 Stage 2 Permeate** | | | | |
| 06/30/2016 13:16 | Strontium | | 0.70 | | ug/L | 0.3 |
| | **201605030822** | **Test 1 Train Permeate** | | | | |
| 06/30/2016 13:21 | Strontium | | 9.2 | | ug/L | 0.3 |
| | **201605030823** | **Test 2 RO Feed** | | | | |
| 06/30/2016 13:23 | Strontium | | 1100 | | ug/L | 0.3 |
| | **201605030824** | **Test 2 Vessel Permeate** | | | | |
| 06/30/2016 13:24 | Strontium | | 2.7 | | ug/L | 0.3 |
| | **201605030825** | **Test 2 Stage 1 Permeate** | | | | |
| 06/30/2016 13:26 | Strontium | | 0.38 | | ug/L | 0.3 |
| | **201605030826** | **Test 2 Stage 2 Feed** | | | | |
| 06/30/2016 13:30 | Strontium | | 2700 | | ug/L | 0.3 |
| | **201605030827** | **Test 2 Stage 2 Permeate** | | | | |
| 06/30/2016 13:32 | Strontium | | 0.63 | | ug/L | 0.3 |
| | **201605030828** | **Test 2 Train Permeate** | | | | |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 588279**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
06/29/2016 1502

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 06/30/2016 13:33 | Strontium | | 0.50 | | ug/L | 0.3 |
| | **201605030829** | **Test 3 RO Feed** | | | | |
| 06/30/2016 13:35 | Strontium | | 1000 | | ug/L | 1.5 |
| | **201605030832** | **Test 3 Stage 2 Feed** | | | | |
| 06/30/2016 13:57 | Strontium | | 2600 | | ug/L | 0.3 |
| | **201605030833** | **Test 3 Stage 2 Permeate** | | | | |
| 06/30/2016 13:58 | Strontium | | 0.65 | | ug/L | 0.3 |
| | **201605030834** | **Test 3 Train Permeate** | | | | |
| 06/30/2016 14:00 | Strontium | | 0.30 | | ug/L | 0.3 |

**SUMMARY OF POSITIVE DATA ONLY**

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

**STRONTIUM ROUND 3 ON UNUSED HYDRANAUTICS ESPA2 LD ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

# Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**07/21/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 588283
Project: SANDIEGO
Group: Strontium
PO#: 24.010-1

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**Laboratory Hits**
**Report: 588283**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
06/29/2016 1505

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201605030842** | **Control RO Feed** | | | | |
| 06/30/2016 14:01 | Strontium | | 1100 | | ug/L | 0.3 |
| | **201605030843** | **Control Vessel Permeate** | | | | |
| 06/30/2016 14:03 | Strontium | | 0.30 | | ug/L | 0.3 |
| | **201605030845** | **Control Stage 2 Feed** | | | | |
| 06/30/2016 14:09 | Strontium | | 2800 | | ug/L | 0.3 |
| | **201605030846** | **Control Stage 2 Permeate** | | | | |
| 06/30/2016 14:11 | Strontium | | 0.72 | | ug/L | 0.3 |
| | **201605030847** | **Control Train Permeate** | | | | |
| 06/30/2016 14:12 | Strontium | | 0.34 | | ug/L | 0.3 |
| | **201605030848** | **Test 1 RO Feed** | | | | |
| 06/30/2016 14:14 | Strontium | | 1100 | | ug/L | 0.3 |
| | **201605030849** | **Test 1 Vessel Permeate** | | | | |
| 06/30/2016 14:18 | Strontium | | 120 | | ug/L | 0.3 |
| | **201605030850** | **Test 1 Stage 1 Permeate** | | | | |
| 06/30/2016 14:23 | Strontium | | 10 | | ug/L | 0.3 |
| | **201605030851** | **Test 1 Stage 2 Feed** | | | | |
| 06/30/2016 14:25 | Strontium | | 2600 | | ug/L | 0.3 |
| | **201605030852** | **Test 1 Stage 2 Permeate** | | | | |
| 06/30/2016 14:29 | Strontium | | 0.88 | | ug/L | 0.3 |
| | **201605030853** | **Test 1 Train Permeate** | | | | |
| 06/30/2016 14:31 | Strontium | | 9.0 | | ug/L | 0.3 |
| | **201605030854** | **Test 2 RO Feed** | | | | |
| 06/30/2016 14:32 | Strontium | | 1000 | | ug/L | 1.5 |
| | **201605030855** | **Test 2 Vessel Permeate** | | | | |
| 06/30/2016 14:34 | Strontium | | 4.4 | | ug/L | 0.3 |
| | **201605030856** | **Test 2 Stage 1 Permeate** | | | | |
| 06/30/2016 14:35 | Strontium | | 0.50 | | ug/L | 0.3 |
| | **201605030857** | **Test 2 Stage 2 Feed** | | | | |
| 06/30/2016 14:37 | Strontium | | 2500 | | ug/L | 0.3 |
| | **201605030858** | **Test 2 Stage 2 Permeate** | | | | |

**SUMMARY OF POSITIVE DATA ONLY**

eurofins | Eaton Analytical

750 Royal Oaks Drive, Suite 100
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Tel: (626) 386-1100
Fax: (626) 386-1101
1 800 566 LABS (1 800 566 5227)

**Laboratory Hits**
**Report: 588283**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
06/29/2016 1505

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 06/30/2016 14:49 | Strontium | | 0.63 | | ug/L | 0.3 |
| | **201605030859** | **Test 2 Train Permeate** | | | | |
| 06/30/2016 14:54 | Strontium | | 0.53 | | ug/L | 0.3 |
| | **201605030860** | **Test 3 RO Feed** | | | | |
| 06/30/2016 14:56 | Strontium | | 1100 | | ug/L | 1.5 |
| | **201605030863** | **Test 3 Stage 2 Feed** | | | | |
| 06/30/2016 15:03 | Strontium | | 2600 | | ug/L | 0.3 |
| | **201605030864** | **Test 3 Stage 2 Permeate** | | | | |
| 06/30/2016 15:08 | Strontium | | 0.52 | | ug/L | 0.3 |

**SUMMARY OF POSITIVE DATA ONLY**

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

# WATER QUALITY ON UNUSED HYDRANAUTICS ESPA2 LD ELEMENTS

## Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**06/13/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 588418
Project: SANDIEGO
Group: WQ Parameters
PO#: 24.010-1

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
* Following the cover page are State Certification List, ISO 17025 Accredited Method List, Acknowledgement of Samples Received, Comments, Hits Report, Data Report, QC Summary, QC Report and Regulatory Forms, as applicable.
* Test results relate only to the sample(s) tested.
* This report shall not be reproduced except in full, without the written approval of the laboratory.

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**Laboratory Hits**
**Report: 588418**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201605040294** | **RO Feed** | | | | |
| 05/27/2016 18:31 | Alkalinity in CaCO3 units | | 110 | | mg/L | 2 |
| 05/27/2016 12:07 | Barium Total ICAP/MS | | 28 | 2000 | ug/L | 2 |
| 06/02/2016 19:02 | Boron Total ICAP | | 0.40 | | mg/L | 0.05 |
| 06/07/2016 05:37 | Bromide | | 360 | | ug/L | 25 |
| 06/02/2016 19:02 | Calcium Total ICAP | | 88 | | mg/L | 1 |
| 05/26/2016 14:12 | Chloride | | 310 | 250 | mg/L | 10 |
| 05/27/2016 16:32 | Fluoride | | 0.59 | 4 | mg/L | 0.05 |
| 06/02/2016 19:02 | Iron Total ICAP | | 0.036 | 0.3 | mg/L | 0.02 |
| 06/02/2016 19:02 | Magnesium Total ICAP | | 38 | | mg/L | 0.1 |
| 05/26/2016 14:12 | Nitrate as Nitrogen by IC | | 18 | 10 | mg/L | 1 |
| 05/26/2016 14:06 | Orthophosphate as P | | 1.6 | | mg/L | 0.05 |
| 06/02/2016 19:02 | Potassium Total ICAP | | 23 | | mg/L | 1 |
| 06/02/2016 19:02 | Silica | | 8.9 | | mg/L | 0.43 |
| 06/02/2016 19:02 | Sodium Total ICAP | | 210 | | mg/L | 1 |
| 05/26/2016 14:12 | Sulfate | | 270 | 250 | mg/L | 5 |
| 05/27/2016 17:05 | Total Dissolved Solids (TDS) | | 1100 | 500 | mg/L | 10 |
| 06/02/2016 09:18 | Total Hardness as CaCO3 by ICP (calc) | | 380 | | mg/L | 3 |
| 05/28/2016 18:15 | Total Organic Carbon | | 6.4 | | mg/L | 3 |
| | **201605040295** | **Vessel Permeate** | | | | |
| 05/27/2016 18:24 | Alkalinity in CaCO3 units | | 2.4 | | mg/L | 2 |
| 06/02/2016 2:13 | Boron Total ICAP | | 0.22 | | mg/L | 0.05 |
| 05/26/2016 13:59 | Chloride | | 2.1 | 250 | mg/L | 1 |
| 05/26/2016 13:59 | Nitrate as Nitrogen by IC | | 0.81 | 10 | mg/L | 0.1 |
| 06/02/2016 2:13 | Sodium Total ICAP | | 4.1 | | mg/L | 1 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Data**
**Report: 588418**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **RO Feed (201605040294)** | | | | | | **Sampled on 05/24/2016 1425** | | |
| | | **EPA 200.8 - ICPMS Metals** | | | | | | |
| 5/27/2016 | 05/27/2016 12:07 | 913383 | (EPA 200.8) | Aluminum Total ICAP/MS | ND | ug/L | 20 | 1 |
| 5/27/2016 | 05/27/2016 12:07 | 913383 | (EPA 200.8) | Barium Total ICAP/MS | 28 | ug/L | 2 | 1 |
| 5/27/2016 | 05/27/2016 12:07 | 913383 | (EPA 200.8) | Manganese Total ICAP/MS | ND | ug/L | 2 | 1 |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Boron Total ICAP | 0.40 | mg/L | 0.05 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Calcium Total ICAP | 88 | mg/L | 1 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Iron Total ICAP | 0.036 | mg/L | 0.02 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Magnesium Total ICAP | 38 | mg/L | 0.1 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Potassium Total ICAP | 23 | mg/L | 1 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Silica | 8.9 | mg/L | 0.43 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Sodium Total ICAP | 210 | mg/L | 1 | 1 |
| | | **SM5310C/E415.3 - Total Organic Carbon** | | | | | | |
| | 05/28/2016 18:15 | 913816 | (SM5310C/E415.3) | Total Organic Carbon | 6.4 | mg/L | 3 | 10 |
| | | **SM 2340B - Total Hardness as CaCO3 by ICP** | | | | | | |
| | 06/02/2016 09:18 | | (SM 2340B) | Total Hardness as CaCO3 by ICP (calc) | 380 | mg/L | 3 | 1 |
| | | **EPA 300.0 - Nitrate, Nitrite by EPA 300.0** | | | | | | |
| | 05/26/2016 14:12 | 913210 | (EPA 300.0) | Nitrate as Nitrogen by IC | 18 | mg/L | 1 | 10 |
| | | **EPA 300.0 - Disinfection ByProducts by 300.0** | | | | | | |
| | 06/07/2016 05:37 | 915303 | (EPA 300.0) | Bromide | 360 | ug/L | 25 | 5 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 05/26/2016 14:12 | 913211 | (EPA 300.0) | Chloride | 310 | mg/L | 10 | 10 |
| | 05/26/2016 14:12 | 913211 | (EPA 300.0) | Sulfate | 270 | mg/L | 5 | 10 |
| | | **EPA 350.1 - Ammonia Nitrogen** | | | | | | |
| | 05/27/2016 14:33 | 913514 | (EPA 350.1) | Ammonia Nitrogen | ND (M2) | mg/L | 0.05 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 05/27/2016 16:32 | 913493 | (SM 4500F-C) | Fluoride | 0.59 | mg/L | 0.05 | 1 |
| | | **SM 2320B - Alkalinity in CaCO3 units** | | | | | | |
| | 05/27/2016 18:31 | 913500 | (SM 2320B) | Alkalinity in CaCO3 units | 110 | mg/L | 2 | 1 |
| | | **E160.1/SM2540C - Total Dissolved Solids (TDS)** | | | | | | |
| 5/27/2016 | 05/27/2016 17:05 | 913594 | (E160.1/SM2540C) | Total Dissolved Solids (TDS) | 1100 | mg/L | 10 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 05/26/2016 14:06 | 913294 | (4500P-E/365.1) | Orthophosphate as P | 1.6 | mg/L | 0.05 | 5 |
| **Vessel Permeate (201605040295)** | | | | | | **Sampled on 05/24/2016 1421** | | |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 588418**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| | | **EPA 200.8 - ICPMS Metals** | | | | | | |
| 5/27/2016 | 05/27/2016 12:09 | 913383 | (EPA 200.8) | Aluminum Total ICAP/MS | ND | ug/L | 20 | 1 |
| 5/27/2016 | 05/27/2016 12:09 | 913383 | (EPA 200.8) | Barium Total ICAP/MS | ND | ug/L | 2 | 1 |
| 5/27/2016 | 05/27/2016 12:09 | 913383 | (EPA 200.8) | Manganese Total ICAP/MS | ND | ug/L | 2 | 1 |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Boron Total ICAP | 0.22 | mg/L | 0.05 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Iron Total ICAP | ND | mg/L | 0.02 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Silica | ND | mg/L | 0.43 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Sodium Total ICAP | 4.1 | mg/L | 1 | 1 |
| | | **SM 2340B - Total Hardness as CaCO3 by ICP** | | | | | | |
| | 06/02/2016 09:18 | | (SM 2340B) | Total Hardness as CaCO3 by ICP (calc) | ND | mg/L | 3 | 1 |
| | | **EPA 300.0 - Nitrate, Nitrite by EPA 300.0** | | | | | | |
| | 05/26/2016 13:59 | 913210 | (EPA 300.0) | Nitrate as Nitrogen by IC | 0.81 | mg/L | 0.1 | 1 |
| | | **EPA 300.0 - Disinfection ByProducts by 300.0** | | | | | | |
| | 06/08/2016 03:38 | 915654 | (EPA 300.0) | Bromide | ND | ug/L | 5 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 05/26/2016 13:59 | 913211 | (EPA 300.0) | Chloride | 2.1 | mg/L | 1 | 1 |
| | 05/26/2016 13:59 | 913211 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **EPA 350.1 - Ammonia Nitrogen** | | | | | | |
| | 05/27/2016 14:37 | 913514 | (EPA 350.1) | Ammonia Nitrogen | ND | mg/L | 0.05 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 05/27/2016 16:36 | 913493 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **SM 2320B - Alkalinity in CaCO3 units** | | | | | | |
| | 05/27/2016 18:24 | 913500 | (SM 2320B) | Alkalinity in CaCO3 units | 2.4 | mg/L | 2 | 1 |
| | | **E160.1/SM2540C - Total Dissolved Solids (TDS)** | | | | | | |
| 5/27/2016 | 05/27/2016 17:26 | 913594 | (E160.1/SM2540C) | Total Dissolved Solids (TDS) | ND | mg/L | 10 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 05/26/2016 14:09 | 913294 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

**STRONTIUM ROUND 1 ON VIRGIN TORAY TMG20D-400 ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

# Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**09/02/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 600455
Project: SANDIEGO-BUREAU
Group: Strontium Day 1
PO#: 24.010-1

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
* Following the cover page are State Certification List, ISO 17025 Accredited Method List, Acknowledgement of Samples Received, Comments, Hits Report, Data Report, QC Summary, QC Report and Regulatory Forms, as applicable.
* Test results relate only to the sample(s) tested.
* This report shall not be reproduced except in full, without the written approval of the laboratory.

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**Laboratory Hits**
**Report: 600455**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
08/10/2016 1506

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201607150613** | **Control RO Feed Day 1** | | | | |
| 08/22/2016 10:45 | Strontium | | 1000 | | ug/L | 0.3 |
| | **201607150614** | **Control Vessel Permeate Day 1** | | | | |
| 08/22/2016 10:47 | Strontium | | 0.90 | | ug/L | 0.3 |
| | **201607150616** | **Control Stage 2 Feed Day 1** | | | | |
| 08/22/2016 10:56 | Strontium | | 2300 | | ug/L | 0.3 |
| | **201607150617** | **Control Stage 2 Permeate Day 1** | | | | |
| 08/22/2016 10:58 | Strontium | | 2.0 | | ug/L | 0.3 |
| | **201607150618** | **Control Train Permeate Day 1** | | | | |
| 08/22/2016 10:59 | Strontium | | 0.46 | | ug/L | 0.3 |
| | **201607150619** | **Control ROC Day 1** | | | | |
| 08/22/2016 11:01 | Strontium | | 4900 | | ug/L | 0.3 |
| | **201607150620** | **Test 1 RO Feed Day 1** | | | | |
| 08/22/2016 11:09 | Strontium | | 1000 | | ug/L | 0.3 |
| | **201607150621** | **Test 1 Vessel Permeate Day 1** | | | | |
| 08/22/2016 11:10 | Strontium | | 81 | | ug/L | 0.3 |
| | **201607150622** | **Test 1 Stage 1 Permeate Day 1** | | | | |
| 08/22/2016 11:15 | Strontium | | 6.8 | | ug/L | 0.3 |
| | **201607150623** | **Test 1 Stage 2 Feed Day 1** | | | | |
| 08/22/2016 11:19 | Strontium | | 2300 | | ug/L | 0.3 |
| | **201607150624** | **Test 1 Stage 2 Permeate Day 1** | | | | |
| 08/22/2016 11:21 | Strontium | | 2.1 | | ug/L | 0.3 |
| | **201607150625** | **Test 1 Train Permeate Day 1** | | | | |
| 08/22/2016 11:23 | Strontium | | 5.8 | | ug/L | 0.3 |
| | **201607150626** | **Test 1 ROC Day 1** | | | | |
| 08/22/2016 11:50 | Strontium | | 4400 | | ug/L | 1.5 |
| | **201607150627** | **Test 3 RO Feed Day 1** | | | | |
| 08/22/2016 11:43 | Strontium | | 1000 | | ug/L | 0.3 |
| | **201607150628** | **Test 3 Vessel Permeate Day 1** | | | | |
| 08/22/2016 11:48 | Strontium | | 210 | | ug/L | 0.3 |
| | **201607150629** | **Test 3 Stage 1 Permeate Day 1** | | | | |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Hits**
**Report: 600455**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
08/10/2016 1506

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 08/22/2016 12:08 | Strontium | | 21 | | ug/L | 0.3 |
| | **201607150630** | **Test 3 Stage 2 Feed Day 1** | | | | |
| 08/22/2016 12:19 | Strontium | | 2300 | | ug/L | 0.3 |
| | **201607150631** | **Test 3 Stage 2 Permeate Day 1** | | | | |
| 08/22/2016 12:21 | Strontium | | 1.9 | | ug/L | 0.3 |
| | **201607150632** | **Test 3 Train Permeate Day 1** | | | | |
| 08/22/2016 12:22 | Strontium | | 17 | | ug/L | 0.3 |
| | **201607150633** | **Test 3 Train ROC Day 1** | | | | |
| 08/22/2016 13:57 | Strontium | | 4000 | | ug/L | 1.5 |

**SUMMARY OF POSITIVE DATA ONLY**

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

**STRONTIUM ROUND 2 ON VIRGIN TORAY TMG20D-400 ELEMENTS**
**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

# Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**09/02/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 600456
Project: SANDIEGO-BUREAU
Group: Strontium Day 2
PO#: 24.010-1

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
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* Test results relate only to the sample(s) tested.
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**Laboratory Hits**
**Report: 600456**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
08/10/2016 1503

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201607150634** | **Control RO Feed Day 1** | | | | |
| 08/22/2016 12:32 | Strontium | | 1000 | | ug/L | 0.3 |
| | **201607150636** | **Control Stage 1 Permeate Day 1** | | | | |
| 08/22/2016 12:41 | Strontium | | 0.98 | | ug/L | 0.3 |
| | **201607150637** | **Control Stage 2 Feed Day 1** | | | | |
| 08/22/2016 12:46 | Strontium | | 2400 | | ug/L | 0.3 |
| | **201607150638** | **Control Stage 2 Permeate Day 1** | | | | |
| 08/22/2016 12:47 | Strontium | | 1.9 | | ug/L | 0.3 |
| | **201607150639** | **Control Train Permeate Day 1** | | | | |
| 08/22/2016 12:49 | Strontium | | 0.45 | | ug/L | 0.3 |
| | **201607150640** | **Control ROC Day 1** | | | | |
| 08/22/2016 14:02 | Strontium | | 4300 | | ug/L | 1.5 |
| | **201607150641** | **Test 1 RO Feed Day 1** | | | | |
| 08/22/2016 13:06 | Strontium | | 1000 | | ug/L | 0.3 |
| | **201607150642** | **Test 1 Vessel Permeate Day 1** | | | | |
| 08/22/2016 13:13 | Strontium | | 80 | | ug/L | 0.3 |
| | **201607150643** | **Test 1 Stage 1 Permeate Day 1** | | | | |
| 08/22/2016 13:15 | Strontium | | 7.0 | | ug/L | 0.3 |
| | **201607150644** | **Test 1 Stage 2 Feed Day 1** | | | | |
| 08/22/2016 13:23 | Strontium | | 2400 | | ug/L | 0.3 |
| | **201607150645** | **Test 1 Stage 2 Permeate Day 1** | | | | |
| 08/22/2016 13:24 | Strontium | | 1.7 | | ug/L | 0.3 |
| | **201607150646** | **Test 1 Train Permeate Day 1** | | | | |
| 08/22/2016 13:40 | Strontium | | 5.9 | | ug/L | 0.3 |
| | **201607150647** | **Test 1 ROC Day 1** | | | | |
| 08/22/2016 14:08 | Strontium | | 4200 | | ug/L | 1.5 |
| | **201607150648** | **Test 3 RO Feed Day 1** | | | | |
| 08/22/2016 13:53 | Strontium | | 1200 | | ug/L | 0.3 |
| | **201607150649** | **Test 3 Vessel Permeate Day 1** | | | | |
| 08/22/2016 14:20 | Strontium | | 100 | | ug/L | 0.3 |
| | **201607150650** | **Test 3 Stage 1 Permeate Day 1** | | | | |

**SUMMARY OF POSITIVE DATA ONLY**

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Fax: (626) 386-1101
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**Laboratory Hits**
**Report: 600456**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
08/10/2016 1503

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| 08/22/2016 14:28 | Strontium | | 10 | | ug/L | 0.3 |
| | **201607150651** | **Test 3 Stage 2 Feed Day 1** | | | | |
| 08/22/2016 14:33 | Strontium | | 2500 | | ug/L | 0.3 |
| | **201607150652** | **Test 3 Stage 2 Permeate Day 1** | | | | |
| 08/22/2016 14:34 | Strontium | | 1.9 | | ug/L | 0.3 |
| | **201607150653** | **Test 3 Train Permeate Day 1** | | | | |
| 08/22/2016 14:36 | Strontium | | 8.0 | | ug/L | 0.3 |
| | **201607150654** | **Test 3 Train ROC Day 1** | | | | |
| 08/22/2016 14:41 | Strontium | | 4900 | | ug/L | 0.3 |

**SUMMARY OF POSITIVE DATA ONLY**

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

# WATER QUALITY ON VIRGIN TORAY TMG20D-400 ELEMENTS

## Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

Date of Issue
06/13/2016

Linda Geddes
EUROFINS EATON ANALYTICAL

LXG: Linda Geddes
Project Manager

NELAP ACCREDITED TNI LABORATORY
ORELAP 4034

Report: 588418
Project: SANDIEGO
Group: WQ Parameters
PO#: 24.010-1

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
* Following the cover page are State Certification List, ISO 17025 Accredited Method List, Acknowledgement of Samples Received, Comments, Hits Report, Data Report, QC Summary, QC Report and Regulatory Forms, as applicable.
* Test results relate only to the sample(s) tested.
* This report shall not be reproduced except in full, without the written approval of the laboratory.

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**Laboratory Hits**
**Report: 588418**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201605040294** | **RO Feed** | | | | |
| 05/27/2016 18:31 | Alkalinity in CaCO3 units | | 110 | | mg/L | 2 |
| 05/27/2016 12:07 | Barium Total ICAP/MS | | 28 | 2000 | ug/L | 2 |
| 06/02/2016 19:02 | Boron Total ICAP | | 0.40 | | mg/L | 0.05 |
| 06/07/2016 05:37 | Bromide | | 360 | | ug/L | 25 |
| 06/02/2016 19:02 | Calcium Total ICAP | | 88 | | mg/L | 1 |
| 05/26/2016 14:12 | Chloride | | 310 | 250 | mg/L | 10 |
| 05/27/2016 16:32 | Fluoride | | 0.59 | 4 | mg/L | 0.05 |
| 06/02/2016 19:02 | Iron Total ICAP | | 0.036 | 0.3 | mg/L | 0.02 |
| 06/02/2016 19:02 | Magnesium Total ICAP | | 38 | | mg/L | 0.1 |
| 05/26/2016 14:12 | Nitrate as Nitrogen by IC | | 18 | 10 | mg/L | 1 |
| 05/26/2016 14:06 | Orthophosphate as P | | 1.6 | | mg/L | 0.05 |
| 06/02/2016 19:02 | Potassium Total ICAP | | 23 | | mg/L | 1 |
| 06/02/2016 19:02 | Silica | | 8.9 | | mg/L | 0.43 |
| 06/02/2016 19:02 | Sodium Total ICAP | | 210 | | mg/L | 1 |
| 05/26/2016 14:12 | Sulfate | | 270 | 250 | mg/L | 5 |
| 05/27/2016 17:05 | Total Dissolved Solids (TDS) | | 1100 | 500 | mg/L | 10 |
| 06/02/2016 09:18 | Total Hardness as CaCO3 by ICP (calc) | | 380 | | mg/L | 3 |
| 05/28/2016 18:15 | Total Organic Carbon | | 6.4 | | mg/L | 3 |
| | **201605040295** | **Vessel Permeate** | | | | |
| 05/27/2016 18:24 | Alkalinity in CaCO3 units | | 2.4 | | mg/L | 2 |
| 06/02/2016 2:13 | Boron Total ICAP | | 0.22 | | mg/L | 0.05 |
| 05/26/2016 13:59 | Chloride | | 2.1 | 250 | mg/L | 1 |
| 05/26/2016 13:59 | Nitrate as Nitrogen by IC | | 0.81 | 10 | mg/L | 0.1 |
| 06/02/2016 2:13 | Sodium Total ICAP | | 4.1 | | mg/L | 1 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Data**
**Report: 588418**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **RO Feed (201605040294)** | | | | | | **Sampled on 05/24/2016 1425** | | |
| | | **EPA 200.8 - ICPMS Metals** | | | | | | |
| 5/27/2016 | 05/27/2016 12:07 | 913383 | (EPA 200.8) | Aluminum Total ICAP/MS | ND | ug/L | 20 | 1 |
| 5/27/2016 | 05/27/2016 12:07 | 913383 | (EPA 200.8) | Barium Total ICAP/MS | 28 | ug/L | 2 | 1 |
| 5/27/2016 | 05/27/2016 12:07 | 913383 | (EPA 200.8) | Manganese Total ICAP/MS | ND | ug/L | 2 | 1 |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Boron Total ICAP | 0.40 | mg/L | 0.05 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Calcium Total ICAP | 88 | mg/L | 1 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Iron Total ICAP | 0.036 | mg/L | 0.02 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Magnesium Total ICAP | 38 | mg/L | 0.1 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Potassium Total ICAP | 23 | mg/L | 1 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Silica | 8.9 | mg/L | 0.43 | 1 |
| 5/27/2016 | 06/02/2016 19:02 | 914488 | (EPA 200.7) | Sodium Total ICAP | 210 | mg/L | 1 | 1 |
| | | **SM5310C/E415.3 - Total Organic Carbon** | | | | | | |
| | 05/28/2016 18:15 | 913816 | (SM5310C/E415.3) | Total Organic Carbon | 6.4 | mg/L | 3 | 10 |
| | | **SM 2340B - Total Hardness as CaCO3 by ICP** | | | | | | |
| | 06/02/2016 09:18 | | (SM 2340B) | Total Hardness as CaCO3 by ICP (calc) | 380 | mg/L | 3 | 1 |
| | | **EPA 300.0 - Nitrate, Nitrite by EPA 300.0** | | | | | | |
| | 05/26/2016 14:12 | 913210 | (EPA 300.0) | Nitrate as Nitrogen by IC | 18 | mg/L | 1 | 10 |
| | | **EPA 300.0 - Disinfection ByProducts by 300.0** | | | | | | |
| | 06/07/2016 05:37 | 915303 | (EPA 300.0) | Bromide | 360 | ug/L | 25 | 5 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 05/26/2016 14:12 | 913211 | (EPA 300.0) | Chloride | 310 | mg/L | 10 | 10 |
| | 05/26/2016 14:12 | 913211 | (EPA 300.0) | Sulfate | 270 | mg/L | 5 | 10 |
| | | **EPA 350.1 - Ammonia Nitrogen** | | | | | | |
| | 05/27/2016 14:33 | 913514 | (EPA 350.1) | Ammonia Nitrogen | ND (M2) | mg/L | 0.05 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 05/27/2016 16:32 | 913493 | (SM 4500F-C) | Fluoride | 0.59 | mg/L | 0.05 | 1 |
| | | **SM 2320B - Alkalinity in CaCO3 units** | | | | | | |
| | 05/27/2016 18:31 | 913500 | (SM 2320B) | Alkalinity in CaCO3 units | 110 | mg/L | 2 | 1 |
| | | **E160.1/SM2540C - Total Dissolved Solids (TDS)** | | | | | | |
| 5/27/2016 | 05/27/2016 17:05 | 913594 | (E160.1/SM2540C) | Total Dissolved Solids (TDS) | 1100 | mg/L | 10 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 05/26/2016 14:06 | 913294 | (4500P-E/365.1) | Orthophosphate as P | 1.6 | mg/L | 0.05 | 5 |
| **Vessel Permeate (201605040295)** | | | | | | **Sampled on 05/24/2016 1421** | | |

Rounding on totals after summation.
(c) - indicates calculated results

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**Laboratory Data**
**Report: 588418**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| | | **EPA 200.8 - ICPMS Metals** | | | | | | |
| 5/27/2016 | 05/27/2016 12:09 | 913383 | (EPA 200.8) | Aluminum Total ICAP/MS | ND | ug/L | 20 | 1 |
| 5/27/2016 | 05/27/2016 12:09 | 913383 | (EPA 200.8) | Barium Total ICAP/MS | ND | ug/L | 2 | 1 |
| 5/27/2016 | 05/27/2016 12:09 | 913383 | (EPA 200.8) | Manganese Total ICAP/MS | ND | ug/L | 2 | 1 |
| | | **EPA 200.7 - ICP Metals** | | | | | | |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Boron Total ICAP | 0.22 | mg/L | 0.05 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Calcium Total ICAP | ND | mg/L | 1 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Iron Total ICAP | ND | mg/L | 0.02 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Magnesium Total ICAP | ND | mg/L | 0.1 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Potassium Total ICAP | ND | mg/L | 1 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Silica | ND | mg/L | 0.43 | 1 |
| 5/27/2016 | 06/02/2016 2:13 | 914117 | (EPA 200.7) | Sodium Total ICAP | 4.1 | mg/L | 1 | 1 |
| | | **SM 2340B - Total Hardness as CaCO3 by ICP** | | | | | | |
| | 06/02/2016 09:18 | | (SM 2340B) | Total Hardness as CaCO3 by ICP (calc) | ND | mg/L | 3 | 1 |
| | | **EPA 300.0 - Nitrate, Nitrite by EPA 300.0** | | | | | | |
| | 05/26/2016 13:59 | 913210 | (EPA 300.0) | Nitrate as Nitrogen by IC | 0.81 | mg/L | 0.1 | 1 |
| | | **EPA 300.0 - Disinfection ByProducts by 300.0** | | | | | | |
| | 06/08/2016 03:38 | 915654 | (EPA 300.0) | Bromide | ND | ug/L | 5 | 1 |
| | | **EPA 300.0 - Chloride, Sulfate by EPA 300.0** | | | | | | |
| | 05/26/2016 13:59 | 913211 | (EPA 300.0) | Chloride | 2.1 | mg/L | 1 | 1 |
| | 05/26/2016 13:59 | 913211 | (EPA 300.0) | Sulfate | ND | mg/L | 0.5 | 1 |
| | | **EPA 350.1 - Ammonia Nitrogen** | | | | | | |
| | 05/27/2016 14:37 | 913514 | (EPA 350.1) | Ammonia Nitrogen | ND | mg/L | 0.05 | 1 |
| | | **SM 4500F-C - Fluoride** | | | | | | |
| | 05/27/2016 16:36 | 913493 | (SM 4500F-C) | Fluoride | ND | mg/L | 0.05 | 1 |
| | | **SM 2320B - Alkalinity in CaCO3 units** | | | | | | |
| | 05/27/2016 18:24 | 913500 | (SM 2320B) | Alkalinity in CaCO3 units | 2.4 | mg/L | 2 | 1 |
| | | **E160.1/SM2540C - Total Dissolved Solids (TDS)** | | | | | | |
| 5/27/2016 | 05/27/2016 17:26 | 913594 | (E160.1/SM2540C) | Total Dissolved Solids (TDS) | ND | mg/L | 10 | 1 |
| | | **4500P-E/365.1 - Orthophosphate as P (OPO4)** | | | | | | |
| | 05/26/2016 14:09 | 913294 | (4500P-E/365.1) | Orthophosphate as P | ND | mg/L | 0.01 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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ANAB ACCREDITED ISO/IEC 17025 TESTING LABORATORY
AT-1807

# SUCRALOSE REJECTION ACROSS AGED AND UNUSED HYDRANAUTICSESPA2 LD ELEMENTS

## Laboratory Report

for

Trussell Technologies, Inc.
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075
Attention: Aleksey Pisarenko
Fax: 626-486-0571

**Date of Issue**
**06/17/2016**

Linda Geddes
**EUROFINS EATON ANALYTICAL**

LXG: Linda Geddes

Project Manager

NELAP ACCREDITED TNI LABORATORY
**ORELAP 4034**

Report: 592378
Project: SANDIEGO
Group: Sucralose
PO#: 24.010-1

* Accredited in accordance with TNI 2009 and ISO/IEC 17025:2005.
* Laboratory certifies that the test results meet all **TNI 2009 and ISO/IEC 17025:2005** requirements unless noted under the individual analysis.
* Following the cover page are State Certification List, ISO 17025 Accredited Method List, Acknowledgement of Samples Received, Comments, Hits Report, Data Report, QC Summary, QC Report and Regulatory Forms, as applicable.
* Test results relate only to the sample(s) tested.
* This report shall not be reproduced except in full, without the written approval of the laboratory.

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**Laboratory Hits**
**Report: 592378**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Analyzed | Analyte | Sample ID | Result | Federal MCL | Units | MRL |
|---|---|---|---|---|---|---|
| | **201605260439** | **RO Feed (1 of 2)** | | | | |
| 06/10/2016 23:29 | Sucralose | | 4200000 | | ng/L | 50000 |
| | **201605260440** | **New Vessel Permeate (1 of 2)** | | | | |
| 06/09/2016 05:11 | Sucralose | | 5300 | | ng/L | 100 |
| | **201605260441** | **Old Vessel Permeate (1 of 2)** | | | | |
| 06/09/2016 05:57 | Sucralose | | 6800 | | ng/L | 100 |
| | **201605260442** | **RO Feed (2 of 2)** | | | | |
| 06/09/2016 16:12 | Sucralose | | 4800000 | | ng/L | 100000 |
| | **201605260443** | **New Vessel Permeate (2 of 2)** | | | | |
| 06/09/2016 07:28 | Sucralose | | 5600 | | ng/L | 100 |
| | **201605260444** | **Old Vessel Permeate (2 of 2)** | | | | |
| 06/14/2016 15:06 | Sucralose | | 5700 | | ng/L | 100 |

**SUMMARY OF POSITIVE DATA ONLY**

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**Laboratory Data**
**Report: 592378**

**Trussell Technologies, Inc.**
Aleksey Pisarenko
380 Stevens Avenue, Suite 308
Solana Beach, CA 92075

Samples Received on:
05/26/2016 1204

| Prepared | Analyzed | QC Ref # | Method | Analyte | Result | Units | MRL | Dilution |
|---|---|---|---|---|---|---|---|---|
| **RO Feed (1 of 2) (201605260439)** | | | | | | **Sampled on 05/17/2016 1120** | | |
| | **LC-MS-MS - Endocrine Disruptors Negative Mode - SPE** | | | | | | | |
| | 06/10/2016 23:29 | 915941 | (LC-MS-MS) | Sucralose | 4200000 | ng/L | 50000 | 500 |
| **New Vessel Permeate (1 of 2) (201605260440)** | | | | | | **Sampled on 05/17/2016 1120** | | |
| | **LC-MS-MS - Endocrine Disruptors Negative Mode - SPE** | | | | | | | |
| | 06/09/2016 05:11 | 915552 | (LC-MS-MS) | Sucralose | 5300 | ng/L | 100 | 1 |
| **Old Vessel Permeate (1 of 2) (201605260441)** | | | | | | **Sampled on 05/17/2016 1120** | | |
| | **LC-MS-MS - Endocrine Disruptors Negative Mode - SPE** | | | | | | | |
| | 06/09/2016 05:57 | 915552 | (LC-MS-MS) | Sucralose | 6800 | ng/L | 100 | 1 |
| **RO Feed (2 of 2) (201605260442)** | | | | | | **Sampled on 05/17/2016 1140** | | |
| | **LC-MS-MS - Endocrine Disruptors Negative Mode - SPE** | | | | | | | |
| | 06/09/2016 16:12 | 915552 | (LC-MS-MS) | Sucralose | 4800000 | ng/L | 100000 | 1000 |
| **New Vessel Permeate (2 of 2) (201605260443)** | | | | | | **Sampled on 05/17/2016 1140** | | |
| | **LC-MS-MS - Endocrine Disruptors Negative Mode - SPE** | | | | | | | |
| | 06/09/2016 07:28 | 915552 | (LC-MS-MS) | Sucralose | 5600 | ng/L | 100 | 1 |
| **Old Vessel Permeate (2 of 2) (201605260444)** | | | | | | **Sampled on 05/17/2016 1140** | | |
| | **LC-MS-MS - Endocrine Disruptors Negative Mode - SPE** | | | | | | | |
| | 06/14/2016 15:06 | 916586 | (LC-MS-MS) | Sucralose | 5700 (M3) | ng/L | 100 | 1 |

Rounding on totals after summation.
(c) - indicates calculated results

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Trussell Technologies, Inc.

---

**Endocrine Disruptors Negative Mode - SPE**

**Analytical Batch: 915552** **Analysis Date: 06/09/2016**

| | | |
|---|---|---|
| 201605260440 | New Vessel Permeate (1 of 2) | Analyzed by: ARH |
| 201605260441 | Old Vessel Permeate (1 of 2) | Analyzed by: ARH |
| 201605260442 | RO Feed (2 of 2) | Analyzed by: ARH |
| 201605260443 | New Vessel Permeate (2 of 2) | Analyzed by: ARH |

**Endocrine Disruptors Negative Mode - SPE**

**Analytical Batch: 915941** **Analysis Date: 06/10/2016**

| | | |
|---|---|---|
| 201605260439 | RO Feed (1 of 2) | Analyzed by: ALI |

**Endocrine Disruptors Negative Mode - SPE**

**Analytical Batch: 916586** **Analysis Date: 06/14/2016**

| | | |
|---|---|---|
| 201605260444 | Old Vessel Permeate (2 of 2) | Analyzed by: ALI |

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**Laboratory QC**
**Report: 592378**

Trussell Technologies, Inc.

| QC Type | Analyte | Native | Spiked | Recovered | Units | Yield (%) | Limits (%) | RPDLimit (%) | RPD% |
|---|---|---|---|---|---|---|---|---|---|
| **Endocrine Disruptors Negative Mode - SPE by LC-MS-MS** | | | | | | | | | |
| **Analytical Batch: 915552** | | | | | | | **Analysis Date: 06/08/2016** | | |
| LCS1 | Sucralose | | 2000 | 1950 | ng/L | 98 | (60-140) | | |
| LCS2 | Sucralose | | 2000 | 2100 | ng/L | 105 | (60-140) | 40 | 7.4 |
| MBLK | Sucralose | | | <100 | ng/L | | | | |
| MRL_CHK | Sucralose | | 100 | 149 | ng/L | 149 | (50-150) | | |
| MS_201605200447 | Sucralose | 44000 | 20000 | 34400 | ng/L | **1720** | (60-140) | | |
| MSD_201605200447 | Sucralose | 44000 | 20000 | 40500 | ng/L | **2020** | (60-140) | 40 | 16 |
| **Endocrine Disruptors Negative Mode - SPE by LC-MS-MS** | | | | | | | | | |
| **Analytical Batch: 915941** | | | | | | | **Analysis Date: 06/08/2016** | | |
| LCS1 | Sucralose | | 2000 | 2020 | ng/L | 101 | (60-140) | | |
| LCS2 | Sucralose | | 2000 | 2170 | ng/L | 108 | (60-140) | 40 | 7.2 |
| MBLK | Sucralose | | | <100 | ng/L | | | | |
| MRL_CHK | Sucralose | | 100 | 118 | ng/L | 119 | (50-150) | | |
| MS_201605260515 | Sucralose | ND | 2000 | 2100 | ng/L | 105 | (60-140) | | |
| MSD_201605260515 | Sucralose | ND | 2000 | 2180 | ng/L | 105 | (60-140) | 40 | 3.7 |
| **Endocrine Disruptors Negative Mode - SPE by LC-MS-MS** | | | | | | | | | |
| **Analytical Batch: 916586** | | | | | | | **Analysis Date: 06/14/2016** | | |
| LCS1 | Sucralose | | 2000 | 1880 | ng/L | 94 | (60-140) | | |
| LCS2 | Sucralose | | 2000 | 2270 | ng/L | 113 | (60-140) | 40 | 18 |
| MBLK | Sucralose | | | <100 | ng/L | | | | |
| MRL_CHK | Sucralose | | 100 | 68.4 | ng/L | 68 | (50-150) | | |
| MS_201605260444 | Sucralose | 5700 | 2000 | 8850 | ng/L | **156** | (60-140) | | |
| MSD_201605260444 | Sucralose | 5700 | 2000 | 9270 | ng/L | **177** | (60-140) | 40 | 4.6 |

Spike recovery is already corrected for native results.
Spikes which exceed Limits and Method Blanks with positive results are highlighted by Underlining.
Criteria for MS and Dup are advisory only, batch control is based on LCS. Criteria for duplicates are advisory only, unless otherwise specified in the method.
RPD not calculated for LCS2 when different a concentration than LCS1 is used.
RPD not calculated for Duplicates when the result is not five times the MRL (Minimum Reporting Level).
(S) - Indicates surrogate compound.
(I) - Indicates internal standard compound.

## SUGAR CHALLENGE TESTING TOC RESULTS

| | | Test # | RO Feed | | | | Vessel 5, Stage 1 | | Stage 1 | | Stage 2 | | | | | | Train | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | TOC measured (grab) | STDEV | Dilution factor | TOC (grab) | TOC (grab) | STDEV | TOC (grab) | STDEV | TOC feed measured (grab) | STDEV | Dilution factor | TOC (grab) | TOC permeate (grab) | STDEV | TOC (grab) | STDEV |
| AGED HYDRANAUTICS ESPA2 LD | ROUND 1 (3/2/16) | Control | 1340 | 0.00 | 100 | 134000 | 175 | 1.53 | 176 | 4.58 | | | | 278667 | 1100 | | 469 | 1.53 |
| | | Test 1 | 1330 | 0.00 | 100 | 133000 | 16100 | 57.7 | 1960 | 0.00 | | | | 274658 | 1266 | | 1740 | 5.77 |
| | | Test 2 | 1340 | 0.00 | 100 | 134000 | 183 | 1.15 | 183 | 2.08 | | | | 278660 | 1009 | | 445 | 1.53 |
| | | Test 3 | 1230 | 0.00 | 100 | 123000 | 175 | 1.53 | 167 | 1.73 | | | | 255786 | 1047 | | 446 | 1.15 |
| | ROUND 2 (3/23/16) | Blank 1 | 4840 | 5.77 | 1 | 4840 | 50.3 | 2.2 | 49.2 | 1.73 | 6900 | 66.6 | 1 | 6900 | 91 | 2.42 | 60.5 | 1.99 |
| | | Blank 2 | 4810 | 35.10 | 1 | 4810 | 47 | 2.02 | 48 | 1.71 | 6910 | 70 | 1 | 6910 | 81 | 2.40 | 57.8 | 2.17 |
| | | Control | 1200 | 5.77 | 100 | 120000 | 157 | 2.31 | 149 | 2.00 | 2640 | 5.77 | 100 | 264000 | 974 | 0.58 | 391 | 0.58 |
| | | Test 1 | 1180 | 0.00 | 100 | 118000 | 13200 | 0 | 1610 | 0.00 | 2620 | 5.77 | 100 | 262000 | 951 | 2.52 | 1430 | 0.00 |
| | | Test 2 | 1180 | 0.00 | 100 | 118000 | 211 | 2.08 | 149 | 2.08 | 2590 | 5.77 | 100 | 259000 | 949 | 1.00 | 383 | 0.58 |
| | | Test 3 | 1170 | 0.00 | 100 | 117000 | 159 | 2.31 | 142 | 1.53 | 2700 | 0.00 | 100 | 270000 | 966 | 0.00 | 390 | 1.00 |
| | ROUND 3 (3/28/16) | Blank 1 | 4950 | 26.50 | 1 | 4950 | 43.7 | 2.23 | 42.8 | 2.34 | 7400 | 72.3 | 1 | 7400 | 83 | 2.40 | 56.3 | 2.19 |
| | | Blank 2 | 4920 | 20.80 | 1 | 4920 | 44.9 | 2.06 | 44.7 | 1.96 | 7430 | 63.5 | 1 | 7430 | 84 | 2.29 | 56.9 | 2.17 |
| | | Control | 1270 | 5.77 | 100 | 127000 | 164 | 2.08 | 146 | 1.73 | 2790 | 0.00 | 100 | 279000 | 996 | 1.53 | 399 | 1.73 |
| | | Test 1 | 1290 | 0.00 | 100 | 129000 | 13700 | 0 | 1810 | 5.77 | 2730 | 5.77 | 100 | 273000 | 999 | 0.58 | 1470 | 0.00 |
| | | Test 2 | 1210 | 0.00 | 100 | 121000 | 236 | 2.08 | 155 | 1.73 | 2710 | 0.00 | 100 | 271000 | 1000 | 5.77 | 410 | 1.73 |
| | | Test 3 | 1230 | 0.00 | 100 | 123000 | 177 | 1.73 | 150 | 1.73 | 2710 | 0.00 | 100 | 271000 | 1010 | 0.00 | 405 | 1.73 |
| UNUSED HYDRANAUTICS ESPA2 LD | ROUND 1 (4/22/16) | Blank 1 | 5360 | 5.77 | 1 | 5360 | 51.5 | 2.71 | 58.1 | 3.69 | | | | | 135 | 3.79 | 76.4 | 2.16 |
| | | Blank 2 | | | | | 42 | 2.15 | 42.3 | 2.65 | 6410 | 69.3 | 1 | 6410 | 112 | 1.00 | 60.9 | 2.12 |
| | | Control | 2590 | 13.40 | 100 | 259000 | 277.5 | 2.37 | 286 | 2.65 | 4490 | 212 | 100 | 449000 | 2340 | 5.77 | 873 | 3.61 |
| | | Test 3 | 2345 | 5.77 | 100 | 234500 | 274 | 2.65 | 277 | 2.08 | 4200 | 58.6 | 100 | 420000 | 2150 | 0.00 | 811 | 2.31 |
| | ROUND 2 (4/26/16) | Blank 1 | 4610 | 130 | 1 | 4610 | 60.8 | 2.9 | 48.9 | 0.88 | 5690 | 134 | 1 | 5690 | 118 | 3.21 | 69.4 | 1.20 |
| | | Blank 2 | 4210 | 86.6 | 1 | 4210 | 42 | 1.17 | 39.9 | 2.54 | 5220 | 107 | 1 | 5220 | 108 | 1.00 | 58 | 1.31 |
| | | Control | 1460 | 5.77 | 100 | 146000 | 189 | 2.65 | 191 | 1.73 | 3380 | 5.77 | 100 | 338000 | 1460 | 10.0 | 566 | 1.15 |
| | | Test 1 | 1530 | 17.3 | 100 | 153000 | 10002 | 57.70 | 1420 | 0.00 | 3210 | 23.1 | 100 | 321000 | 1350 | 0.00 | 1610 | 0.00 |
| | | Test 2 | 1370 | 10.0 | 100 | 137000 | 624 | 1.15 | 219 | 1.53 | 3070 | 20.0 | 100 | 307000 | 1280 | 0.00 | 550 | 0.58 |
| | | Test 3 | 1340 | 17.3 | 100 | 134000 | 174 | 2.52 | 180 | 2.08 | 2930 | 5.8 | 100 | 293000 | 1290 | 5.77 | 501 | 0.58 |
| | ROUND 3 (4/26/16) | Blank 1 | 4110 | 131 | 1 | 4110 | 44.6 | 1.03 | 42.3 | 0.62 | 5140 | 95 | 1 | 5140 | 106 | 2.52 | 58.9 | 2.26 |
| | | Blank 2 | 4070 | 247.0 | 1 | 4070 | 41.1 | 1.03 | 41 | 2.79 | 5130 | 60.3 | 1 | 5130 | 97.8 | 3.69 | 56.9 | 2.71 |
| | | Control | 1320 | 5.77 | 100 | 132000 | 182 | 2.65 | 191 | 1.73 | 3100 | 10.00 | 100 | 310000 | 1430 | 0.0 | 566 | 1.53 |
| | | Test 1 | 1430 | 5.8 | 100 | 143000 | 10600 | 57.7 | 1730 | 0.00 | 3240 | 10.0 | 100 | 324000 | 1480 | 5.77 | 1670 | 0.00 |
| | | Test 2 | 1400 | 7.1 | 100 | 140000 | 9290 | 75.10 | 1310 | 6.77 | 3200 | 11.3 | 100 | 320000 | 1470 | 0.00 | 1410 | 0.00 |
| | | Test 3 | 1440 | 5.77 | 100 | 144000 | 188 | 2.65 | 203 | 0.59 | 3270 | 15.3 | 100 | 327000 | 1490 | 5.77 | 571 | 0.00 |
| VIRGIN TORAY TMG20D-400 | ROUND 1 (8/5/16) | Blank 1 | 6500 | 20.80 | 1 | 6500 | 25.6 | 0.95 | 25 | 0.49 | 10400 | 2690 | | | 35 | 1.62 | 27.9 | 0.32 |
| | | Blank 2 | 5920 | 10.00 | 1 | 5920 | 31.5 | 1.81 | 32.5 | 2.10 | 11100 | 153 | 1 | 11100 | 45 | 2.14 | 48.8 | 3.56 |
| | | Control | 764 | 0.58 | 100 | 76400 | 73.1 | 1.70 | 77.5 | 2.49 | 838 | 2.1 | 100 | 83800 | 143 | 1.15 | 96.9 | 0.81 |
| | | Test 1 | 751 | 1.15 | 100 | 75100 | 5500 | 5.77 | 660 | 1.00 | 1510 | 2.1 | 100 | 151000 | 152 | 2.65 | 529 | 1.53 |
| | | Test 3 | 714 | 2.52 | 100 | 71400 | 7990 | 2.65 | 934 | 2.08 | 1500 | 5.8 | 100 | 150000 | 153 | 0.00 | 811 | 2.31 |
| | ROUND 2 (8/12/16) | Blank 1 | 6690 | 0.00 | 1 | 6690 | 35 | 1.66 | 35.3 | 1.74 | 12000 | 100 | 1 | 12000 | 57 | 2.26 | 40.9 | 1.76 |
| | | Control | 762 | 4.73 | 100 | 76200 | 86.3 | 1.65 | 103 | 1.15 | 1620 | 0.0 | 100 | 162000 | 148 | 1.00 | 106 | 1.53 |
| | | Test 1 | 746 | 1.53 | 100 | 74600 | 5740 | 0.00 | 657 | 1.15 | 1570 | 5.8 | 100 | 157000 | 165 | 1.15 | 544 | 3.51 |
| | | Test 3 | 731 | 2 | 100 | 73100 | 6980 | 0.00 | 744 | 3.61 | 1530 | 1.3 | 100 | 153000 | 164 | 2.08 | 633 | 0.58 |

**TEST 1: FEED ENDCAP COMPROMISE**
**TEST 2: BRINE ENDCAP COMPROMISE**
**TEST 3: INTERCONNECTOR COMPROMISE**

# Appendix B – Wet test results from aged ESPA2 LD elements

# O.S.C.A.R. RESULTS

Avista TECHNOLOGIES
*Creative Chemistry. Smart Solutions.*

## Customer Information:

**Name:** Trussell Technologies, Inc.
**End User:** Trussell Tech c/o NCWRP
**Date:** 5/3/16
**Customer PO:** 24.010-3-RT-4/19
**Work Order No:** 041916-3
**Membranes Cleaned:** 7

**Cleaners Used:**
RoClean L403
RoClean P112

**Preserve Chemical**

**Hydranautics ESPA2-LD**

**Normalized Conditions:**
Temperature, °C:
Net Driving Pressure, psig: 130
Original Recovery % Spec: 15

**Manufacturer Specifications:**
Flow Rate: 5.9 to 7.9
% Rejection: 99.5% to 99.6%

| Serial Number | Test | Delta Pressure psi | Normalized Results | | Notes |
|---|---|---|---|---|---|
| | | | Flow, gpm | Rejection, % | |
| SOY32365 | Pre Clean | 3 | 4.57 | 98.9 | |
| | Post Clean | 3 | 6.55 | 99.1 | |
| SOY33245 | Pre Clean | 3 | 4.30 | 99.2 | |
| | Post Clean | 3 | 7.10 | 99.1 | |
| SOY34055 | Pre Clean | 3 | 4.55 | 99.0 | |
| | Post Clean | 3 | 7.23 | 99.1 | |
| SOY34065 | Pre Clean | 3 | 4.57 | 98.9 | |
| | Post Clean | 3 | 7.19 | 99.1 | |
| SOY35455 | Pre Clean | 3 | 4.87 | 98.8 | |
| | Post Clean | 3 | 6.92 | 99.0 | |
| SOY35925 | Pre Clean | 3 | 4.56 | 99.0 | |
| | Post Clean | 3 | 6.40 | 99.1 | |
| SOY36095 | Pre Clean | 3 | 4.54 | 98.8 | |
| | Post Clean | 3 | 6.65 | 99.1 | |

Thank You For Your Business!


Avista Technologies, 140 Bosstick Blvd, San Marcos, CA 92069
Phone: 760 744-0536 | Fax: 760 744-0619 | www.avistatech.com

# Appendix C – WERF 14-12 Webcast

**Presentation title: Demonstrating Redundancy and Monitoring to Achieve Reliable Potable Reuse**

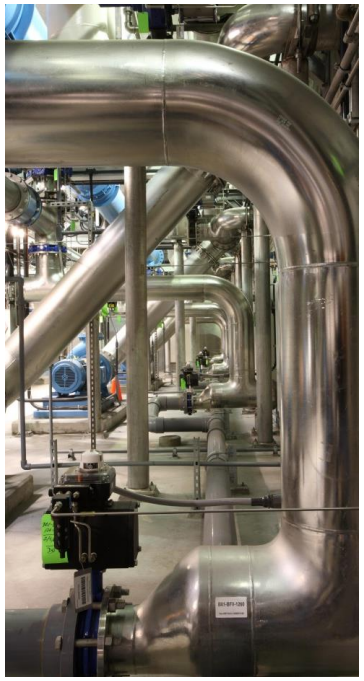
**Date: 11/10/16**

**Location: Water Environment & Research Foundation (WERF) webcast**

**Notes: only relevant slides are provided**

# Demonstrating Redundancy and Monitoring to Achieve Reliable Potable Reuse

Shane Trussell, Ph.D., P.E.
Brian Pecson, Ph.D., P.E
Aleksey Pisarenko, Ph.D.
Rodrigo Tackaert



WATEREUSE

WATER ENVIRONMENT & REUSE FOUNDATION WE&RF

Trussell TECHNOLOGIES INC

# A Few Notes Before We Start…

- Today's webcast will be 90 minutes.
- There is one and a half Professional Development Hour available.
- A PDF of today's presentation can be downloaded when you complete the survey at the conclusion of this webcast.
- If you have questions for the presenters please send a message by typing it into the chat box located on the panel on the left side of your screen.
- If you would like to enlarge your view of the slides, please click the Full Screen button in the upper right corner of the window. To use the chat box, you must exit full screen.

# Introductions

Jeffrey Pasek
Moderator
City of San Diego

Shane Trussell
Project Manager
Trussell Tech

Brian Pecson
Project Engineer
Trussell Tech

Aleks Pisarenko
Project Engineer
Trussell Tech

Rodrigo Tackaert
Project Engineer
Trussell Tech

# California's Big Question

Division of Drinking Water
(DDW)

*Is it <u>feasible</u> to do potable reuse without an environmental buffer (DPR)?*

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Division of Drinking Water (DDW)

*Is it <u>feasible</u> to do potable reuse without an environmental buffer (DPR)?*

# California's Big Question

Division of Drinking Water (DDW)

*Is it <u>feasible</u> to do potable reuse without an environmental buffer (DPR)?*

**KEY QUESTION**

*Can we do DPR <u>safely</u>?*

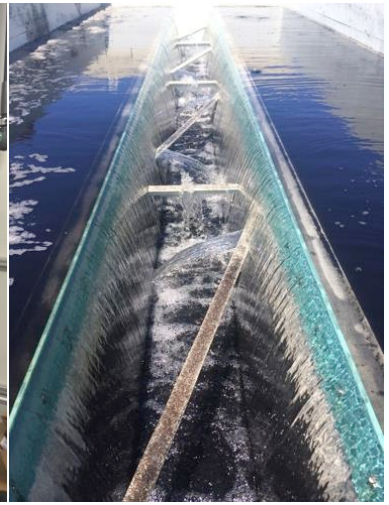
# California Direct Potable Reuse Initiative

- Began in 2012 and has raised more than $6M for research to develop information for the State Expert Panel
- WRRF 14-12 is a $2M project funded by CA DWR

# WRRF 14-12 Builds on Previous Investments

1. San Diego Constructed 1 MGD Full Advanced Treatment Train at Demonstration Scale in June 2011 ($6.5M)

City of San Diego
PUBLIC UTILITIES
Water & Wastewater



2. Ozone/BAC Pretreatment with Additional Monitoring Equipment Commissioned in July 2014 ($1.5M)

# Project Team

- Operations, Test Plans, Reporting, Data Analysis
  - Shane Trussell
  - Rhodes Trussell
  - Aleks Pisarenko
  - Eileen Idica
  - Brian Pecson
  - Elaine Howe
  - Elise Chen
  - Sarah Triolo
  - Rodrigo Tackaert
  - Aviv Kolakovsky
  - Anya Kaufmann
- Data Integration and Analysis
  - Simon Olivieri
- Ozone System Support
  - Kerwin Rakness (1946 to 2016)

# Acknowledgements

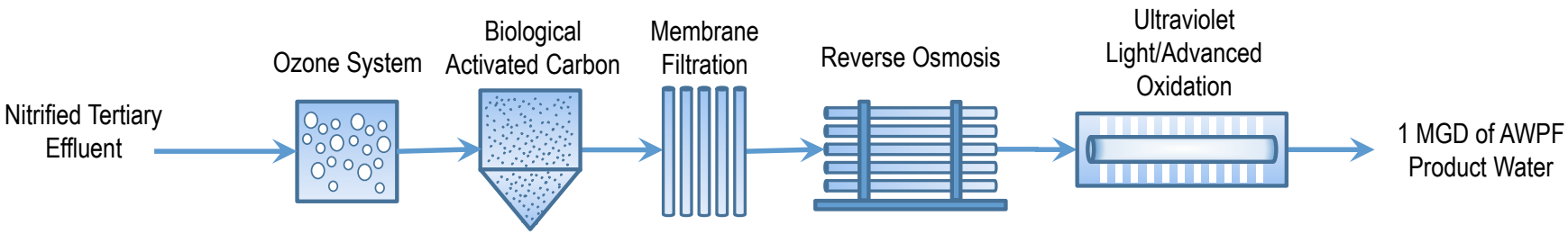
- City of San Diego Public Utilities
- Water Environment and Reuse Foundation
- California Department of Water Resources
- U.S. Bureau of Reclamation
- San Diego County Water Authority
- Padre Dam Municipal Water District
- Helix Water District

*The project team gratefully acknowledges the WateReuse Research Foundation's financial, technical, and administrative assistance in funding and managing the project through which this information was discovered, developed, and presented. The project team further wishes to acknowledge the State of California Department of Water Resources for its grant award in support of this project as well as the San Diego County Water Authority for its support in the administration of the project funding.*

# Project Goal

To leverage industry “state of the art” to demonstrate how a combination of treatment redundancy and enhanced monitoring techniques can *reliably* achieve potable reuse treatment objectives

# Demonstration Facility Treatment Train




***Step 1*** – Ozone disinfection

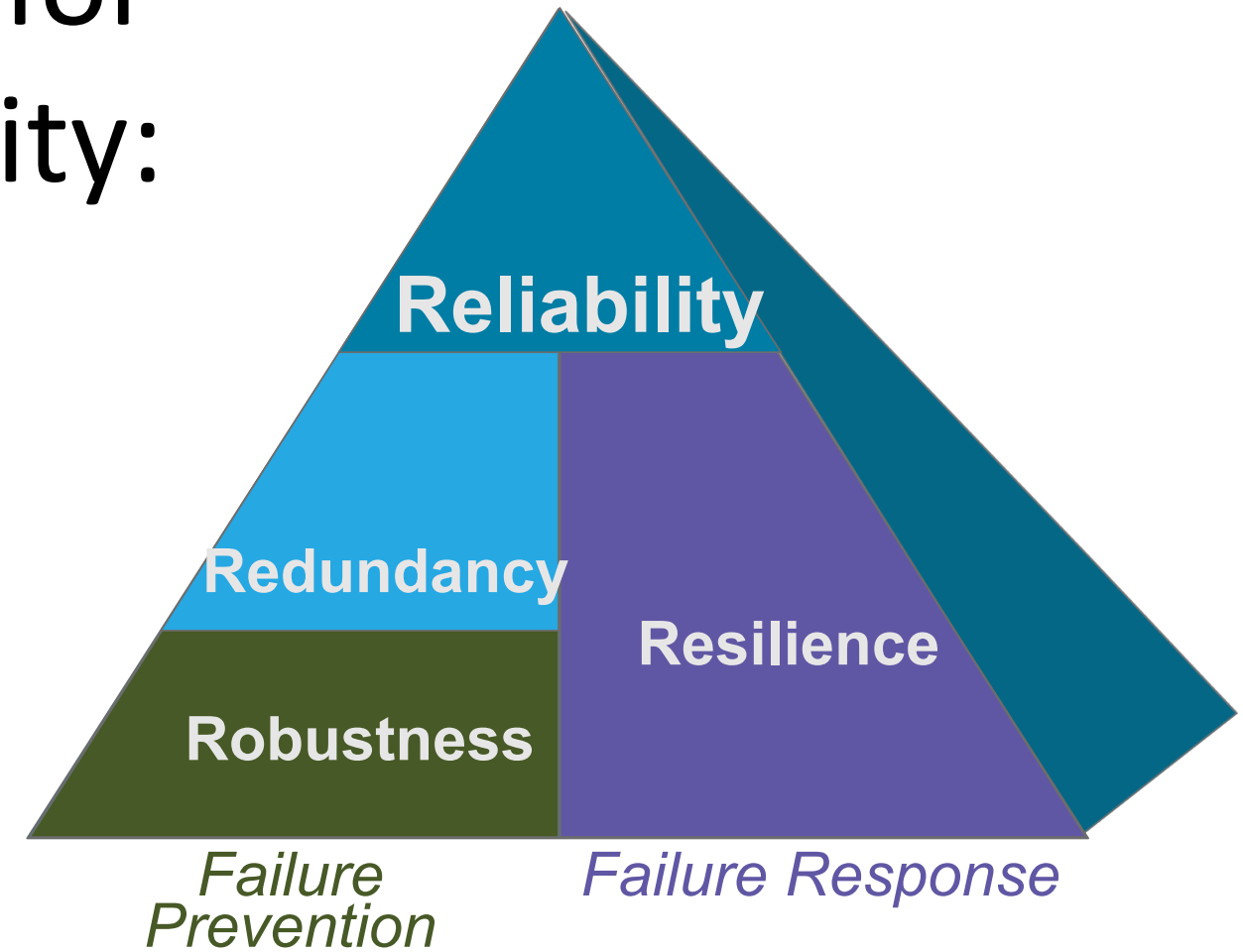
***Step 2*** – Biological activated carbon

***Step 3*** – Membrane filtration

***Step 4*** – Reverse osmosis

***Step 5*** – UV advanced oxidation

# Framework for DPR Reliability: the 4Rs




Pecson, B.M., Trussell, R.S., Pisarenko, A.N. and Trussell, R.R. (2015) Achieving reliability in potable reuse: The four Rs. J. - Am. Water Works Assoc. 107(3), 48-58.

# Failure Prevention: Redundancy

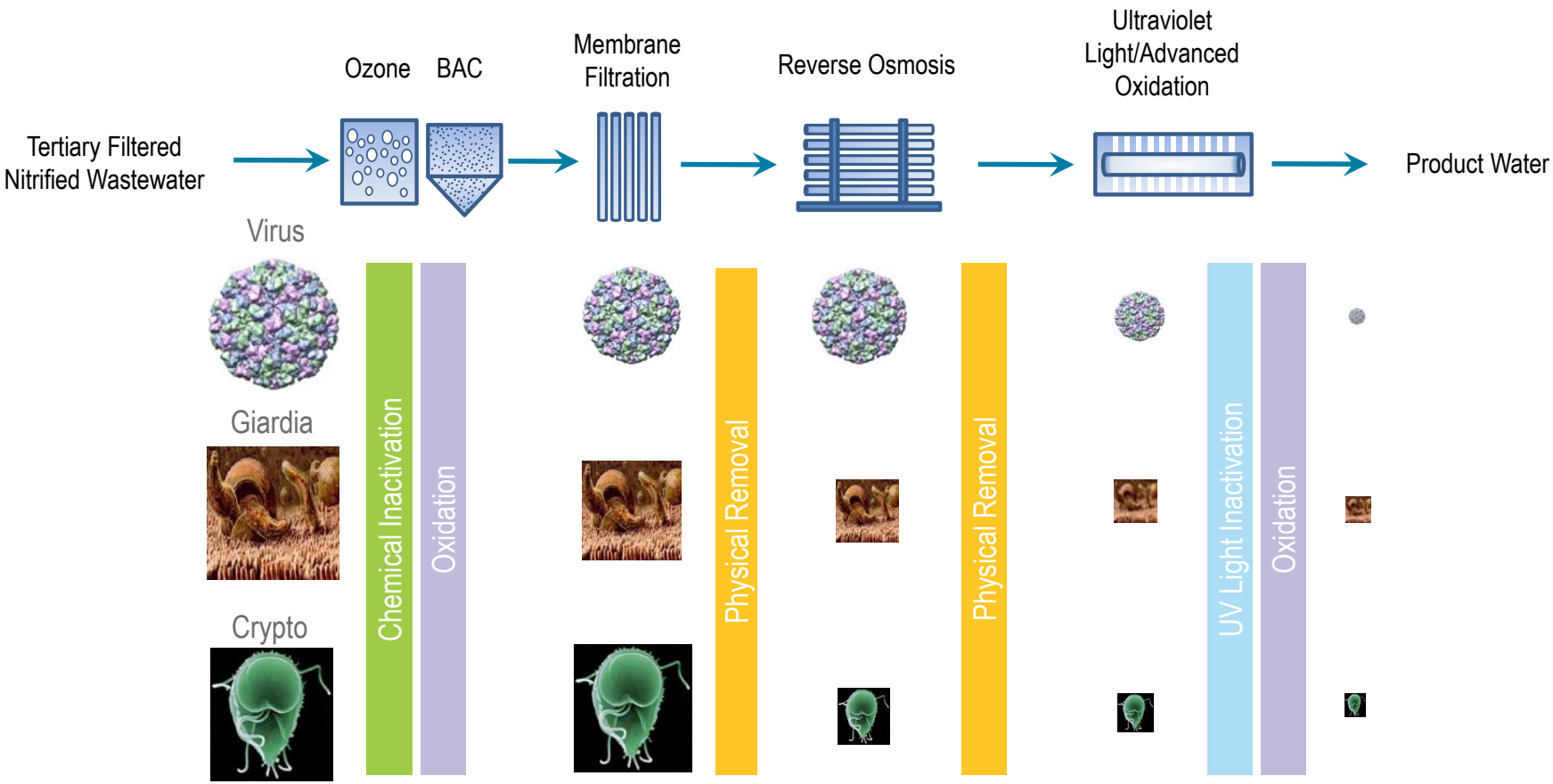
- Theory: *the use of measures beyond minimum requirements to ensure that treatment goals are more reliably met or that performance can be more reliably demonstrated*
- Practice: AWPF provides treatment beyond 12/10/10

| Pathogen | $O_3$/BAC | MF/UF | RO | UV/AOP | Total |
|---|---|---|---|---|---|
| Virus | 6 | 0 | 2 | 6 | **14** |
| *Giardia* | 6 | 4 | 2 | 6 | **18** |
| *Crypto* | 2 | 4 | 2 | 6 | **14** |

- Benefits
  - Excursions and failures do not jeopardize public health
  - Treatment redundancy protective against multiple types of failure
  - Provides high degree of operational flexibility

# Failure Prevention: Robustness

- Multiple & diverse barriers protect against spectrum of pathogens

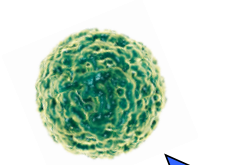


# Failure Response: Online Monitoring Data

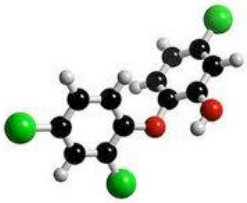
| | Ozone | BAC | MF | RO | UV/AOP |
|---|---|---|---|---|---|
| Critical Control Points | $DO_3$ (x3) | -- | Turb. (Eff)<br>PDT | Δ TOC<br>Δ Cond. | UV Intensity<br>Power<br>UVT |
| Operational Metrics | UVT (Inf)<br>UVT (Eff)<br>Turb. (Inf)<br>Turb. (Eff) | TOC (Inf)<br>TOC (Eff)<br>UVT (Eff)<br>Turb. (Eff) | $tCl_2$ (Eff)<br>TMP | ORP (Inf)<br>Temp (Inf) | $tCl_2$ (Inf)<br>$tCl_2$ (Eff)<br>UVT (Inf) |

# Acute vs. Chronic Contaminants

- Pathogen control is most important for public health protection
- Why is this the case?



Norovirus



Triclosan

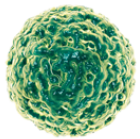
*One time exposure*

*Lifetime Exposure*

# Task 1: Quantify Treatment Train Reliability

- Document the reliability of treatment barrier for one (1) year
  - Collect data every 10 seconds for analysis
  - Document treatment anomalies and cause
  - Engage the California Division of Drinking Water on basis for pathogen removal credit for each process
  - Focus is on acute contaminants → pathogens

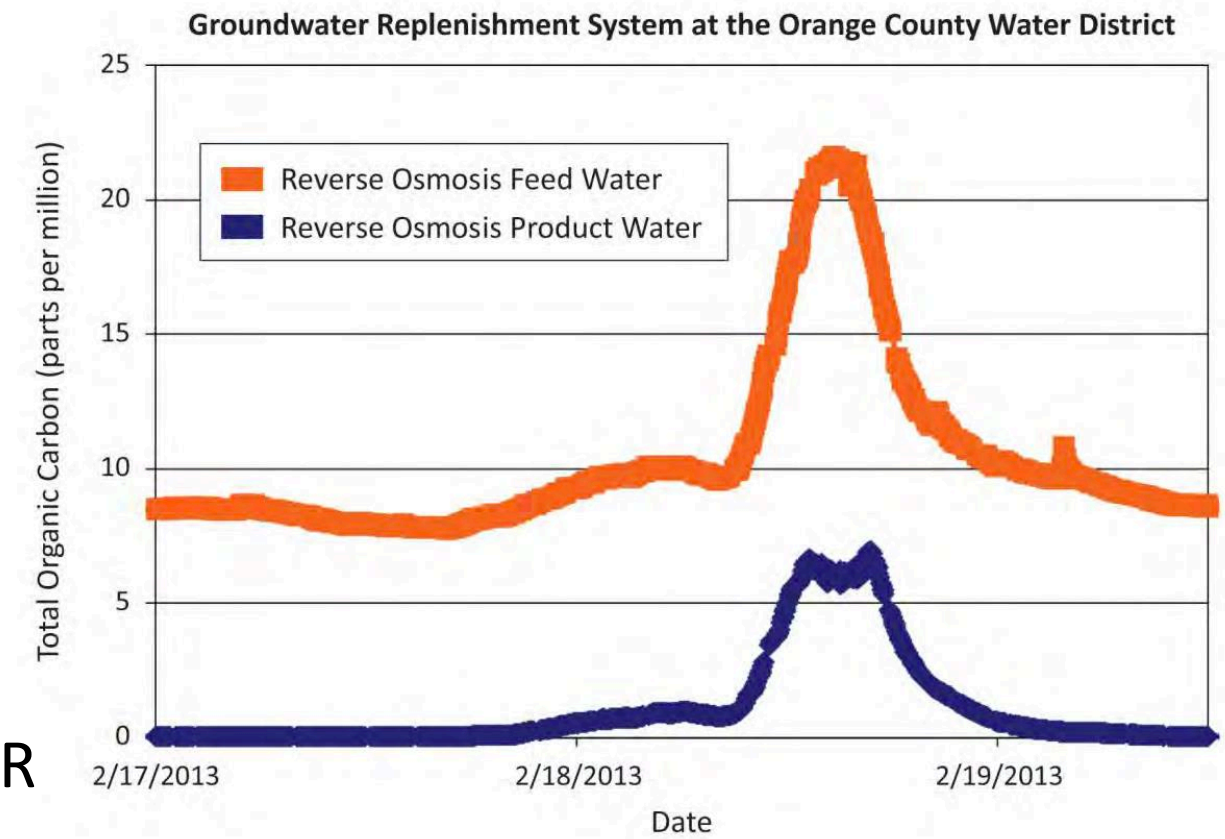
Norovirus



| Log Removal | | |
|---|---|---|
| Virus | Giardia | Crypto |
| 12 | 10 | 10 |

# Low Molecular Weight Organics

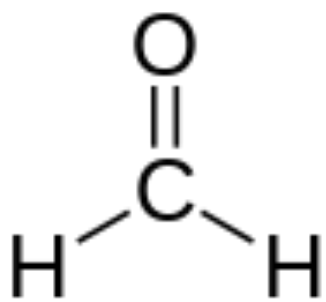
- Full advanced treatment is an effective barrier for organics attenuation
- Yet, our experience has shown us that certain compounds can remain a challenge
- Not an issue for IPR, but this may be an issue for DPR



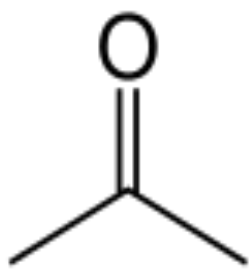

Olivieri, et al. 2016

# Task 2: Challenge Tests with Low Molecular Weight Organics

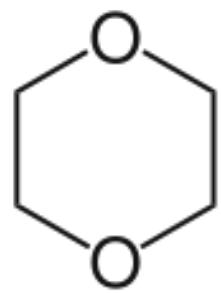
- Spike chemical mixtures ahead of FAT train both with and without $O_3$/BAC pretreatment
- Evaluate UV/$Cl_2$ and UV/$H_2O_2$ effectiveness as AOP



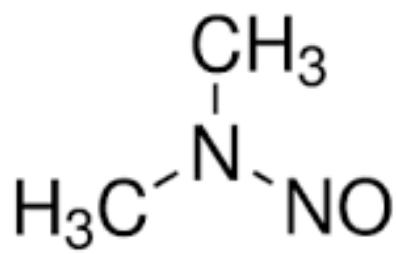

Formaldehyde




Acetone



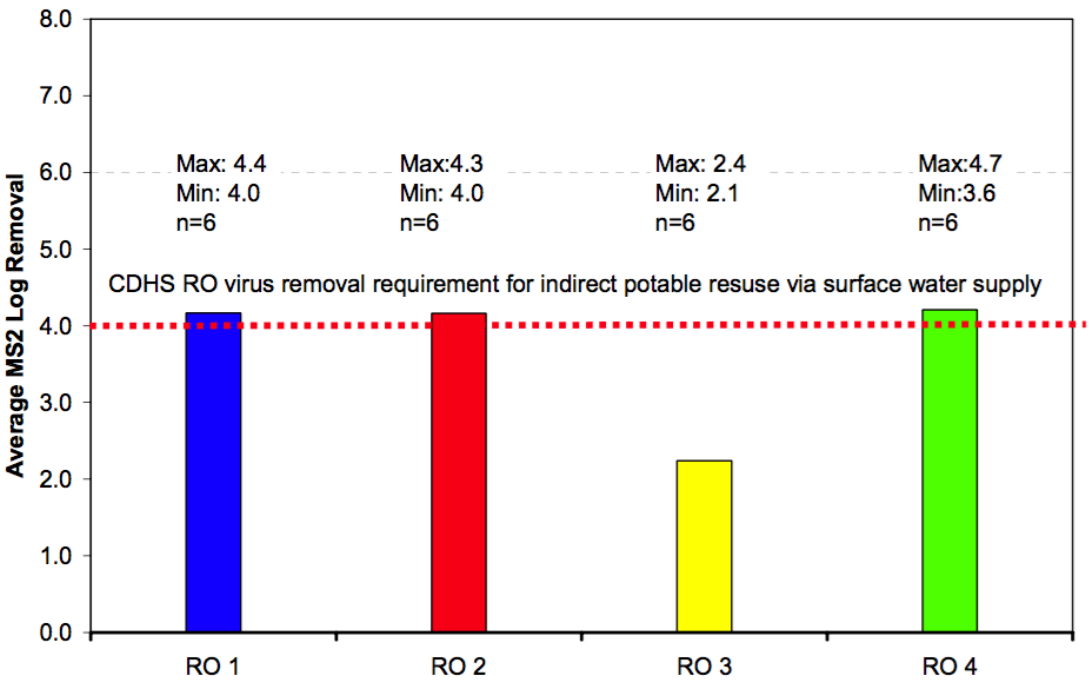

1,4-dioxane




NDMA

# Surrogates and Log Removal for Reverse Osmosis

- Reverse osmosis has proven challenging to establish pathogen removal credits
- Demonstrated virus removal varies in literature
- WRRF 12-07 identified compromised o-rings as a significant potential system breach
- Trasar® has shown promise

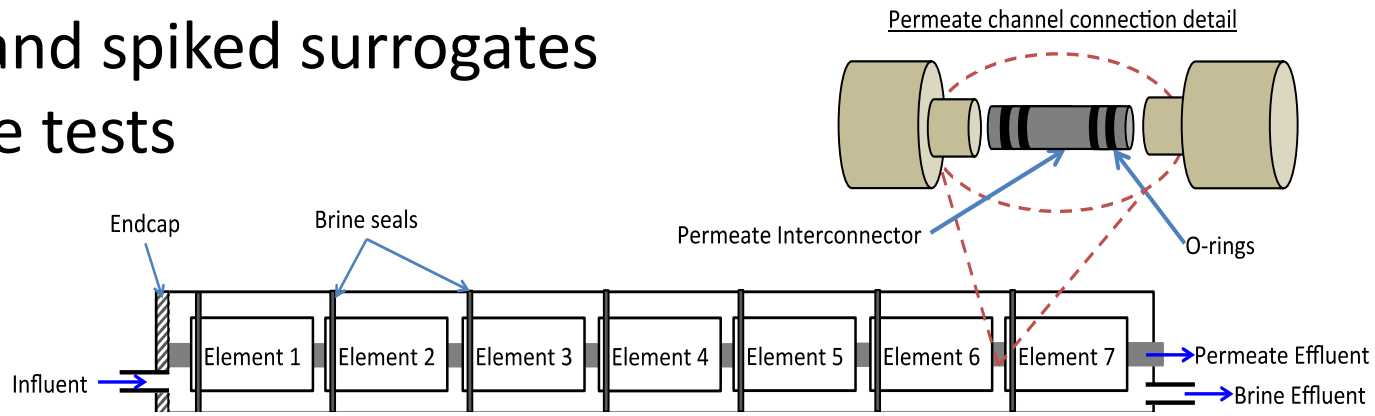



Decarolis, et al. 2006

| MS2 Log Removal (Flat Sheet) - Adham et al., 1998 | | |
|---|---|---|
| A | B | C |
| >6.5 | 5.6 | 2.7 |

# Task 3: RO Challenge Tests with MS2 and Surrogates

- Goal was to build on published research
- Perform MS2 challenge tests
  - Intact system
  - Compromised system
  - Document log removal at vessel, stage and train on 8-inch elements
- Evaluate ambient and spiked surrogates with MS2 challenge tests

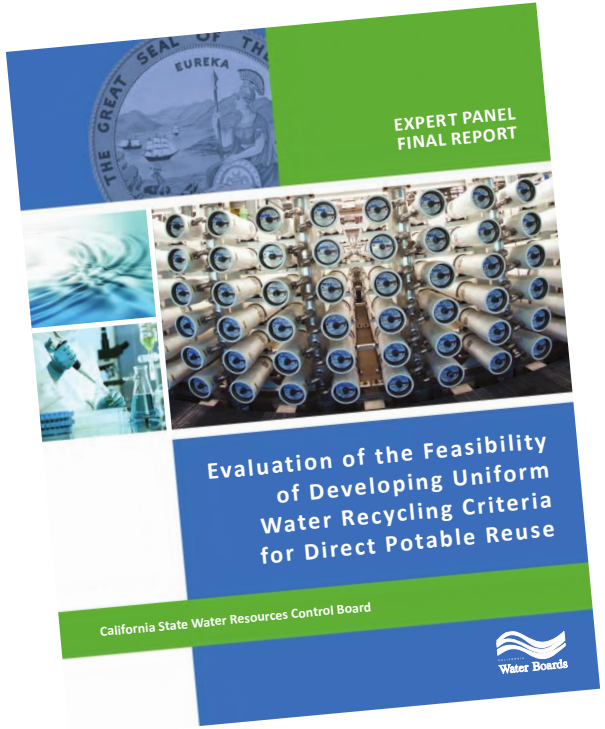


# Other Major Research Tasks in WRRF 14-12

- Document MF/UF performance at increased flux rates with $O_3$/BAC pretreatment
- Confirm USEPA table for ozone inactivation of *Crypto* at bench-scale with recycled water and surface water
- Document ozone residual meter reliability, required maintenance and factors that influence performance
- Evaluate the use of total chlorine analyzers and/or a free chlorine analyzer for UV/$Cl_2$ for AOP
- Document product water quality for drinking water

# Conclusions

- California State Expert Panel concluded that it is feasible to create uniform regulations for DPR



# Today's Webcast

- Task 1 on Reliability by Dr. Brian Pecson
- Task 2 on Low Molecular Weight Organics by Dr. Aleks Pisarenko
- Task 3 on RO Integrity Monitoring by Rodrigo Tackaert

Rodrigo Tackaert

# TASK 3: RO CHALLENGE TESTS WITH MS2 AND SURROGATES

# 14-12 RO Integrity work

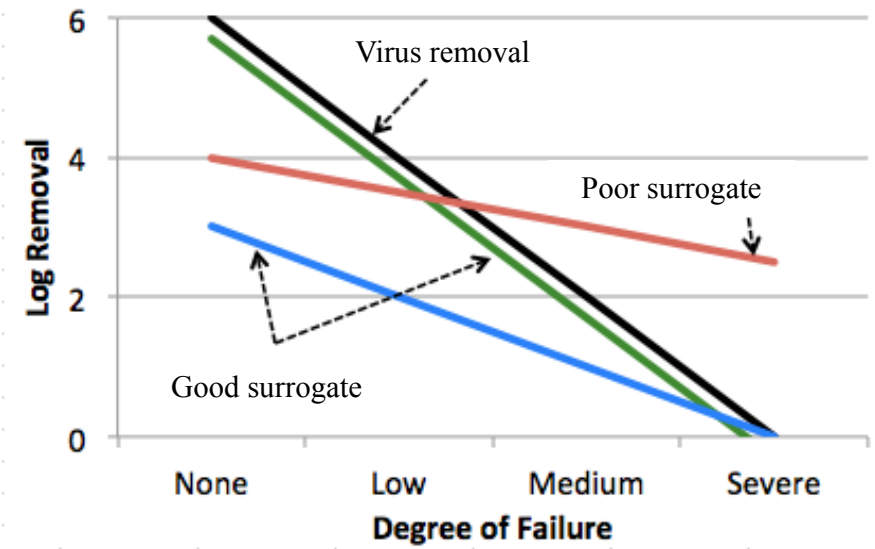
To provide a better understanding of existing and potentially more sensitive methodologies for monitoring and validating reverse osmosis pathogen removal and to secure enhanced log removal credit

# Approach

(1) Evaluate intact and compromised conditions using ambient constituents to determine optimum testing conditions for full-scale challenge testing

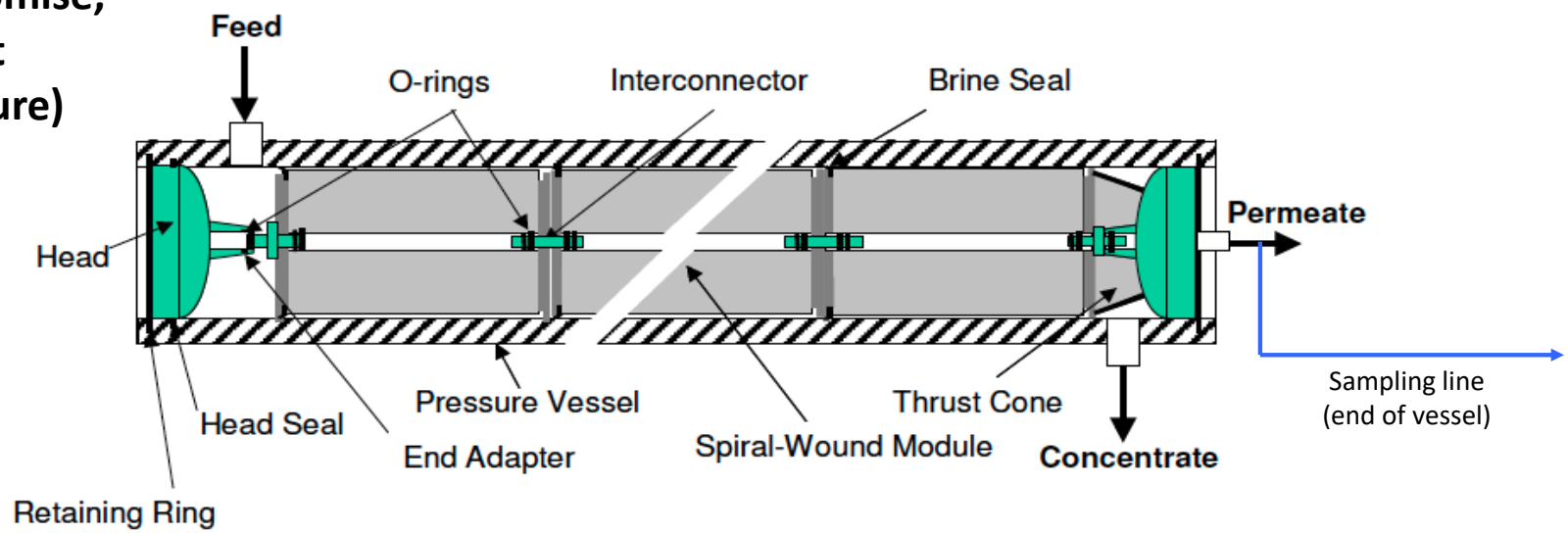
(2) MS2 challenge testing to establish degree of virus removal and ability of standard and novel surrogates to track virus removal

(3) Identify surrogates that provide enhanced LRV credit and that are conservative under both normal and compromised conditions

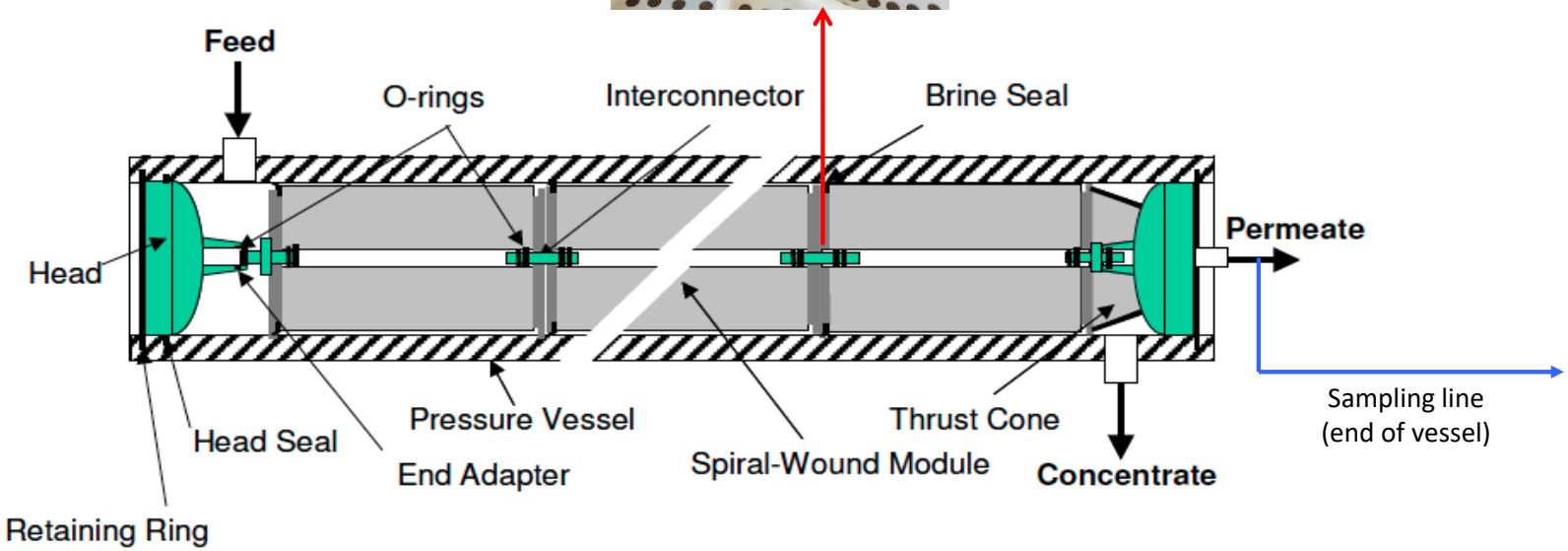


# Testing conditions for challenge testing

**Control**
**no compromise,**
**intact**
**(No failure)**

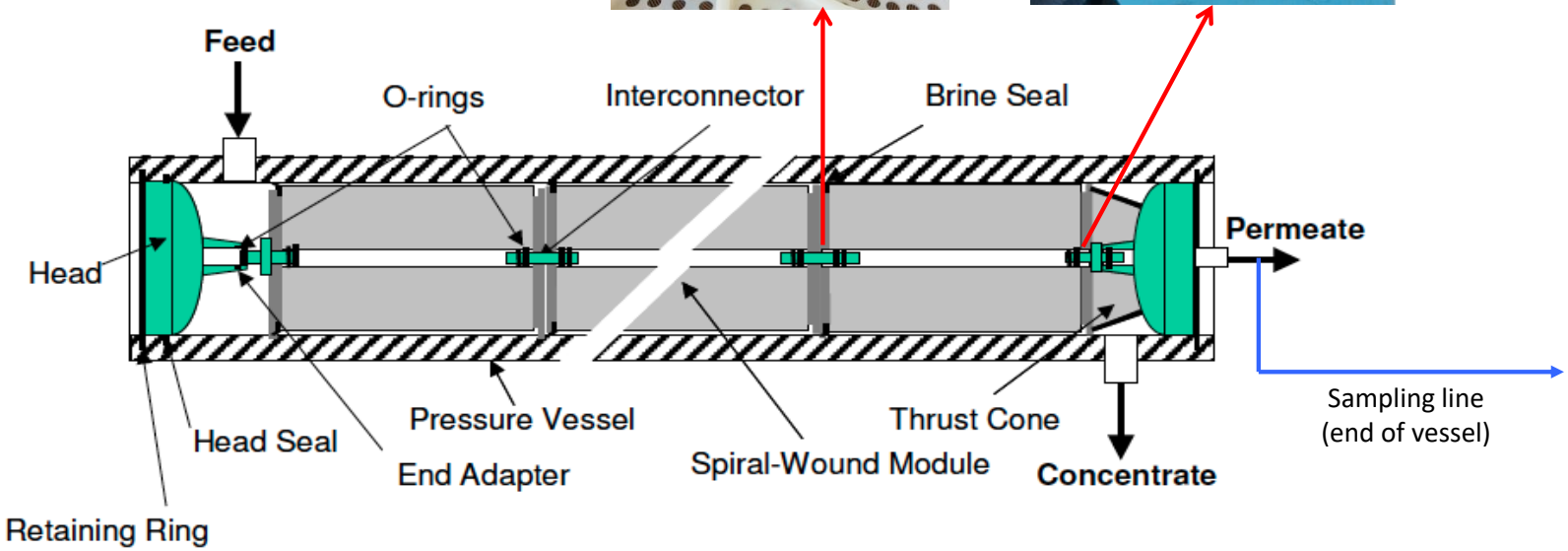


# Interconnector Compromise (Low failure)



**Interconnector Compromise (Low failure)**

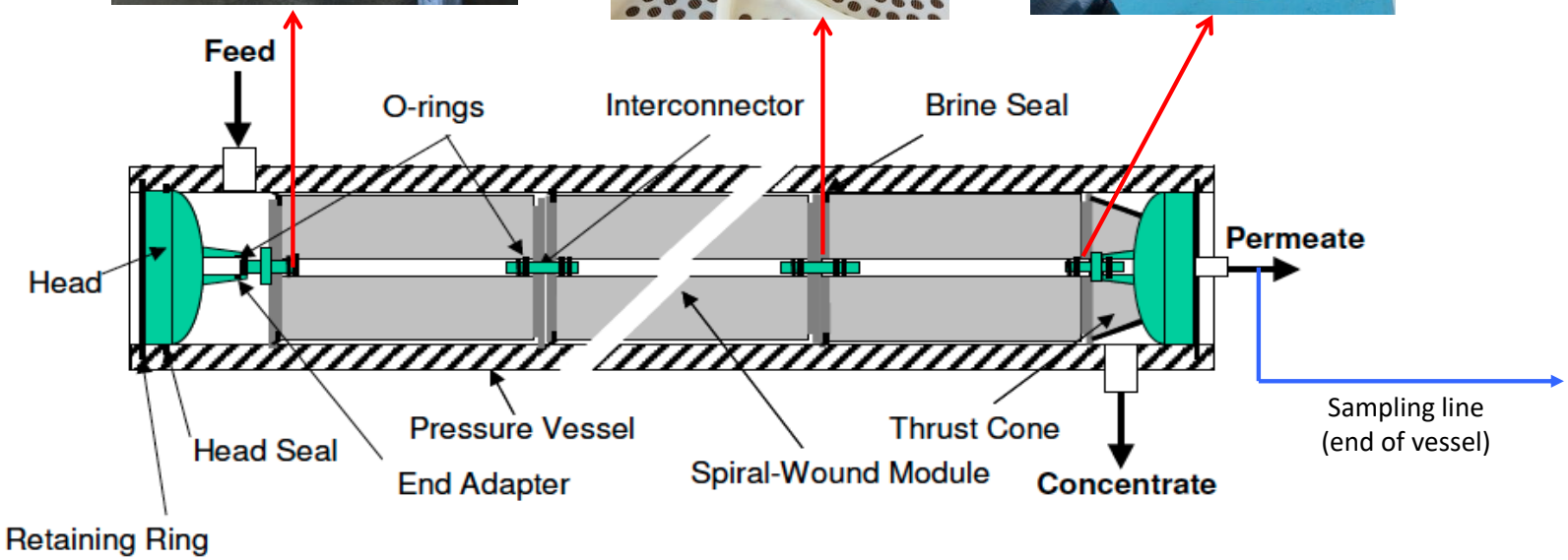
**Brine endcap Compromise (Medium failure)**



**Feed endcap Compromise (Severe failure)**

**Interconnector Compromise (Low failure)**

**Brine endcap Compromise (Medium failure)**

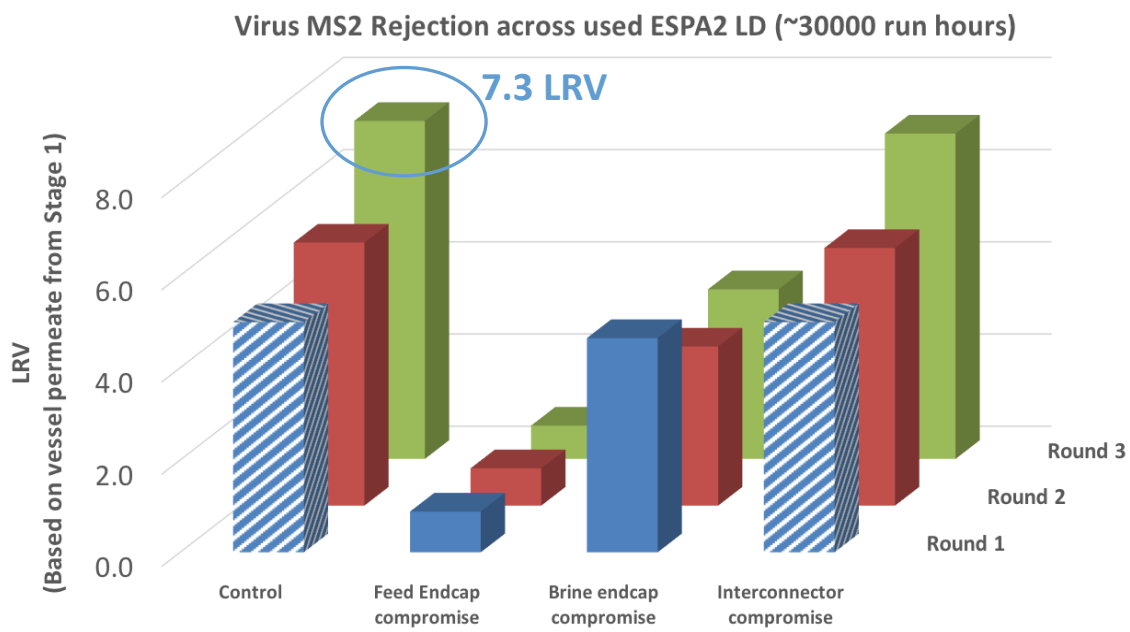


# Challenge testing

## MS2 bacteriophage

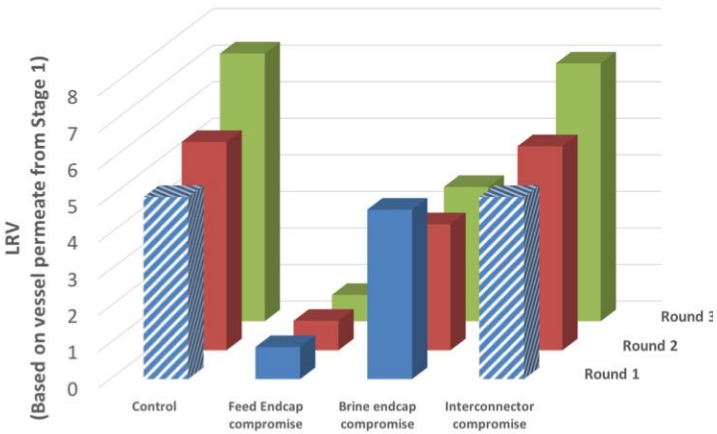
## (accepted surrogate for enteric virus)

- $10^{11}$ pfu/mL MS2 stock
- Analysis by IEH-BioVir (Benicia, CA)
- Double-layer method (Adams 1959)
  - EPA 1602 backup samples
- Target MS2 feed: $10^{6}$ pfu/mL
- Triplicate samples on vessel permeate and RO feed
- Up to 7.3 LRV
- Testing performed on three different elements



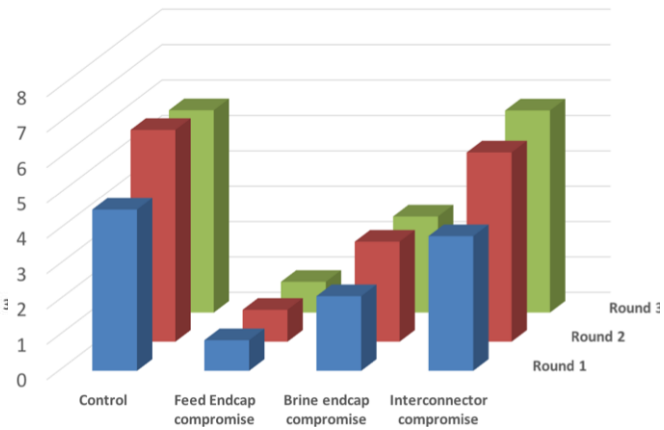

**Shaded indicates non-detect permeate samples*

## Used (aged) ESPA2 LD

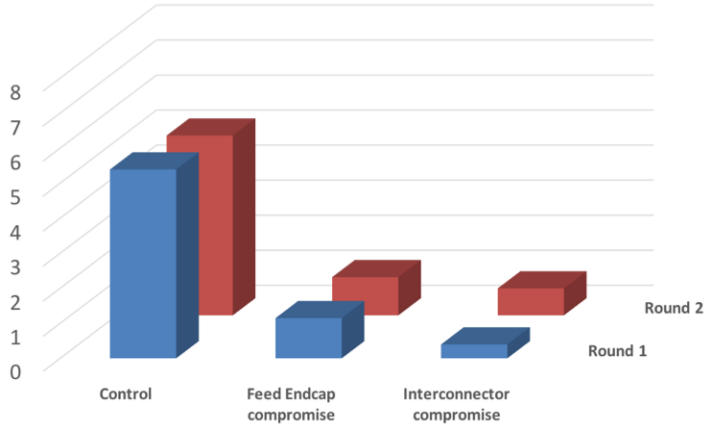



**Shaded bar indicate non-detect permeate samples*

## Unused (virgin) ESPA2 LD




## New Toray TMG20D

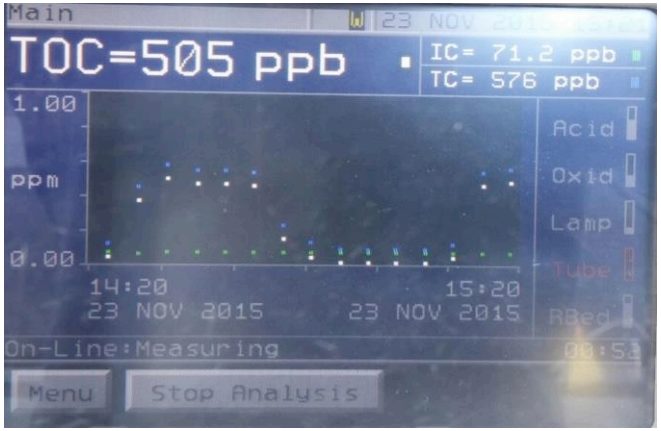



Same compromise, yet different results for elements of different manufacturers (different seals, connections…)

# Challenge testing

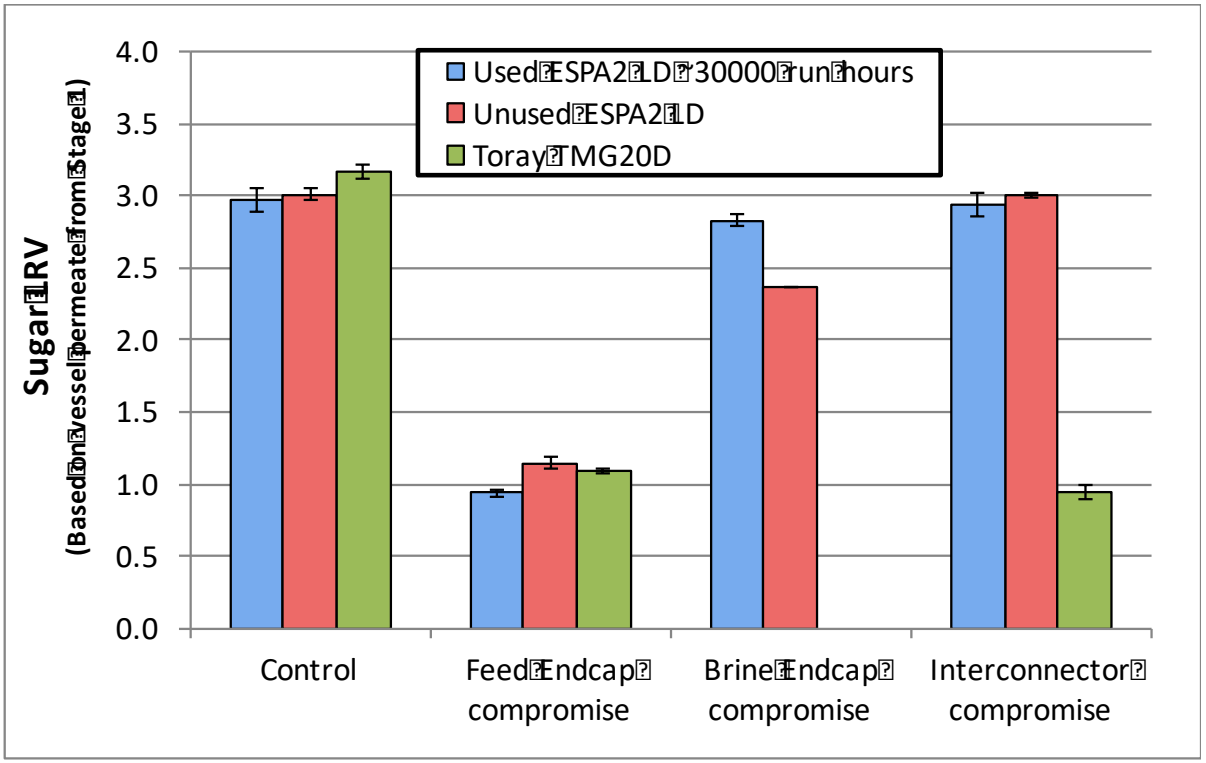
## Sugar

- 8 rounds of testing
  - Incl. testing on aged/virgin ESPA2 and new Toray's
- Feed concentration: 300-600 mg/L
  - LRV determined by ΔTOC using on-site TOC meter
  - Grab samples collected in certified GE® TOC vials



# Challenge testing

## Sugar

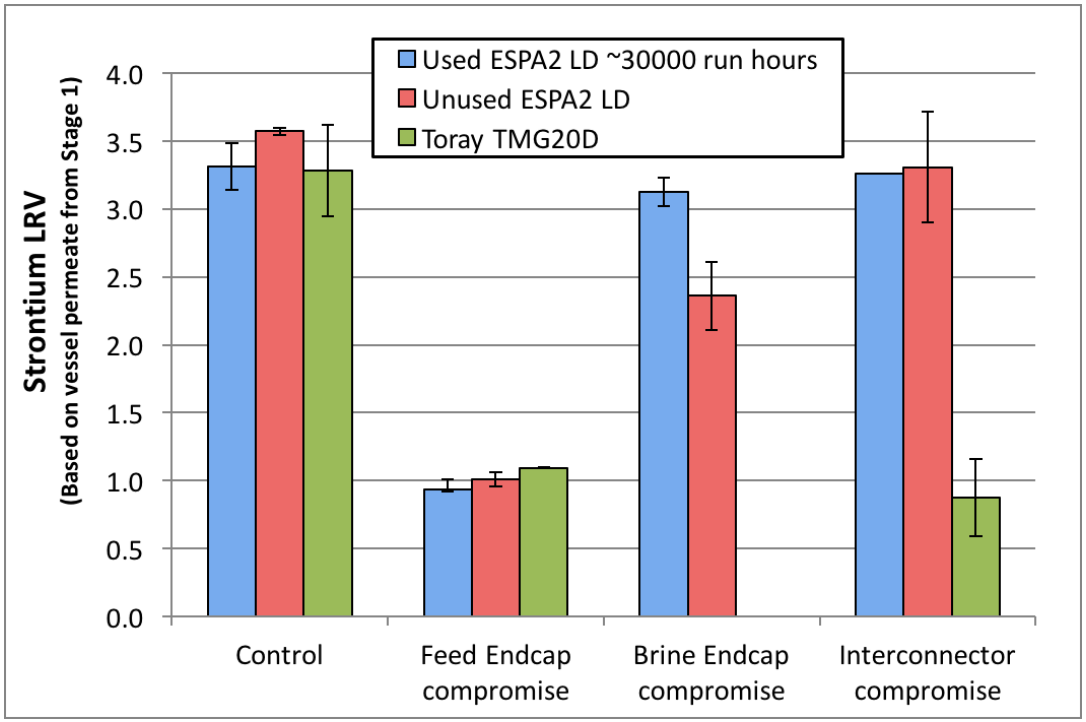



- ~3-logs across intact/control membrane (vessel-level data)
- Sugar rejection was susceptible to breaches

# Strontium (naturally occurring)

## Using low detection method (UCMR3 200.8)

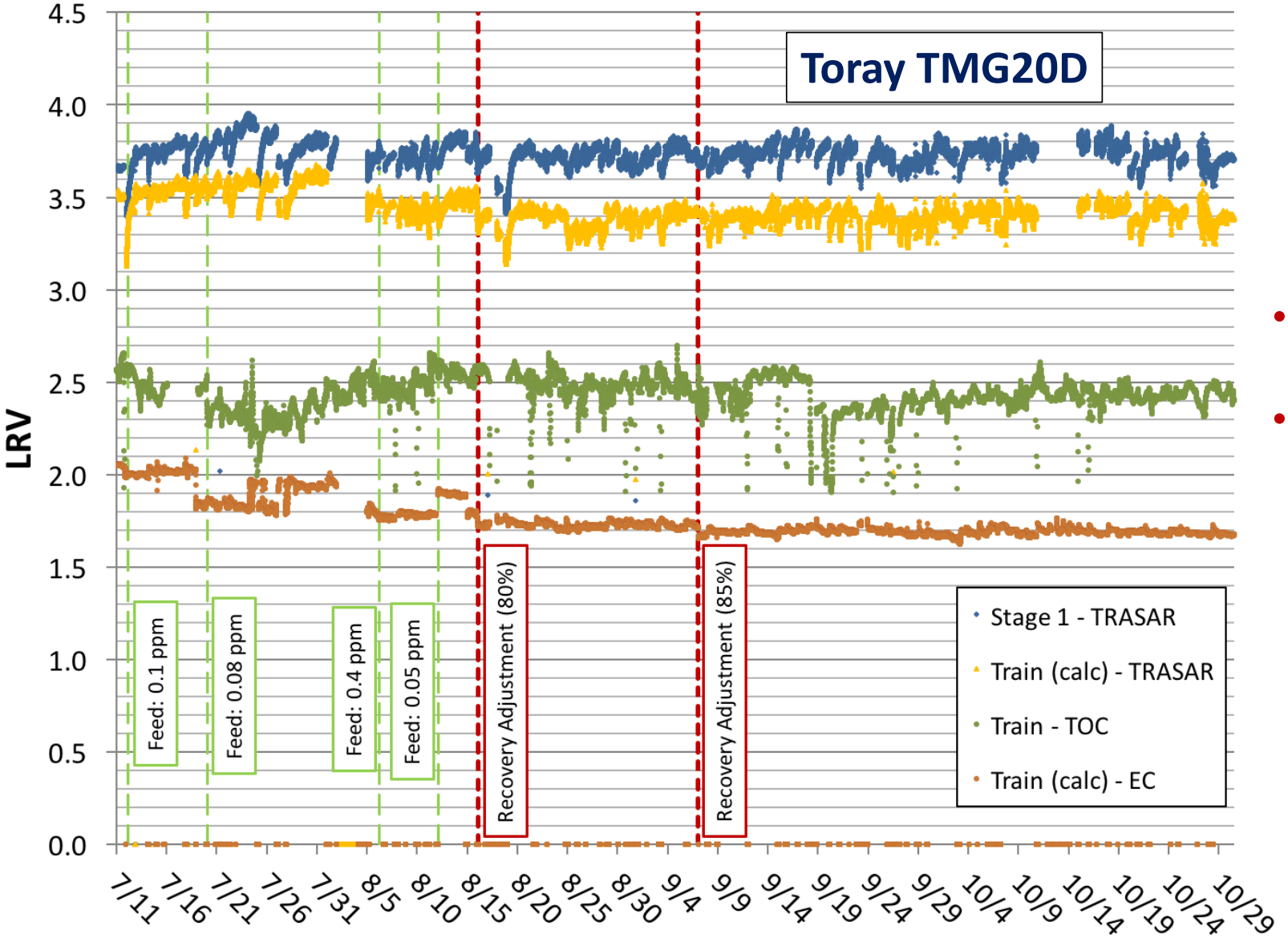
- Strontium integrity monitoring using lower detection method
  - MRL: 0.3 µg/L vs 10 µg/L
- 3.2 – 3.5 LRV across intact membranes (vessel-level data)



# Nalco's 3D TRASAR

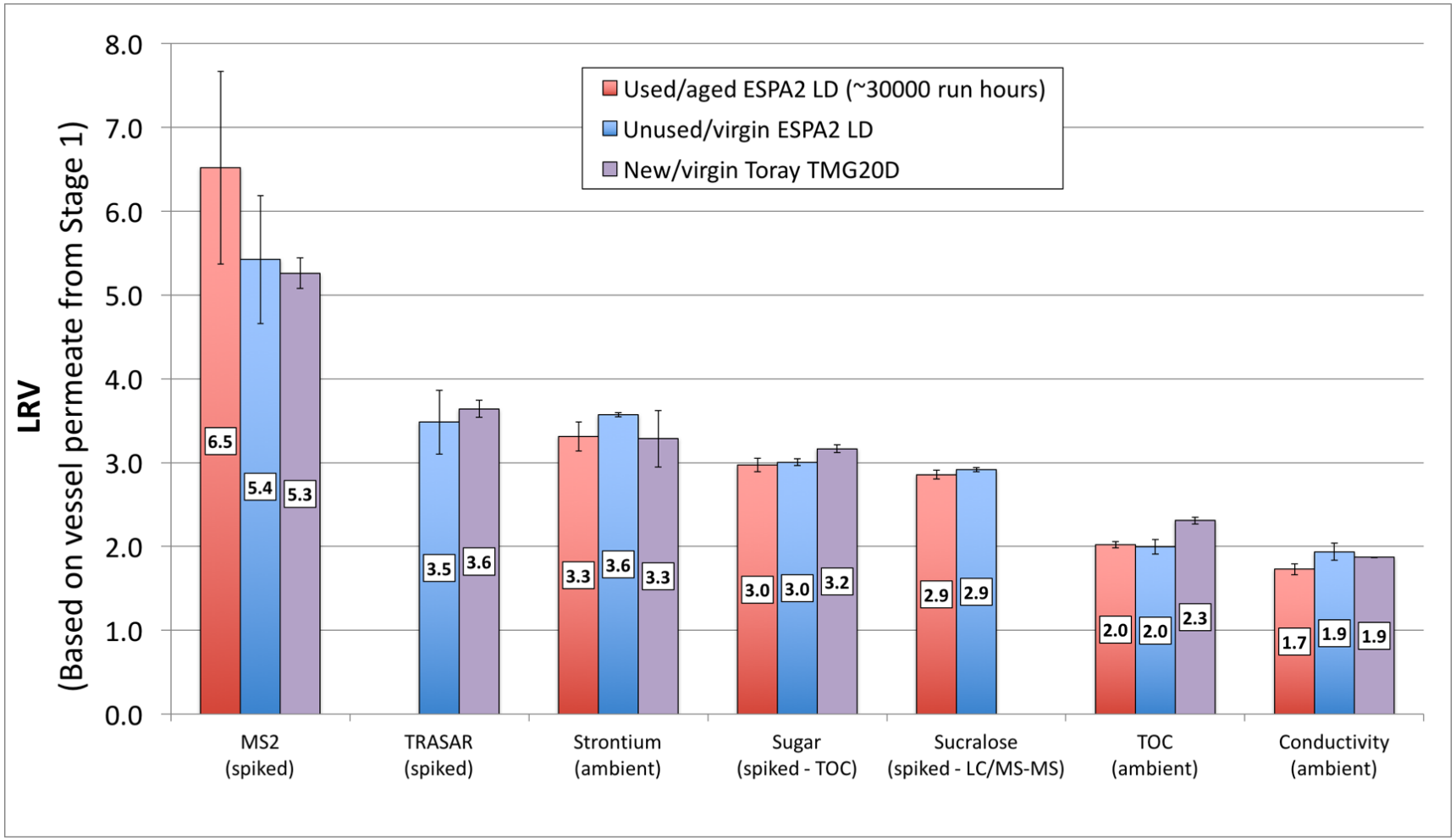
- Continuous integrity monitoring by fluorescent dye rejection

- Feed concentrations tested: 0.4 – 0.05ppm as active compound (TRASAR 23299)

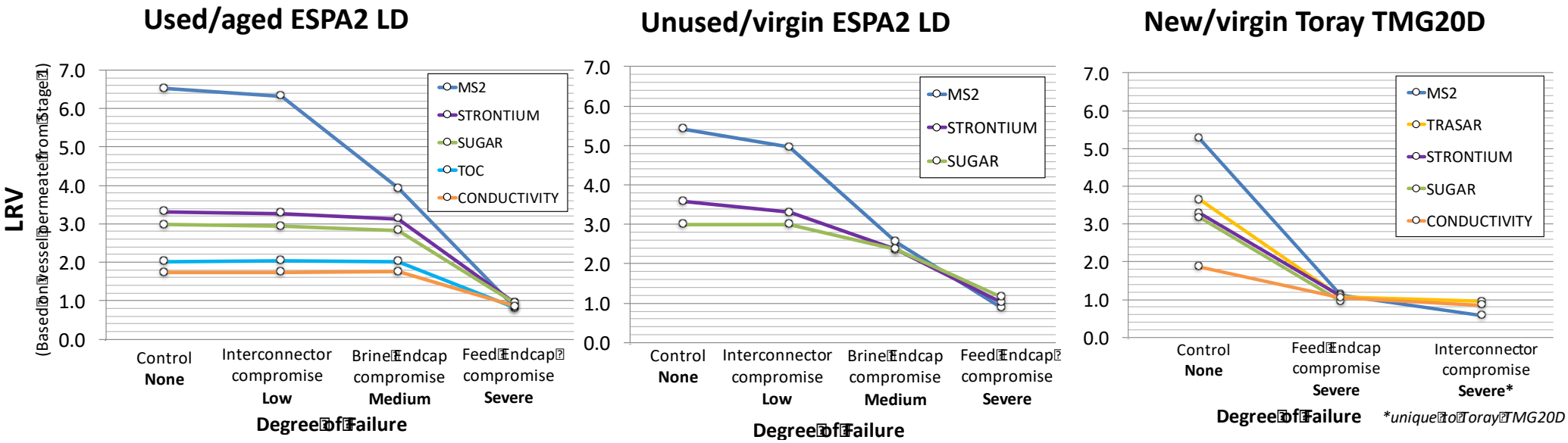



- **Consistently above 3-logs**
- **More than EC and TOC**

# Summarizing the data



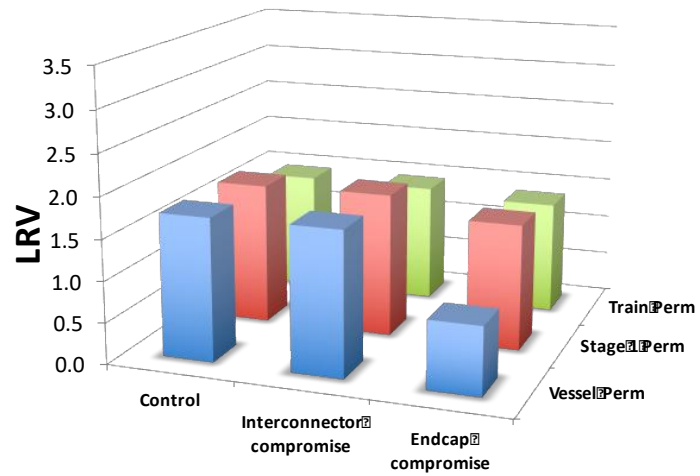
# Summarizing the data




- All tested markers were conservative to MS2 rejection
- Accurately tracked MS2 during compromised conditions

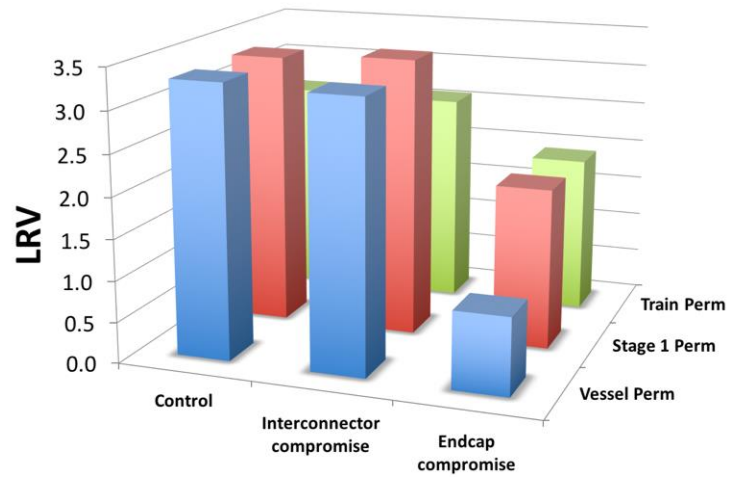
# Effect of compromise dilution & resolution of failure

**Conductivity:** unable to detect a breach at train level, compromise is *diluted*




Conductivity

**Strontium:** higher LRV implies greater resolution of failure, and thus *potentially* less monitoring locations to identify a breach




Strontium

# Conclusions and Considerations for RO Integrity Monitoring

- RO is currently undercredited and may benefit from more sensitive surrogates
  - Strontium, TRASAR, and sugar can provide enhanced LRV
- Full-scale monitoring requirements per EPA Membrane Guidance Manual
- Cost and operational implications of using alternative surrogate
- Surrogate performance during lifespan of RO membranes

# Thank you!

**WRRF 14-12: Demonstrating Redundancy and Monitoring to Achieve Reliable Potable Reuse**

Trussell TECHNOLOGIES INC

WATER ENVIRONMENT & REUSE FOUNDATION WE&RF

# Appendix D – WateReuse California Annual Conference Presentation

**Presentation title: Potable Reuse Reliability Through Enhanced Treatment and Monitoring**

**Date: 03/13/16**

**Location: Santa Rosa, CA (WateReuse California Annual Conference Presentation)**

**Notes: only relevant slides are provided**

# Potable Reuse Reliability Through Enhanced Treatment and Monitoring

WATEREUSE
CALIFORNIA ANNUAL CONFERENCE
REUSE: THE NEW NORMAL

**WateReuse Research Project 14-12**

**Santa Rosa, CA**

**March 13, 2016**

*Shane Trussell*

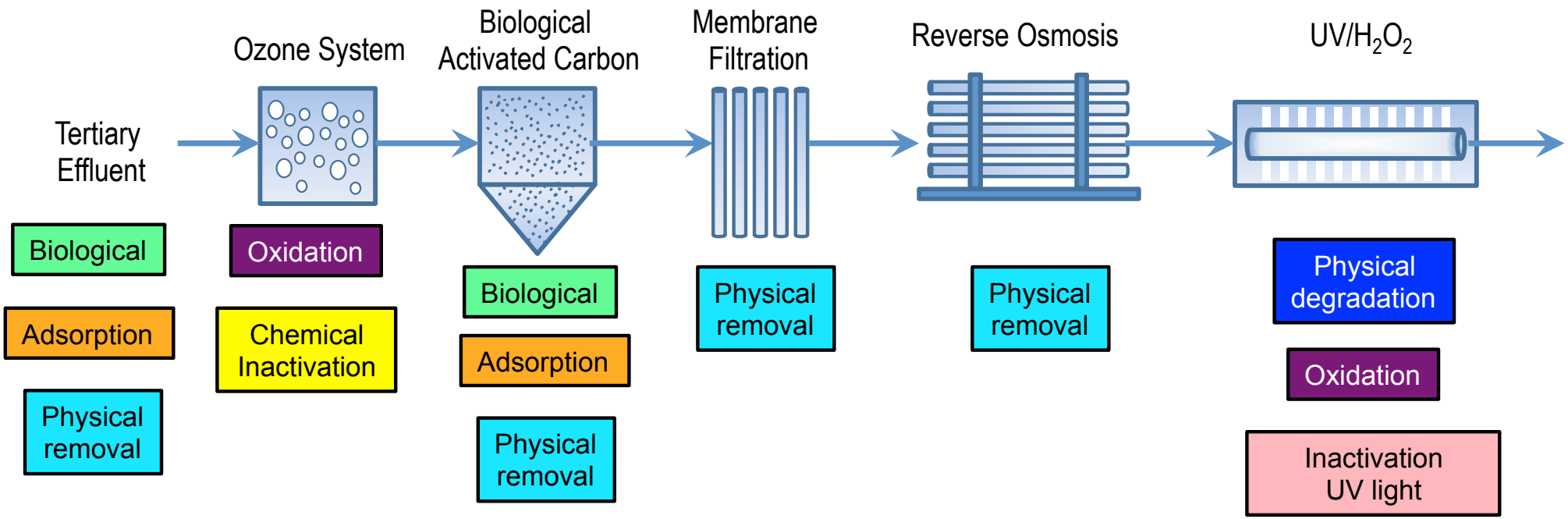
Trussell
TECHNOLOGIES INC

# Project Goal

To leverage industry “state of the art” to demonstrate how a combination of treatment redundancy and enhanced monitoring techniques can *reliably* achieve potable reuse treatment objectives

# 1 MGD Advanced Water Purification Demonstration Facility

## *at the North City Water Reclamation Plant, San Diego, CA*




No single process can adequately address all concerns

# Treatment redundancy
## Ozone-BAC

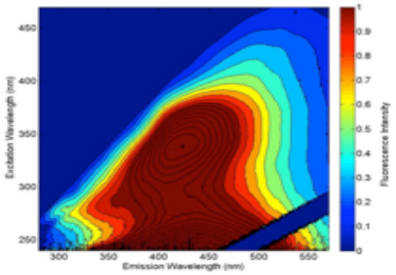
1. Ozone inactivates pathogens:

   > 6 log virus inactivation

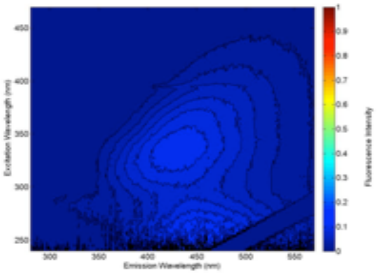
   > 6 log *Giardia* inactivation

   2 log *Crypto* inactivation

Ozone influent EEM



BAC effluent EEM



2. Ozone provides advanced oxidation that destroys CECs
3. BAC removes oxidation byproducts (i.e. aldehydes, acetic acid, NDMA) and reduces TOC concentration
4. Ozone/BAC reduces capital and O&M costs of downstream treatment processes
5. Reduces mass load (lb/d) of CECs in RO brine

# Enhanced Monitoring

| Monitor | Location |
|---|---|
| UVT | Ozone Influent, Ozone Effluent, BAC Effluent, RO Permeate |
| Dissolved $O_3$ | Ozone Effluent |
| TOC | Ozone Effluent, BAC Effluent, RO Permeate |
| Turbidity | Ozone Effluent, BAC Effluent, MF Effluent, UF Effluent |
| pH | BAC Effluent |
| Conductivity | MF/UF Filtrate, RO Train A Permeate, RO Train B Permeate |
| Temp | MF/UF Filtrate |
| ORP | MF/UF Filtrate |
| Total Chlorine | MF/UF Filtrate, RO Permeate, UV/AOP Effluent |
| UVi, Power | UV/AOP |

HACH®

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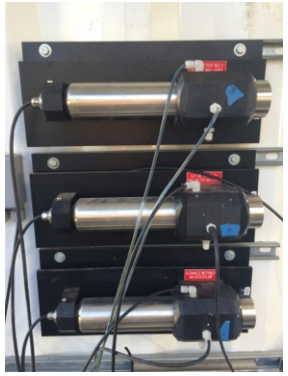
Kuntze INSTRUMENTS

GE Power & Water
Water & Process Technologies
Analytical Instruments

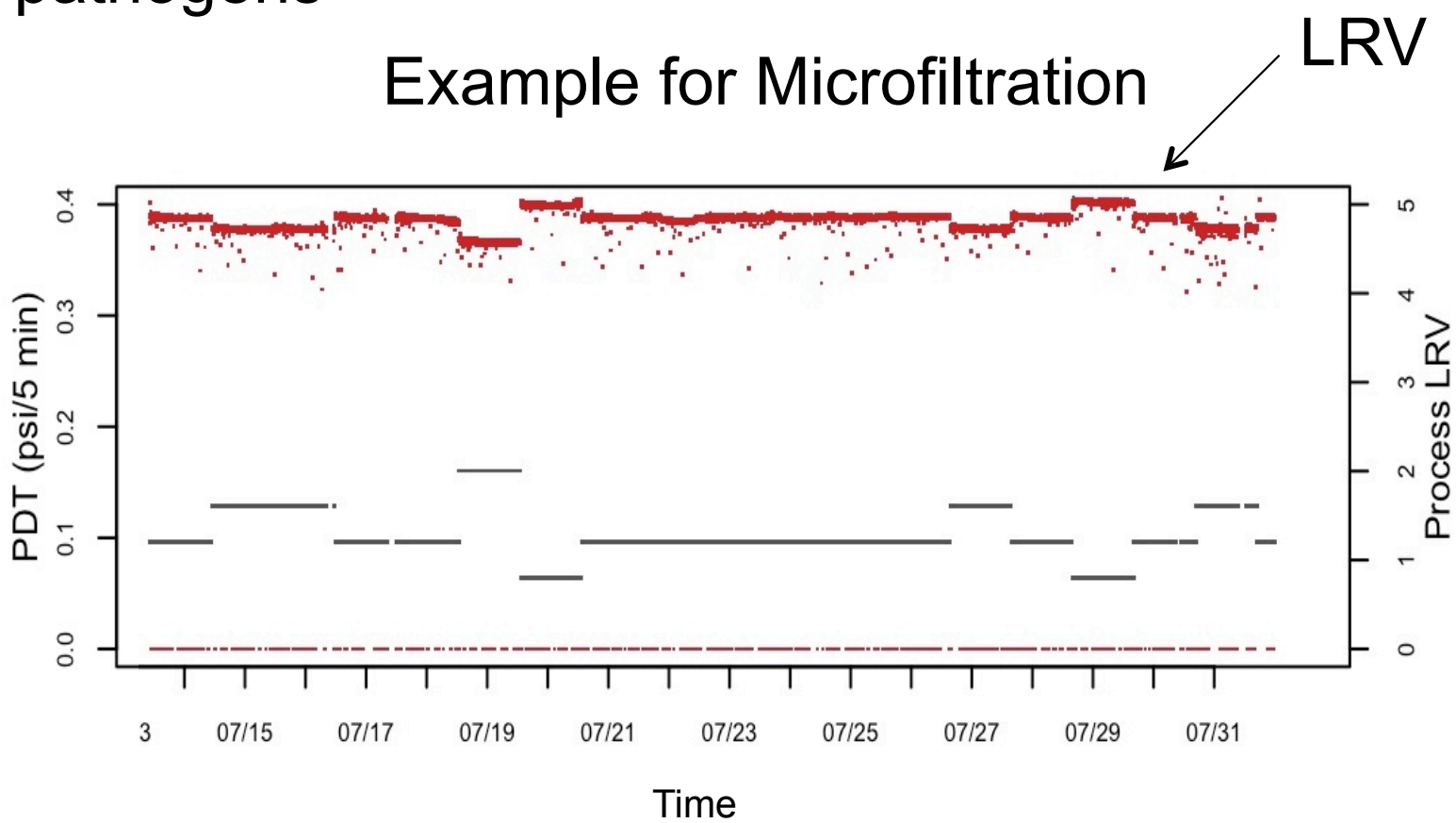
2B Technologies



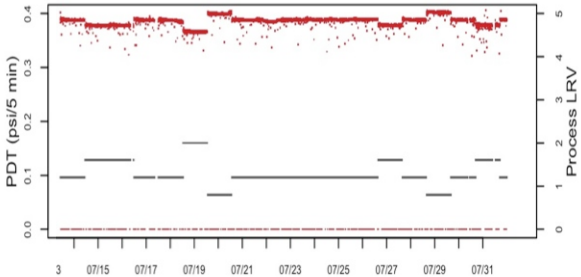
# Measuring system reliability

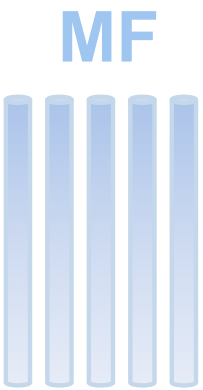
- Unit process performance data to create probability density function (PDF) curves that quantify consistency and degree of performance against pathogens

Example for Microfiltration

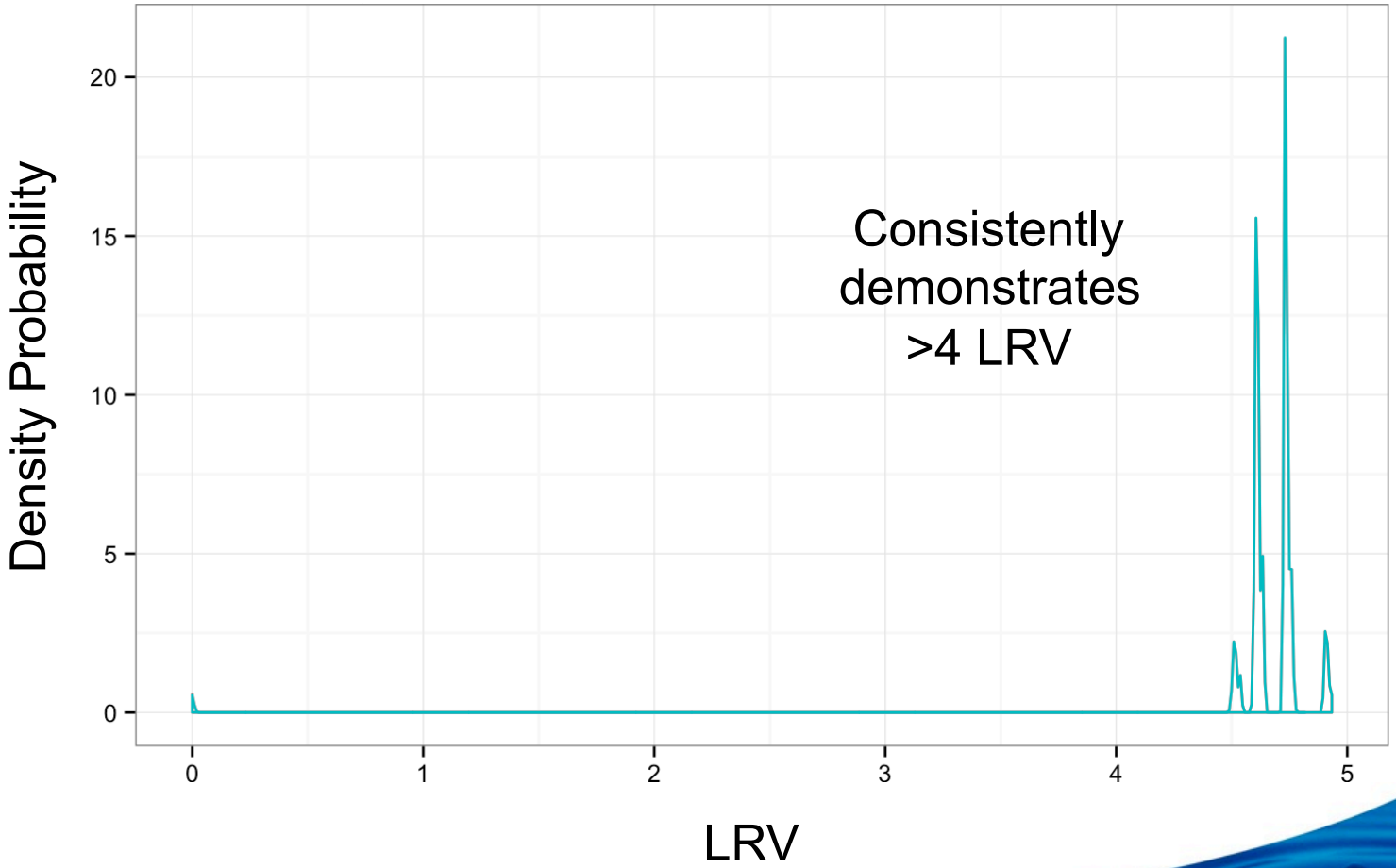


# Constructing PDFs



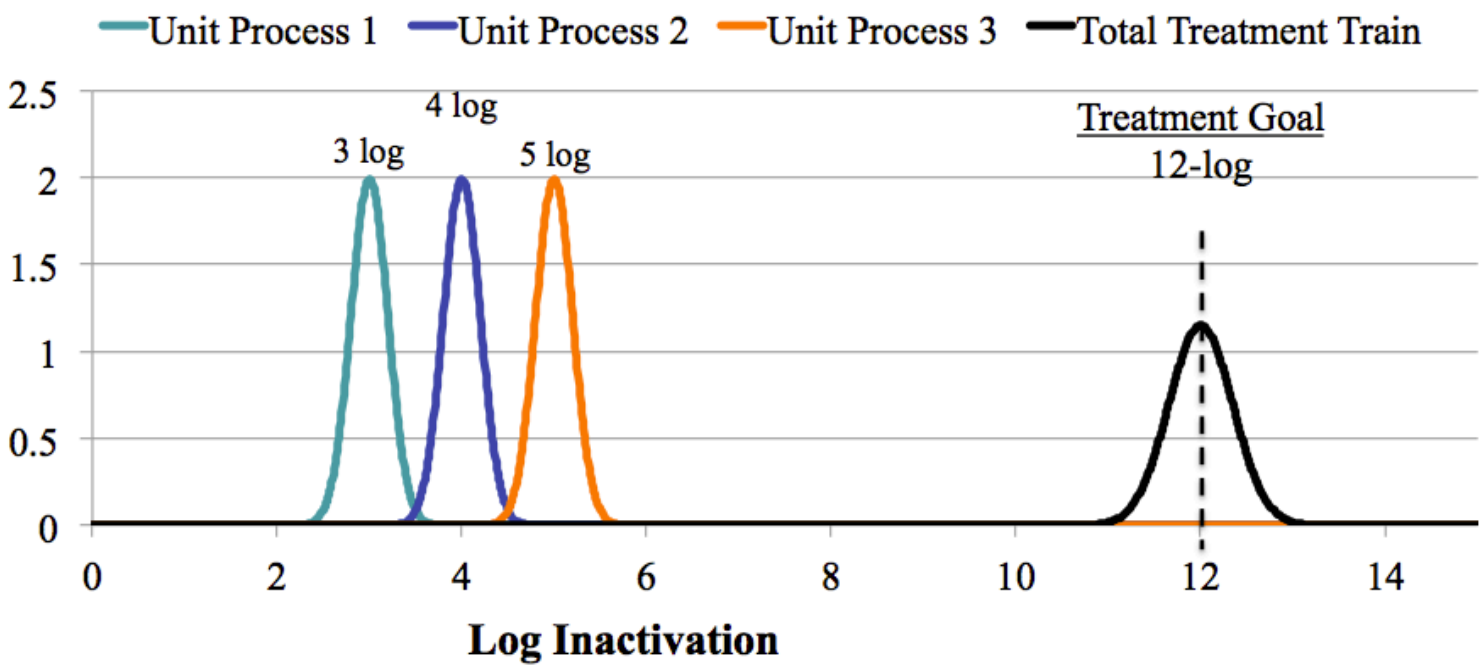




**Crypto & Giardia**

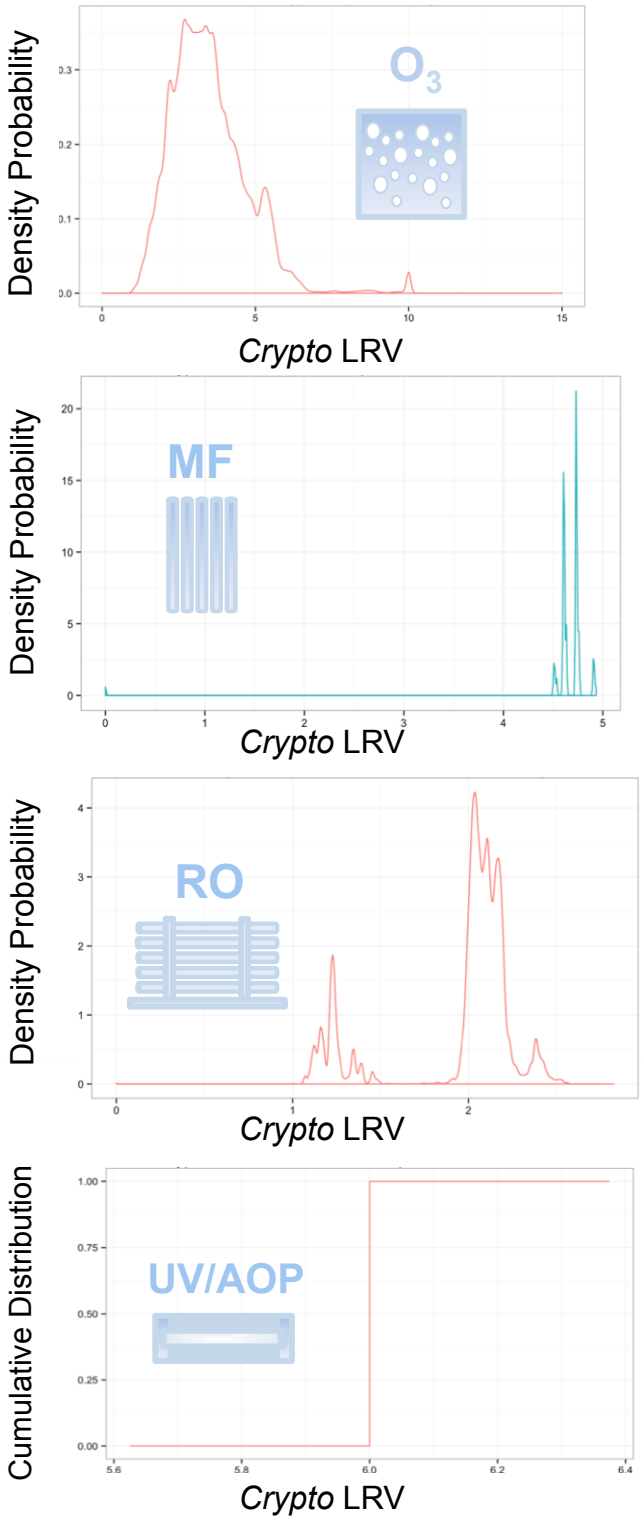


# Treatment train performance

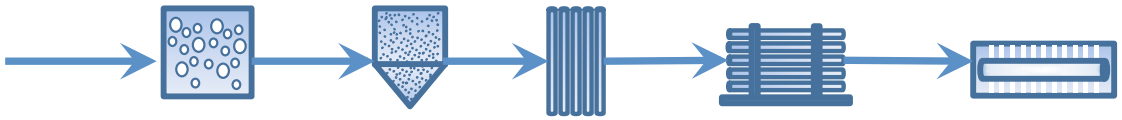
1. Consider each unit process separately
2. Sum individual PDFs to obtain treatment train PDF

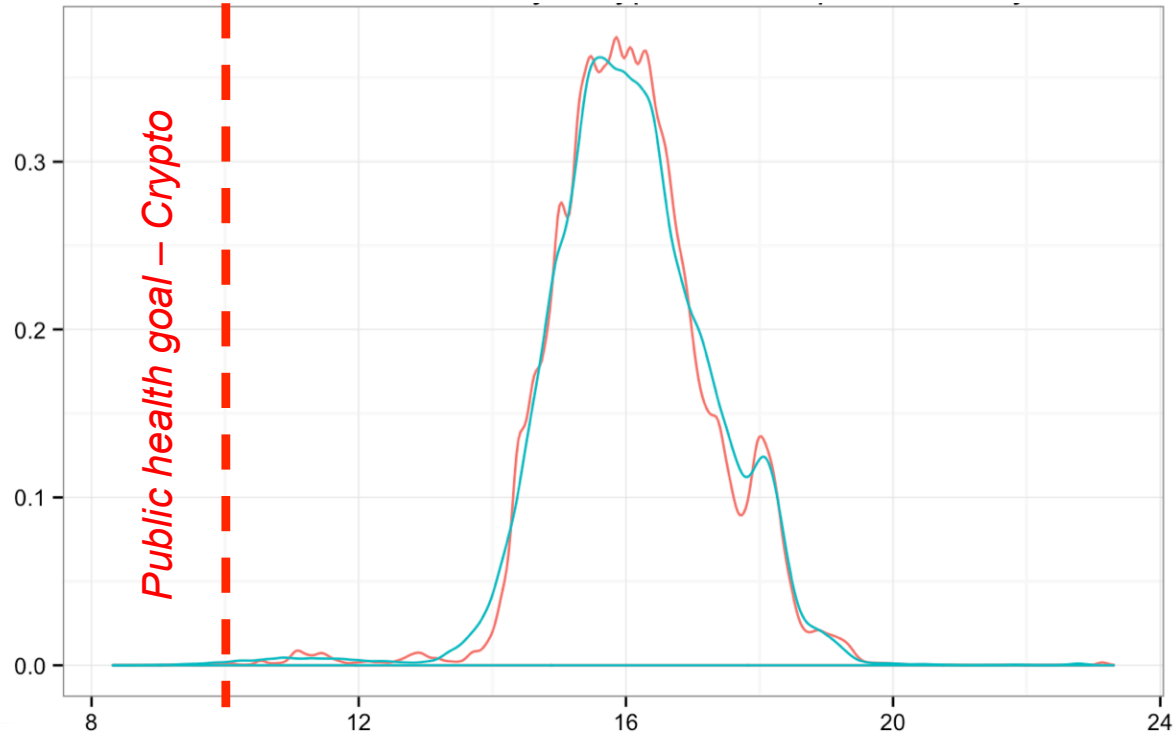



**Is treatment train protective of public health?**
**Do they consistently reach 12-10-10 (G/C/V)?**
**Let's look closer into *Crypto…***




## Train Performance PDF: *Crypto*

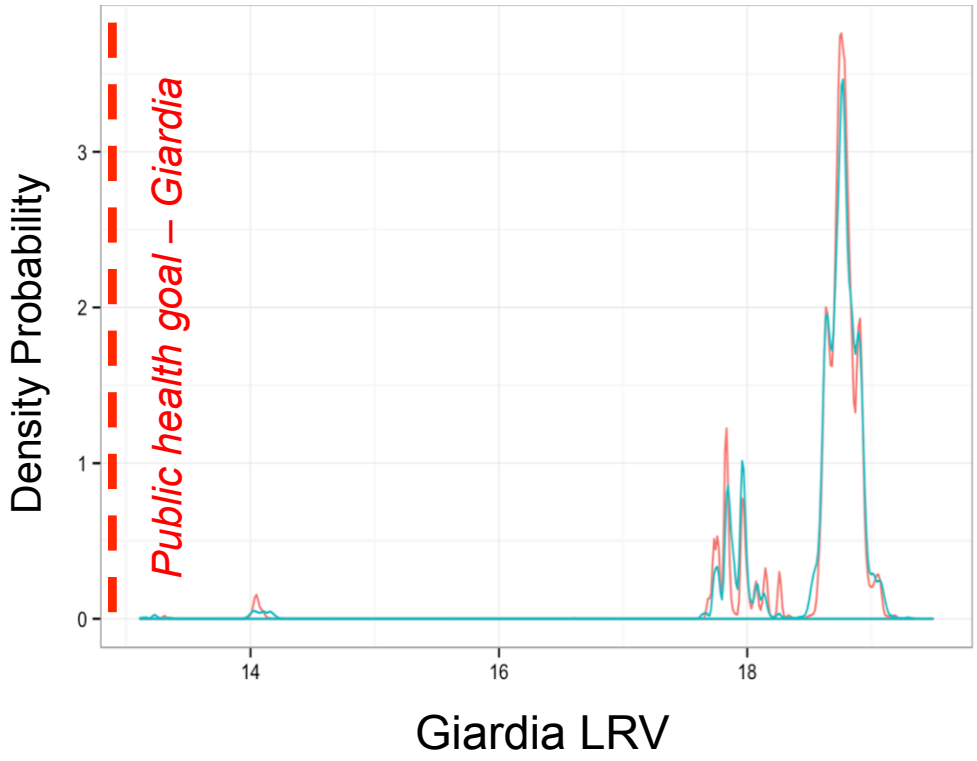




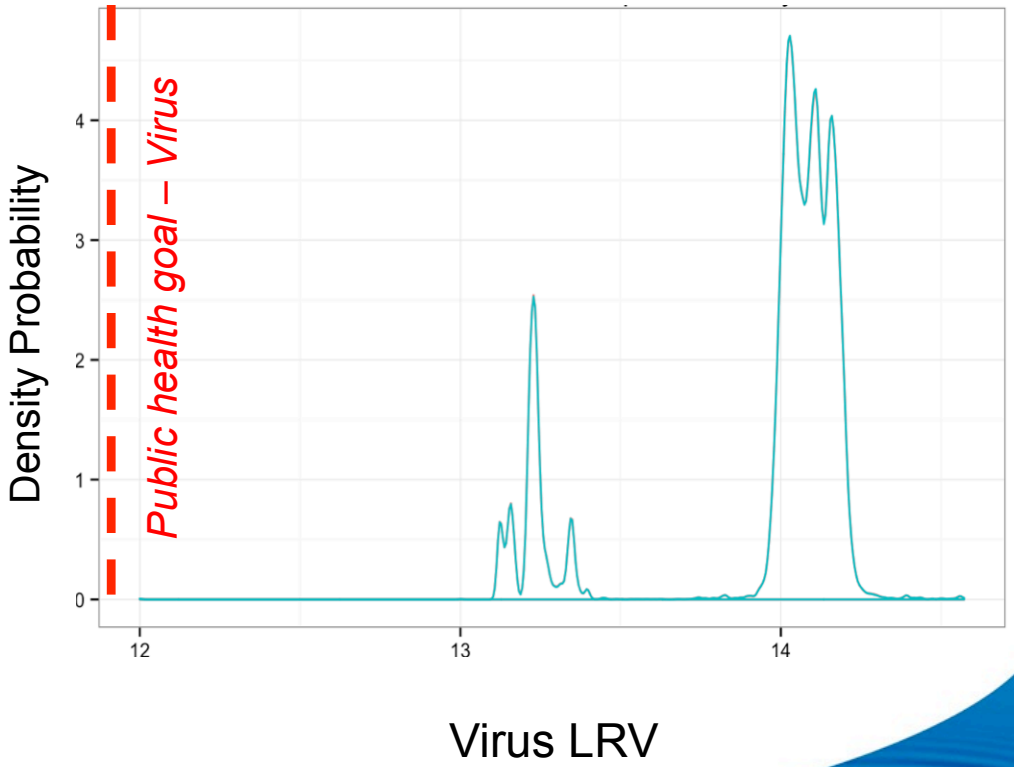

**Evidence of treatment redundancy**
**Consistently surpassing treatment goal**

# Redundancy also for Giardia and Virus

**Train Performance PDF: Giardia**




**Train Performance PDF: Virus**



# Demonstrating “failsafe” treatment via Challenge Testing

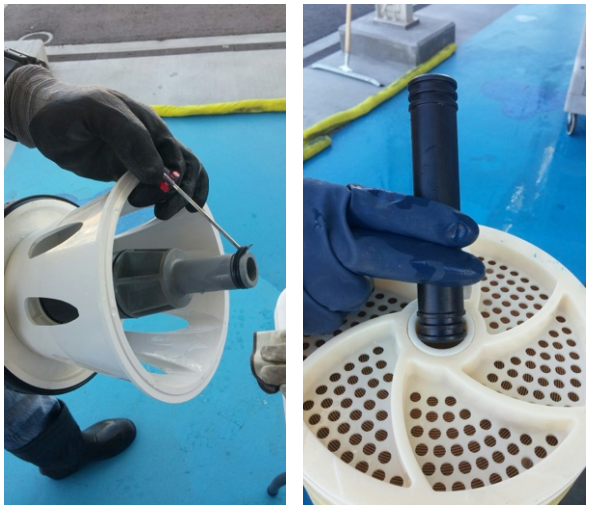
- System-wide chemical challenge tests
- Bench-top ozone *Cryptosporidium* inactivation studies
- Reverse osmosis integrity challenge tests

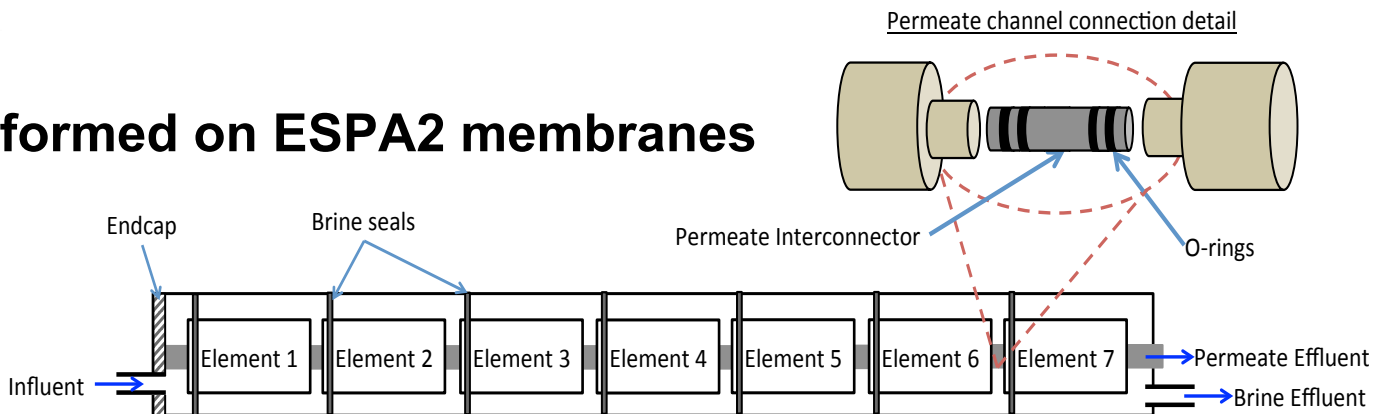
# Demonstrating “failsafe” treatment via Challenge Testing

- System-wide chemical challenge tests
- Bench-top ozone *Cryptosporidium* inactivation studies
- Reverse osmosis integrity challenge tests

# Approach and Methodology

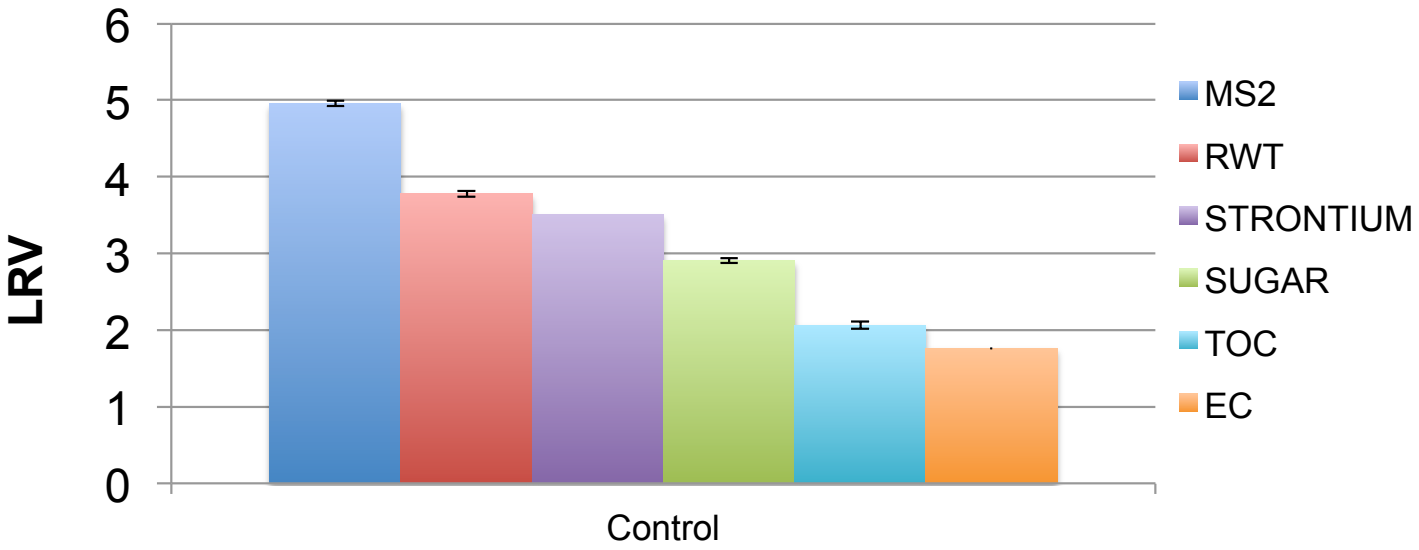
- **Objective:** investigate potential surrogates to evaluate integrity of RO for virus removal in a full-scale setting
- **O-ring compromise**
  - Literature: reported it as most detrimental compromise
  - Test sensitivity of surrogates
  - Permeate interconnectors & endcaps
- **Surrogates tested (ambient and spiked)**
  - Metals and Ions (Sulfate, Strontium, Phosphate…)
  - Rhodamine WT
  - Sugar
  - MS2
- **All tests performed on ESPA2 membranes**





# Summary of results

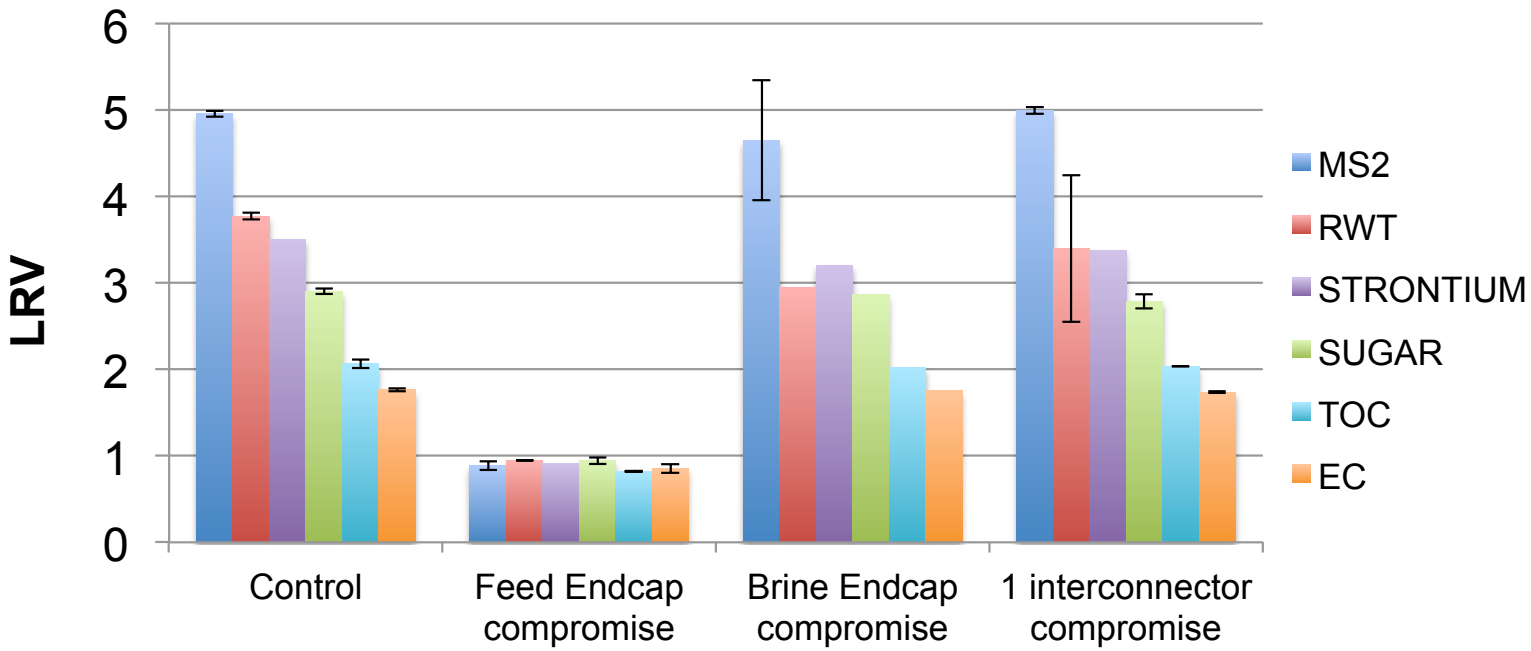
## Intact membrane




- **RWT offered highest LRV (3.5)**
  - Adsorption on membranes likely occurring (skewed LRVs)
  - Still conservative against virus removal (MS2)
- **Sugar removal measured using TOC meters**
  - Highly reproducible
  - Cheaper than RWT
- **Strontium: promising results**
  - No need for spiking – already present in water
  - Likely unfeasible to continuously monitoring

# Summary of results

## Intact and compromised conditions




- **Feed endcap compromise**
  - Identified by all surrogates
  - Similar LRVs observed across all tested surrogates
- **Interconnector compromises**
  - Minor to no breach detected
  - Likely that pressure within vessel is enough to form seal even in the absence of O-rings

# Closing Remarks & Project Status

- **Challenge tests are providing evidence to understand:**
  - Reliability of a potable reuse facility under challenging water quality conditions
  - Feasibility of surrogates to increase RO virus removal credit
  - Application of existing ozone CT and LRV framework for potable reuse applications
- **Quantification of reliability through PDFs**
  - Important tool for installing confidence among stakeholders
  - Record tracking of treatment train performance
  - Evidence of treatment redundancy
- **Implementation period ending April 2016**
  - Reporting period to follow (late 2016)

# Acknowledgements


- WateReuse Research Foundation
- U.S. Bureau of Reclamation
- City of San Diego
- San Diego County Water Authority
- California Department of Water Resources

# Thank you for your attention

shanet@trusselltech.com

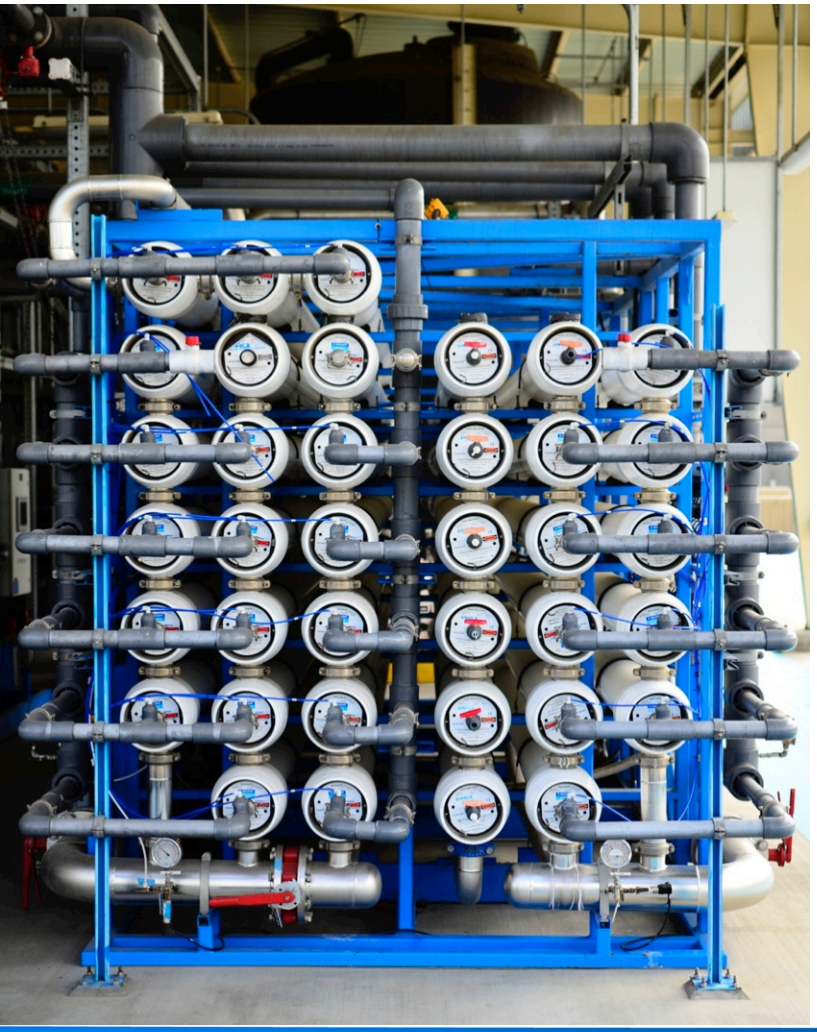
Trussell TECHNOLOGIES INC

# Appendix E – Presentation of on-going results to State regulators

**Presentation title: Realizing Reverse Osmosis Potential for Potable Reuse: Demonstration Enhanced Pathogen Removal**

**Date: 05/06/16**

**Location: Trussell Technologies, Inc. office in Solana Beach, CA**



# Realizing Reverse Osmosis Potential for Potable Reuse: Demonstrating Enhanced Pathogen Removal

WateReuse

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Shane Trussell, Ph.D., P.E. BCEE

Presentation to DDW

May 6th, 2016

Trussell TECHNOLOGIES INC

# Acknowledgements


- **The United States Bureau of Reclamation** and **WateReuse Research Foundation's** financial, technical, and administrative assistance in funding and managing the project through which this information was discovered, developed, and presented
- **State of California Department of Water Resources** for its grant award in support of this project
- **San Diego County Water Authority** for its support in the administration of the project funding.

# Project Goal

To provide a better understanding of existing and potentially more sensitive methodologies for monitoring and validating reverse osmosis pathogen removal and to secure enhanced log removal credit

# Direction of Today's meeting

- Brief background on RO performance for pathogen removal
- Existing projects receiving RO pathogen removal credit
- EPA Membrane Guidance Manual for RO
- Highlights of project literature review
- Presentation of on-going project results
- Applicability of project findings in the regulatory context
- Closing remarks

- **Brief background on RO performance for pathogen removal**
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# Background

## RO is currently not credited for much of its potential

- While UF receives 0.5-4-4 V/G/C credit, RO receives only 1.5-1.5-1.5
- **Current state**: There is no established integrity monitoring method to demonstrate higher (>2) LRV for RO. TDS as EC & TOC are the methods of choice.
- **Moving forward**: To develop a monitoring method that detects RO membrane integrity failures while conservatively demonstrating performance closer to its potential
- RO can offer a high level of pathogen removal (up to 6-log MS2)

- Brief background on RO performance for pathogen removal
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# Projects currently securing RO pathogen credit

## Carlsbad Desalination Plant

State of California—Health and Human Services Agency
Department of Health Services

SANDRA SHEWRY
Director

ARNOLD SCHWARZENEGGER
Governor

**SYSTEM NO. 3710045 - CARLSBAD DESALINATION PROJECT**

Reverse osmosis (RO) treatment processes have not demonstrated the ability to remove all viruses; therefore, adequate disinfection (via free chlorine and chloramines) is needed. The Department will grant a virus log removal credit to the RO process equal to the Total Dissolved Solids (TDS) reduction without requiring a demonstration study. The project proposes to use online electroconductivity (EC) meters as a surrogate for TDS.

**Methodology: Conductivity monitoring as a surrogate for TDS**

# Sand City

STATE OF CALIFORNIA

***AMENDMENT TO THE***
***DOMESTIC WATER SUPPLY PERMIT ISSUED TO***

**California American Company – Monterey District**
**Public Water System No. 2710004**

**Reverse Osmosis (RO) Membrane Filtration Process Operation**

14. The RO membrane filtration process shall achieve 2-log removal of Giardia, Cryptosporidium, and viruses. The reverse osmosis filtration process shall be deemed out of compliance with the 2-log removal requirement if the PLC calculation of conductivity log reduction through the RO membrane train is less than 1.91 for a period not to exceed fifteen (15) continuous minutes.

**Methodology: Conductivity monitoring**

**WASTE DISCHARGE REQUIREMENTS AND WATER RECLAMATION REQUIREMENTS**

**FOR THE**

**LEO J. VANDER LANS WATER TREATMENT FACILITY AND THE ALAMITOS BARRIER RECYCLED WATER PROJECT**

**Table 5 - Pathogen Credits applied at Vander Lans WTF under the GWRR**

| Pathogen | 2013 Draft GWRR Minimum | Proposed Pathogen Treatment Credits | | | | | Total Credits |
|---|---|---|---|---|---|---|---|
| | | WRP[a] | MF | RO | UV/AOP | Travel Time | |
| *Giardia* | 10 | 2[b] | 2.7[c] | 1.5[c] | 6[d] | 0 | 12.2 |
| *Crypto-sporidium* | 10 | 1[b] | 2.7[c] | 1.5[c] | 6[d] | 0 | 11.2 |
| Viruses | 12 | 2[b] | N/A[e] | 1.5[c] | 6[d] | 6[f] | 15.5 |

c. Per discussions with CDPH, based on membrane integrity and concomitant minimum reductions. Pathogen reduction credit includes the potential impact of the backwash water cycled.

RO facility, Conductivity and TOC shall be continuously measured upstream and downstream of the RO using online analyzers, and for each day of operation, the following shall be reported for both conductivity and TOC – daily minimum and maximum, average, and percent reduction calculated from daily average values.

**Methodology: Conductivity & TOC monitoring**

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**Methodology: Conductivity & TOC monitoring**

*Are there any others you would like us to be aware of?*

- Brief background on RO performance for pathogen removal
- Existing projects receiving RO pathogen removal credit
- **EPA Membrane Guidance Manual for RO**
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# EPA Membrane *Guidance Manual* for RO

## How is membrane filtration defined?

United States Environmental Protection Agency | Office of Water (4601) | EPA 815-R-06-009 November 2005

**MEMBRANE FILTRATION GUIDANCE MANUAL**

**Membrane Filtration** – (as defined under the LT2ESWTR) a pressure- or vacuum-driven separation process in which particulate matter larger than 1 µm is rejected by an engineered barrier, primarily through a size-exclusion mechanism and which has a measurable removal efficiency of a target organism that can be verified through the application of a direct integrity test;

# Mention of RO in the EPA *Guidance Manual*

## Can pathogen credit be sought for RO?

### 2.2.2 Nanofiltration and Reverse Osmosis

NF and RO are eligible for *Cryptosporidium* removal credit under the LT2ESWTR based on the demonstrated ability of these technologies to remove pathogens, as well as on the high probability that these processes can meet the requirements for membrane filtration specified in the rule.

# Receiving pathogen removal credit for membrane filtration

Seek virus removal credit

(*transcribe* credit to Giardia and *Crypto* – larger pathogens)

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LT2ESWTR provides regulatory framework for obtaining *Crypto* removal credit

# Receiving pathogen removal credit for membrane filtration

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LT2ESWTR provides regulatory framework for obtaining *Crypto* removal credit

**Appendix E** of Membrane Filtration Guidance Manual mentions LT2ESWTR framework for **virus** removal can be pursued, as long as:

# Receiving pathogen removal credit for membrane filtration

Seek virus removal credit
(*transcribe* credit to Giardia and *Crypto* – larger pathogens)

LT2ESWTR provides regulatory framework for obtaining *Crypto* removal credit

**Appendix E** of Membrane Filtration Guidance Manual mentions LT2ESWTR framework for **virus** removal can be pursued, as long as:

"… the membrane filtration process complies with appropriate pathogen-specific criteria for the three primary regulatory elements: **challenge testing, direct integrity testing, and continuous indirect integrity monitoring**"

## Thus, RO can secure pathogen removal credit as long as:

- challenge testing
- direct integrity testing (DIT)
- continuous indirect integrity monitoring (CIIM)

…are appropriately satisfied

- **challenge testing**
- direct integrity testing (DIT)
- continuous indirect integrity monitoring (CIIM)

# Challenge testing

## One-time verification of membrane efficiency

- **Purpose**: a study conducted to determine the removal efficiency (i.e., log removal value (LRV)) of a membrane material for a particular organism, particulate, or surrogate
- Typically performed by manufacturers (available for MF & UF)
- Establish a $LRV_{max}$ for a line of modules/membranes[1]
  - Appropriate surrogates (ideal vs conservative)
  - 3µm breach for *Cryptosporidium*
  - 0.01µm breach for enteric virus

$$LRV = \log(C_f) - \log(C_p)$$

**Removal efficiency**

[1]*Must be performed for each commercial membrane product*

# Industry lacks standardized method to demonstrate Pathogen removal for RO

## … but studies have shown its potential

| MS2 Log Removal Value (LRV) | Reference |
|---|---|
| 6.7 | Madireddi et al. (2007) |
| 2 – >5.9 | Gagliardo et al. (1997a); Gagliardo et al. (1997b) |
| 3.4 | Adham et al. (1998a) |
| 2.7 – >6.5 | Adham et al. (1998b) |
| 3 – 4.8 | Kruithof et al. (2001) |
| 4 | Lozier et al. (2004) |
| 5.4 | Mi et al. (2004) |
| 7 | Casani et al. (2005) |
| 1.4 – >7.4 | Kumar et al. (2007) |

- challenge testing
- **direct integrity testing (DIT)**
- continuous indirect integrity monitoring (CIIM)

# Direct integrity test (DIT)

## Daily demonstration of barrier integrity

- **Definition**: a physical test applied to a membrane unit in order to identify and isolate integrity breaches
- **Must** meet the following specified performance criteria:
  - **Frequency: ≥** once a day, unless otherwise approved by State
  - **Resolution:** must be responsive to a 3 µm breach (0.01 µm for virus)
  - **Sensitivity:** test must verify LRV equal or greater than awarded removal credit value

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- **Multi-stage systems**: sensitivity must be determined for each stage *independently*; such that the stage using membranes with lowest sensitivity limits the max credit awarded for the overall process (§4.3)
- **Control limits**: Establish limits that "provide operators with an indication that there may be an integrity breach before becom[ing] a compliance concern." (§4.5)

## How are DITs carried out?

**Marker-based tests**

Pressure-based tests
(i.e. PDT)

# How are DITs carried out?

**Marker-based tests**

~~Pressure-based tests (i.e. PDT)~~

- Limited to mechanical impairments
- No insight on chemical damage
- Membranes must be drained

# Marker-based tests

## "mini challenge study"

- *Marker* periodically (i.e. daily) applied to feed water to measure integrity
- *Marker* must be conservative to pathogen's size
  - *Molecular markers* are more suitable since RO systems are "not designed to accommodate large particulate concentrations" (§3.9.3)

**Table 3.2 Comparative Summary of *Cryptosporidium* and Potential Surrogates**

| Challenge Particulate | Size Range | Advantages | Disadvantages |
|---|---|---|---|
| *Cryptosporidium parvum* | 3 - 7 µm | • No verification of surrogate required | • High cost<br>• Difficult to measure |
| Alternate microorganisms | 0.01 - 1 µm | • Low cost<br>• Easy to measure<br>• Accepted use | • Difficult to handle<br>• Potential clumping |
| Inert particles | ≤ 1 µm | • Moderate cost<br>• High uniformity<br>• Easy to use | • Difficult to measure accurately |
| Molecular markers | < 100,000 Daltons | • Low cost<br>• Easy to measure | • Inappropriate for some applications |

# *Molecular marker (<100,000 Da)*

## Applicability to RO

- EPA recognizes that rejection mechanisms may be different than those associated with discrete particles
  - However, it is understood that semi-permeable membranes offer high rejection of particulates given their removal efficiency on dissolved substances (§3.9.3.3)

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- EPA recognizes that rejection mechanisms may be different than those associated with discrete particles
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## Applicability to RO

- EPA recognizes that rejection mechanisms may be different than those associated with discrete particles
  - However, it is understood that semi-permeable membranes offer high rejection of particulates given their removal efficiency on dissolved substances (§3.9.3.3)
- Need for sufficiently sensitive instrumentation with a dynamic range able to account for discrepancy between feed and permeate
- Account for possible adsorption (and other losses) through mass balance assessment
- Suitable for use at a water treatment facility (e.g. FDA approved)

- challenge testing
- direct integrity testing (DIT)
- **continuous indirect integrity monitoring (CIIM)**

## Continuous indirect integrity monitoring (CIIM)

**Real-time indication of membrane integrity**

- Monitor some aspect of filtrate water quality as a surrogate measure of membrane integrity
  - Online, continuous (every 15 minutes), non-proprietary
  - Generally provides less sensitivity than DIT
- Turbidity is set as the default CIIM for membrane filtration
  - 0.15 NTU as control limit
  - 2 consecutive 15-min readings above 0.15 NTU trigger a DIT
- Other monitoring methods may be used with State approval
  - Conductivity is mentioned as a potential method for RO (§5.4)

- Brief background on RO performance for pathogen removal
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# Highlights of Project Literature Review

- 24 papers, project reports, conference proceedings (1998-2016)
- To date, there is no ideal monitoring technique
- Categorized: spiked and non-spiked; direct and indirect
  - Need for spiking can be avoided by improving sensitivity of analytical methods
- An ideal monitoring technique should be inexpensive and simple to implement by operators

# Highlights of Project Literature Review

- MS2 seen as the referee for actual virus removal
  - and thus, basis for comparison of marker performance
- Dyes (TRASAR, RWT) have highest reported LRVs (> 4)
  - Drawbacks include: adsorption & necessity of spiking
  - Pulsed-spikes are said to resolve adsorption issue (Frenkel et al., 2014)
- Monitoring of naturally occurring ions/metals: little explored
  - LRV limited by presence of constituent in feed and resulting permeate
  - Lower detection limits could widen possibilities

# Literature Review: Summary Table

| Monitoring Technique | Ambient or spiked? | Description | Scale | Method | Advantages/ Limitations | LRV potential | Reference |
|---|---|---|---|---|---|---|---|
| Conductivity | Ambient | Monitor conductivity of feed and permeate | Full-scale | Conductivity meter (e.g. Signet® 2850) | • Fluctuations with temperature and fouling<br>• Inexpensive meters<br>• Can identify compromised membranes | Up to 2 | Adham et al. (1998a) |
| TOC | Ambient | Monitor TOC of feed and permeate | Full-scale | TOC meter (e.g. GE® Sievers M5410 C) | • Currently implemented at OCWD GWRS<br>• Higher LRV than conductivity | Slightly above 2 | Adham et al. (1998a) |
| Sulfate | Ambient | Monitor sulfate of feed and permeate | Prelim. results from demo. facility | Online IC (e.g. Metrohm® 850 Pro IC) Off-site analysis | • High LRV potential given sufficient sulfate in feed<br>• Expensive online application<br>• Limited experience for this application<br>• No spiking necessary | Up to 3 | Kruithof et al. (2001) Jacangelo et al. (2013) |
| Phosphate | Ambient | Monitor phosphate of feed and permeate | Pilot- and full-scale | Phosphate meter (e.g. PHOSPHAX sc) Off-site analysis | • High LRV potential given sufficient feed phosphate<br>• Limited experience for this application<br>• No spiking necessary | Up to 3 | Trussell et al. (2015) |
| Dye Removal (i.e., RWT) | Spiked | Monitor removal of spiked dye with calibrated instrumentation | Pilot and full-scale | RWT sensor (e.g. TurnerDesign C3) | • High LRV potential<br>• Spiking necessary<br>• Facility not producing during testing<br>• RWT affected by chloramines<br>• Possible adsorption of dyes on membranes | Above 4 | Lozier et al. (2011) Lozier et al. (2003) DeCarolis et al. (2006) Ostarcevic et al. (2013) |
| Microbial surrogate (i.e., MS2)* | Spiked | Measure removal of spiked bacteriophage | Pilot- and full-scale | Off-site analysis (e.g. EPA 1602) | • High LRV potential<br>• Similar characteristics as microbial pathogens<br>• High cost at full-scale<br>• Health concerns at high concentrations<br>• Serves as a referee for virus removal | Above 6 | DeCarolis et al. (2006) Adham et al. (1998b) Jacangelo et al. (2015) |
| 3D TRASAR® | Spiked | Monitor removal of spiked (pulsed or continuously) florescent molecules using proprietary instrumentation | Pilot- and full-scale | Proprietary fluorescence meter (e.g. 3D TRASAR®) | • High LRV potential<br>• Spiking necessary<br>• Can be added together with antiscalant<br>• NSF approved (up to 15 mg/L)<br>• Proprietary technology | Up to 6 (continuous spike) Up to 3.4 (coupled antiscalant spikes) | MWH (2007) Steinle-Darling et al. (2015) Jacangelo et al. (2015) DeCarolis et al. (2006) |

* MS2 seeding experiments are understood as a referee for actual virus removal

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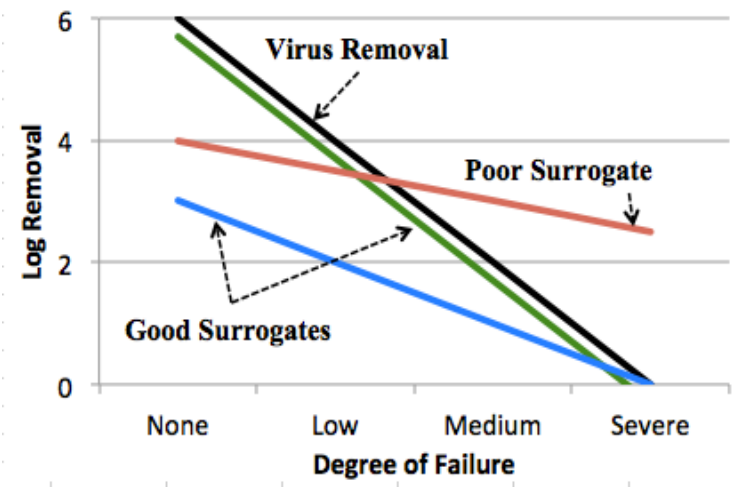
# Project approach

(1) Evaluate intact and compromised conditions to determine optimum testing conditions

(2) MS2 challenge testing to establish degree of virus removal and ability of standard and novel markers to track virus removal

(3) Identify best marker for LRV credit that is conservative under both normal and compromised conditions



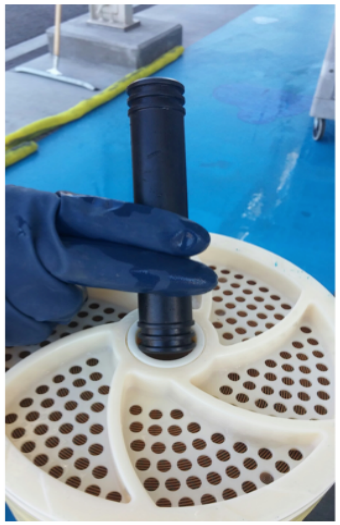
# Reverse Osmosis system

**At San Diego's 1 MGD demo AWPF**

- Two-train setup
  - **Train A: 2 stages (Hydranautics ESPA2 ND)**
  - 5-year old elements (June 2011)
  - Compromises took place on a single vessel from Stage 1
- No acid pre-treatment
  - Recovery 75-80%
- Flux 12 gfd
- CIP frequency > 3 months
- ~95% TDS rejection
- ~99% TOC removal

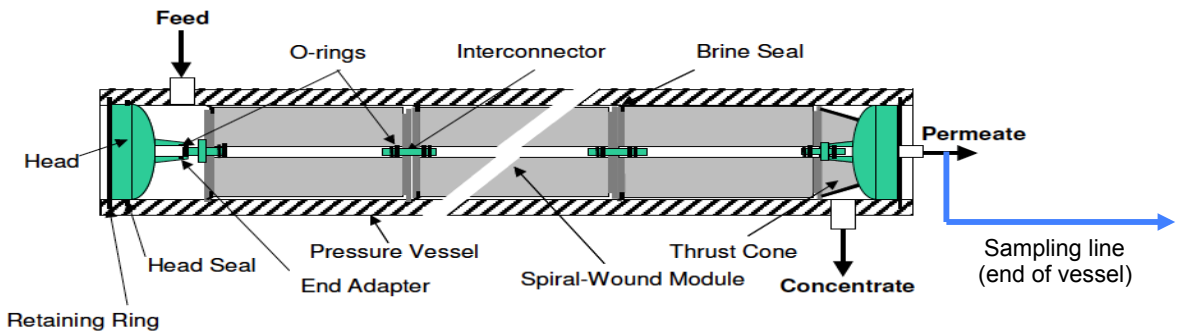
# Initial Investigated Compromises

Cut O-rings



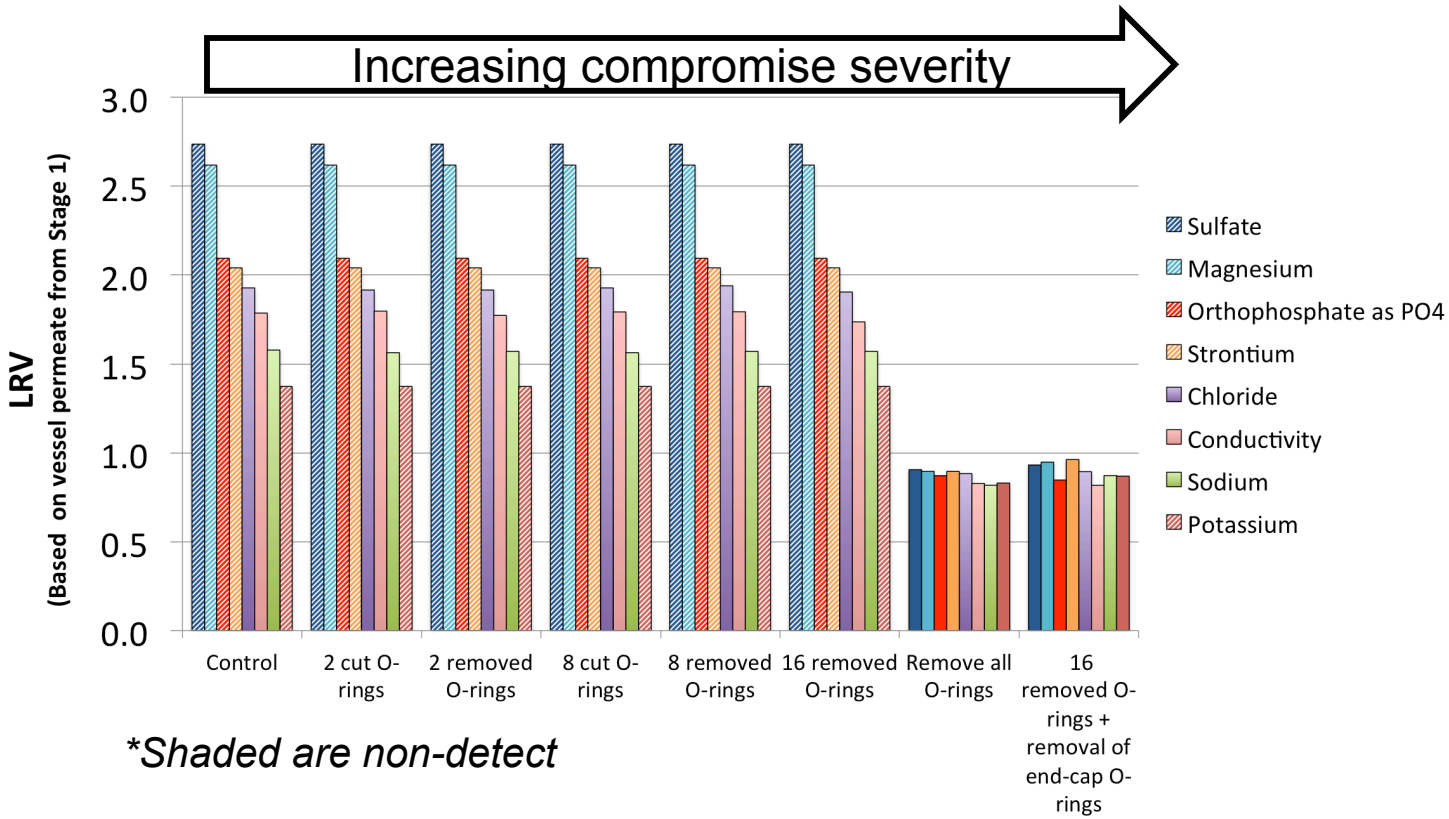
Remove O-rings

Endcap O-rings



# Assessing testing conditions

## By monitoring sensitivity of EC & ions present in water




**Shaded are non-detect*

- Sensitivity limited by permeate samples

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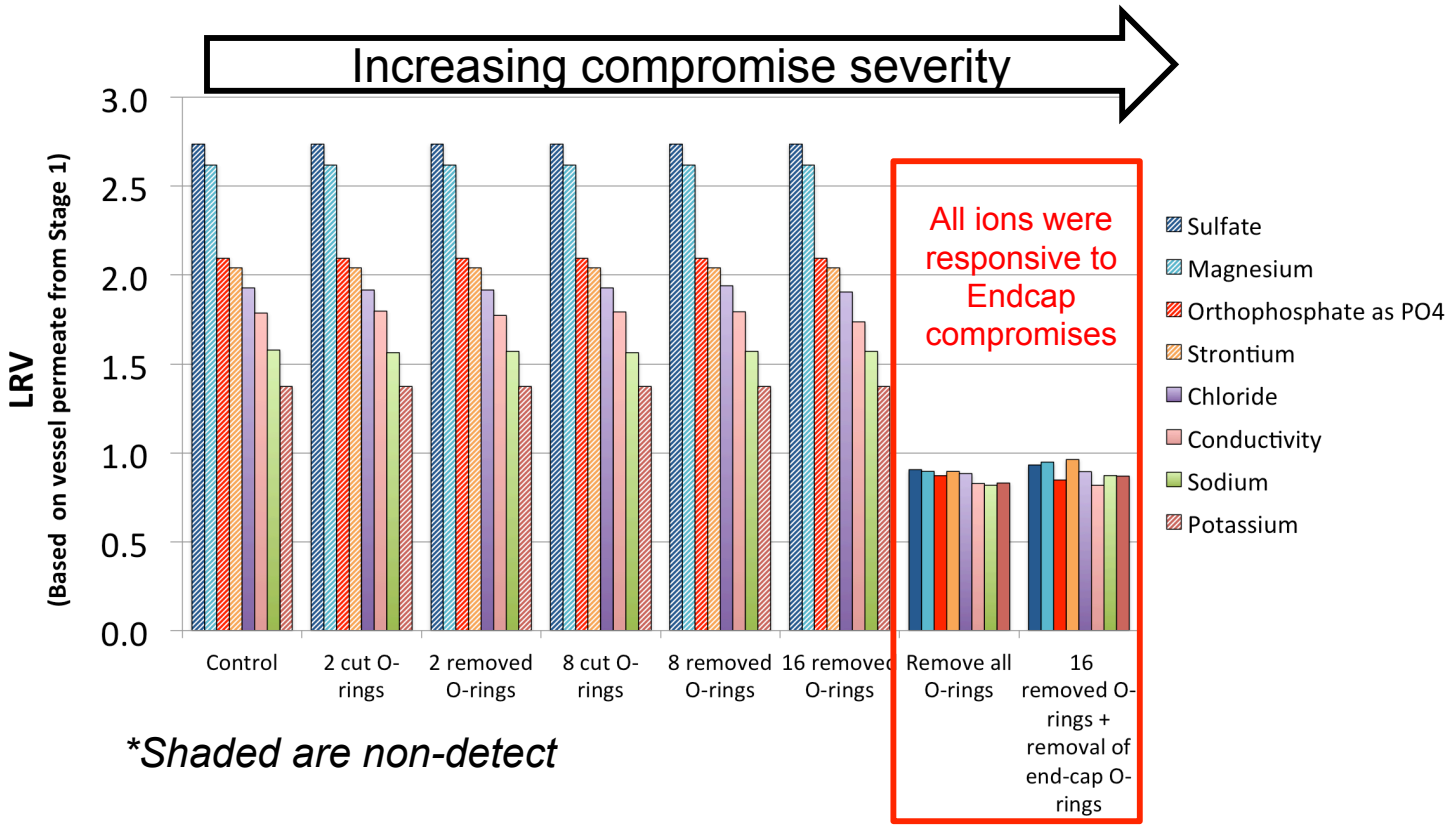



**Shaded are non-detect*

- Sensitivity limited by permeate samples

# Testing conditions for challenge testing

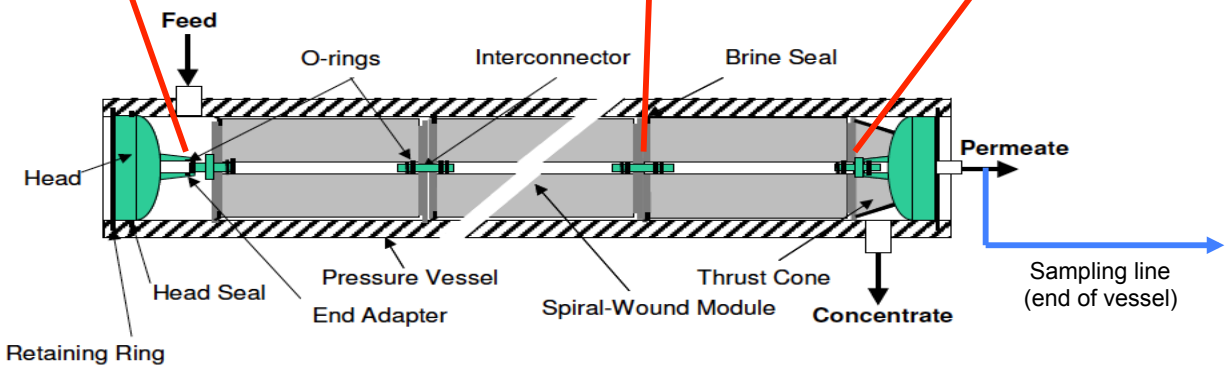
## Various degrees of failure

| Description of compromise | Category of failure |
|---|---|
| No compromise; intact<br><br>**(Control)** | None |
| Removal of o-rings (4 total) from a single permeate interconnector from a membrane in the middle of the pressure vessel (e.g. between third and fourth element)<br><br>**(Interconnector compromise)** | Low |
| Removal of o-rings (2 total) from end-cap's permeate adaptor on the brine side of the pressure vessel<br><br>**(Brine endcap compromise)** | Medium |
| Removal of o-rings (2 total) from end-cap's permeate adaptor on the feed side of the pressure vessel<br><br>**(Feed endcap compromise)** | Severe |

**Feed endcap Compromise**

**Interconnector Compromise**

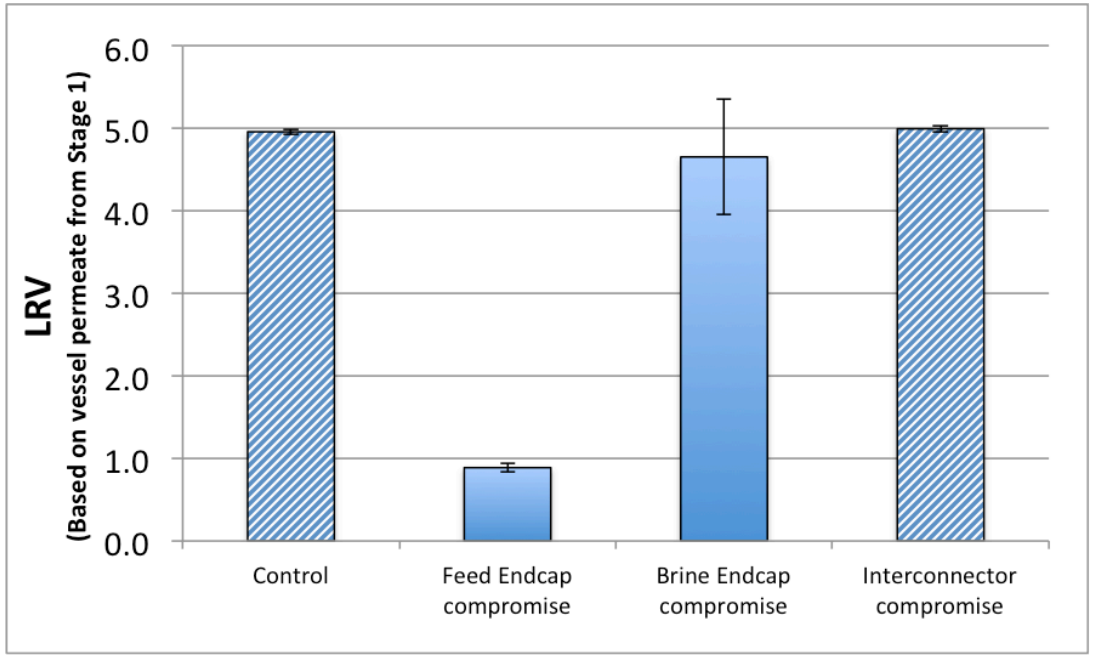
**Brine endcap Compromise**



# Challenge testing

## MS2 (preliminary results)

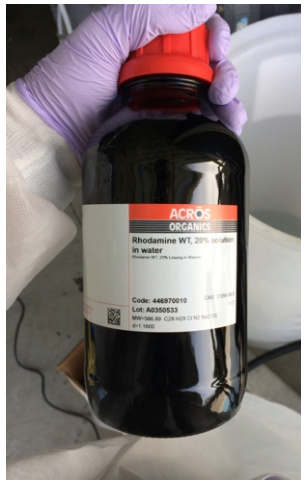
- MS2 stock ($10^{11}$ pfu/mL) and analysis provided by BioVir
- Target MS2 feed: $10^{6}$ pfu/mL
- Triplicate samples on vessel permeate and RO feed
- 5 more data sets to be added
- Up to 5 LRV achieved

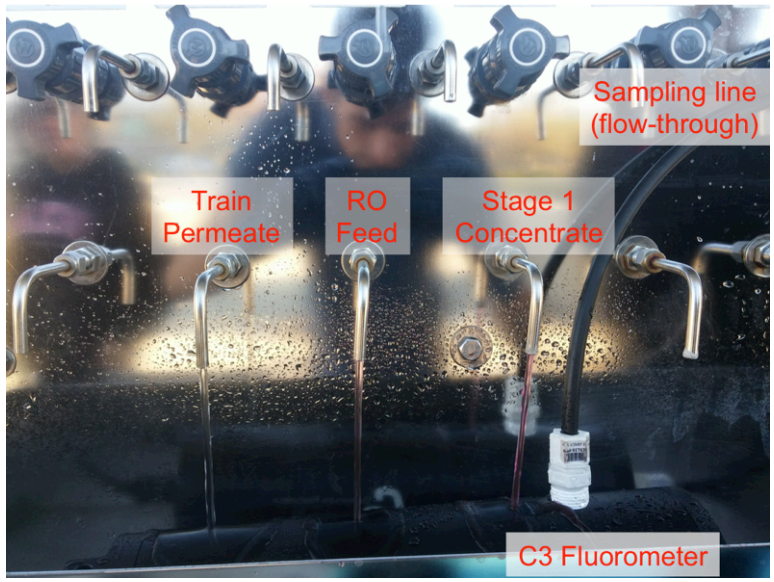


# Challenge testing

## Rhodamine WT

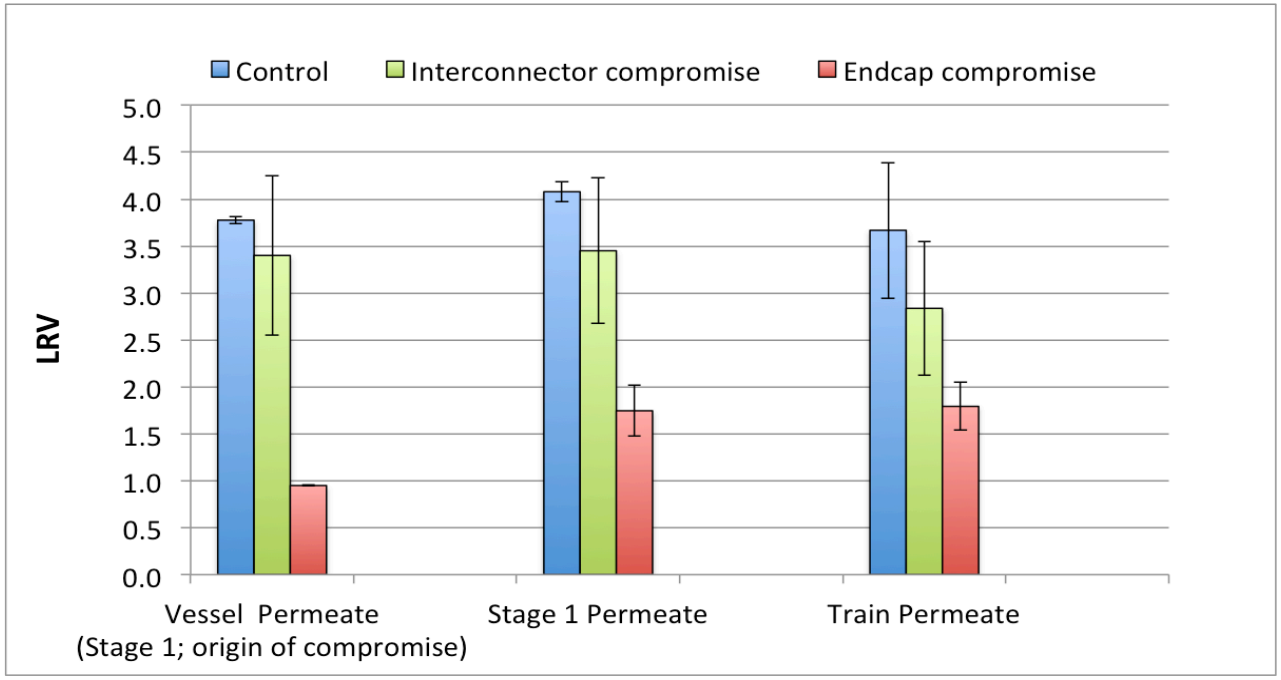
- Two rounds of testing
- Feed concentration: 3-8 mg/L
  - Feed samples: absorbance (Tai and Rathbun, 1988)
  - Permeate samples: C3 fluorometer
  - Calibration across both instruments ($r^2 > 0.99$)





# Challenge testing

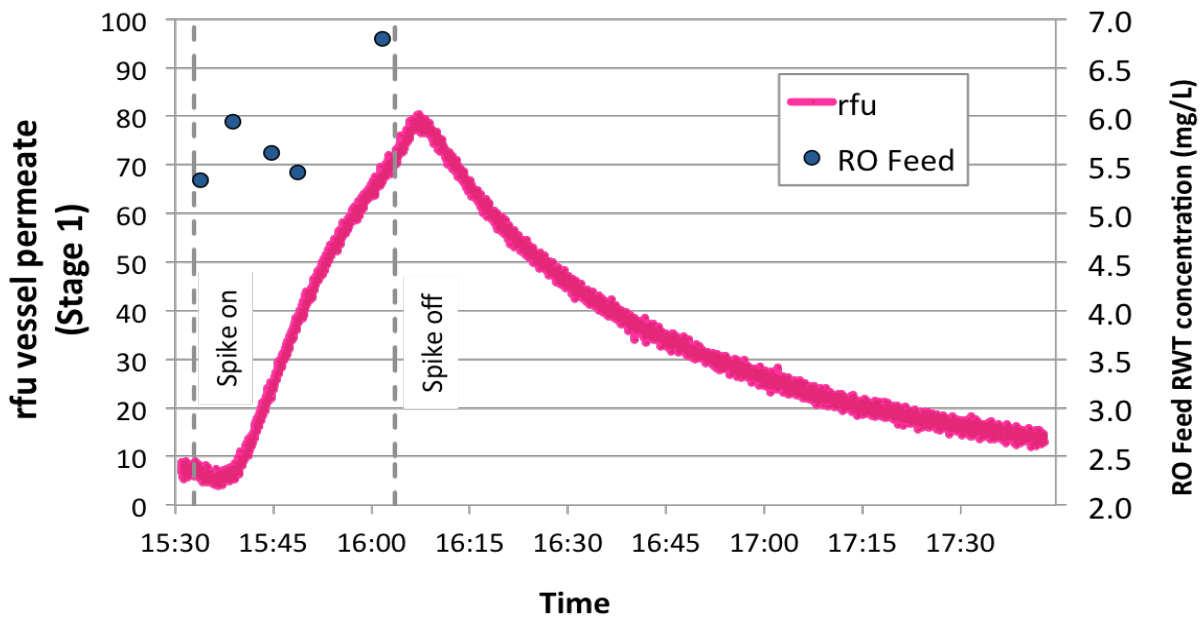
## Rhodamine WT




- LRV during intact condition: 3.7 – 4.1 LRV
- Endcap compromise → breach captured even at train permeate
- Large spread in data caused by adsorption (?)

# Rhodamine WT

## Investigating adsorption on membranes

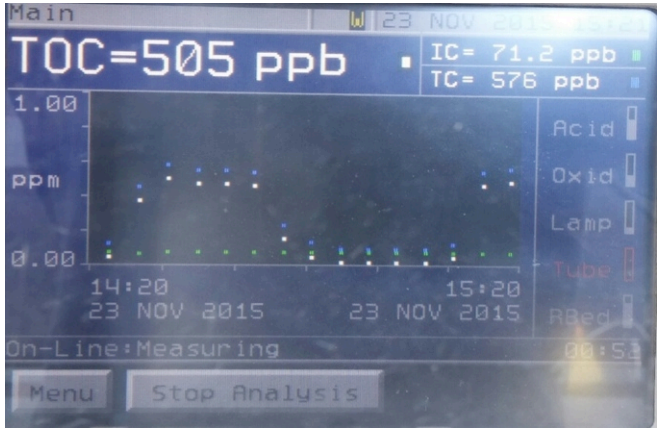



- Steady state never reached during 30-min continuous spike
- Skewed LRVs – dependent on sampling time
- Questionable assessment for membrane integrity
  - A pulsed spike would be more appropriate for such markers (Fenkel et al. 2014)

# Challenge testing

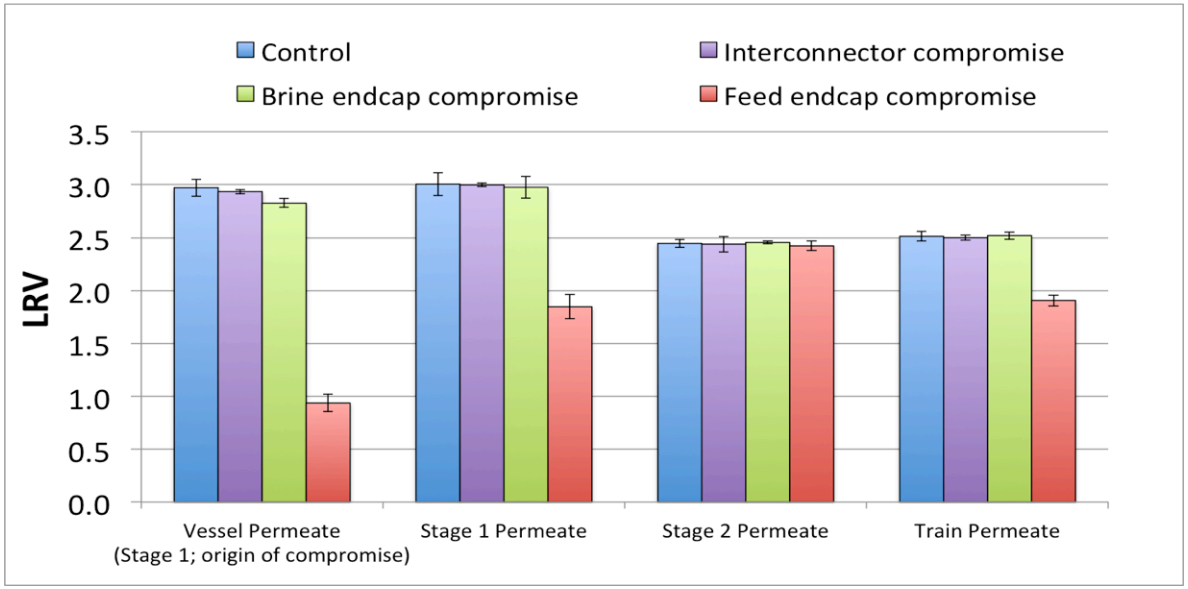
## Sugar

- 6 rounds of testing
  - Incl. testing on new membranes
- Feed concentration: 300-600 mg/L
  - Sensitivity determined via ΔTOC
  - Grab samples collected in certified GE® TOC vials



# Challenge testing

## Sugar: data from 3 rounds of challenge tests

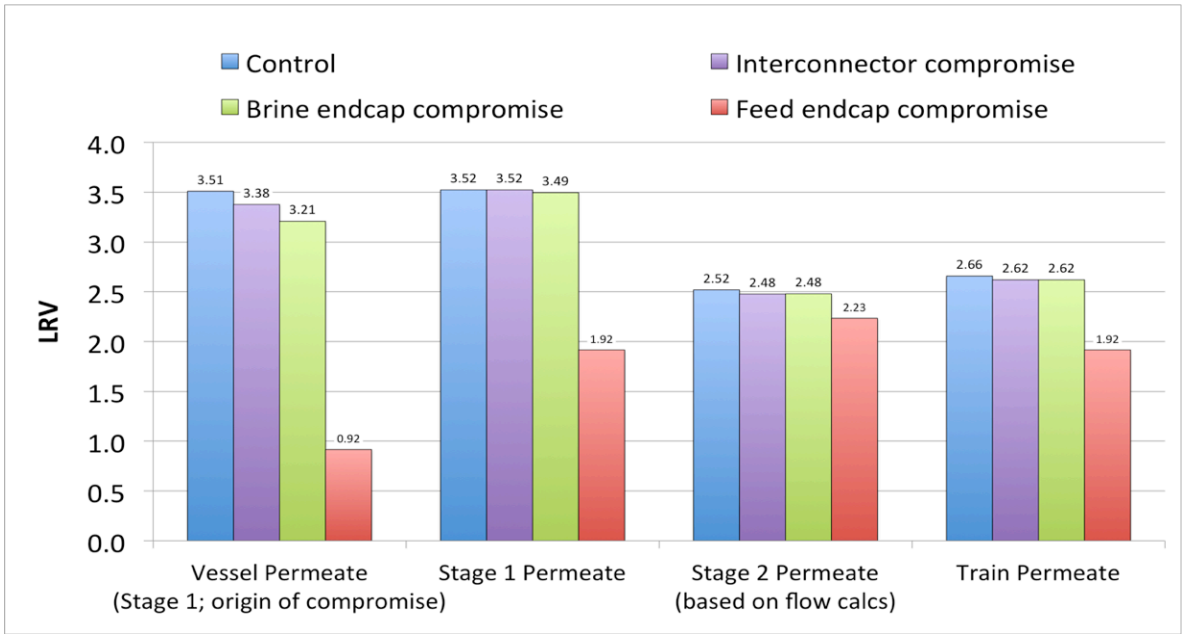



- Results were consistent across replicates
- Marker somewhat responsive to degrees of failure
- Intact LRV varied by stage
  - 3.0 for Stage 1
  - 2.4 for Stage 2
    - Due to higher wear from more aggressive chemical cleanings (5 years)

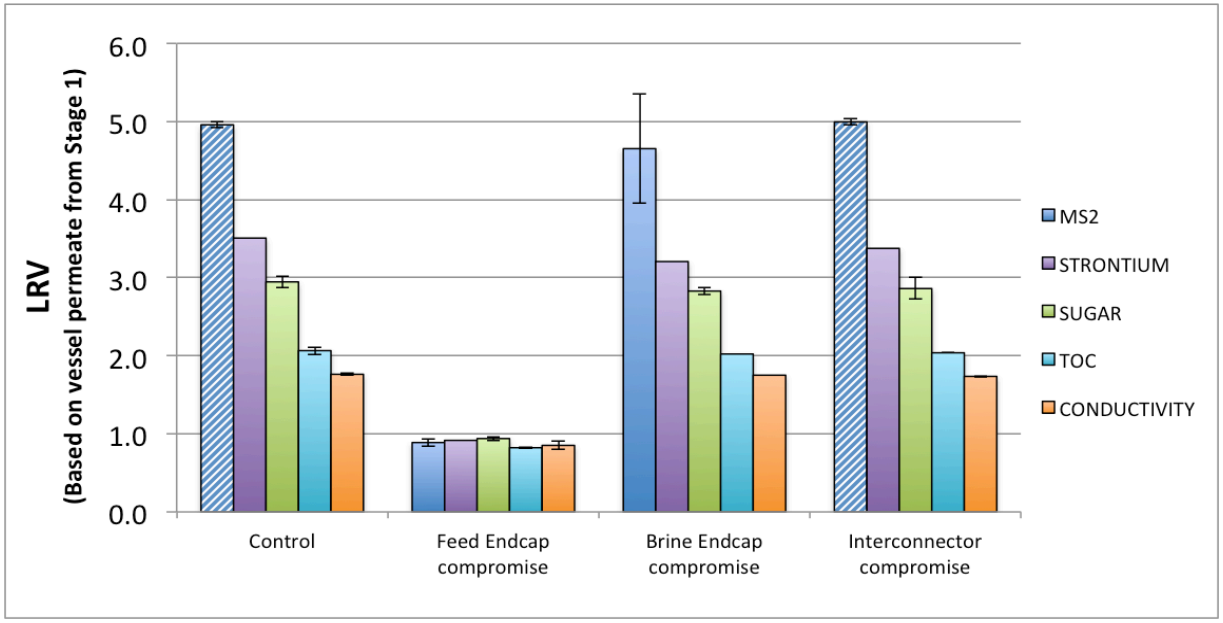
# Strontium

## Exploring lower detection method (UCMR 200.8)

- Additional strontium sampling at ambient concentrations using lower detection method
  - MRL: 0.3 µg/L vs 10 µg/L (EPA 200.7)
- Responsive to all degrees of failure on vessel permeate level
- Higher LRV than sugar (3.5 for Stage 1; 2.5 for Stage 2)
  - Condition of membranes in Stage 2
- 5 additional sets of data being processed



# Summarizing the data




- All tested markers appeared to be conservative in terms of MS2 rejection
  - Both during intact and compromised conditions
- Strontium shows great potential
  - Present at high enough concentrations to demonstrate >3 LRV
  - No spiking necessary
  - Responsive to smallest on the vessel permeate level
- RWT not included due to suggestion of adsorption

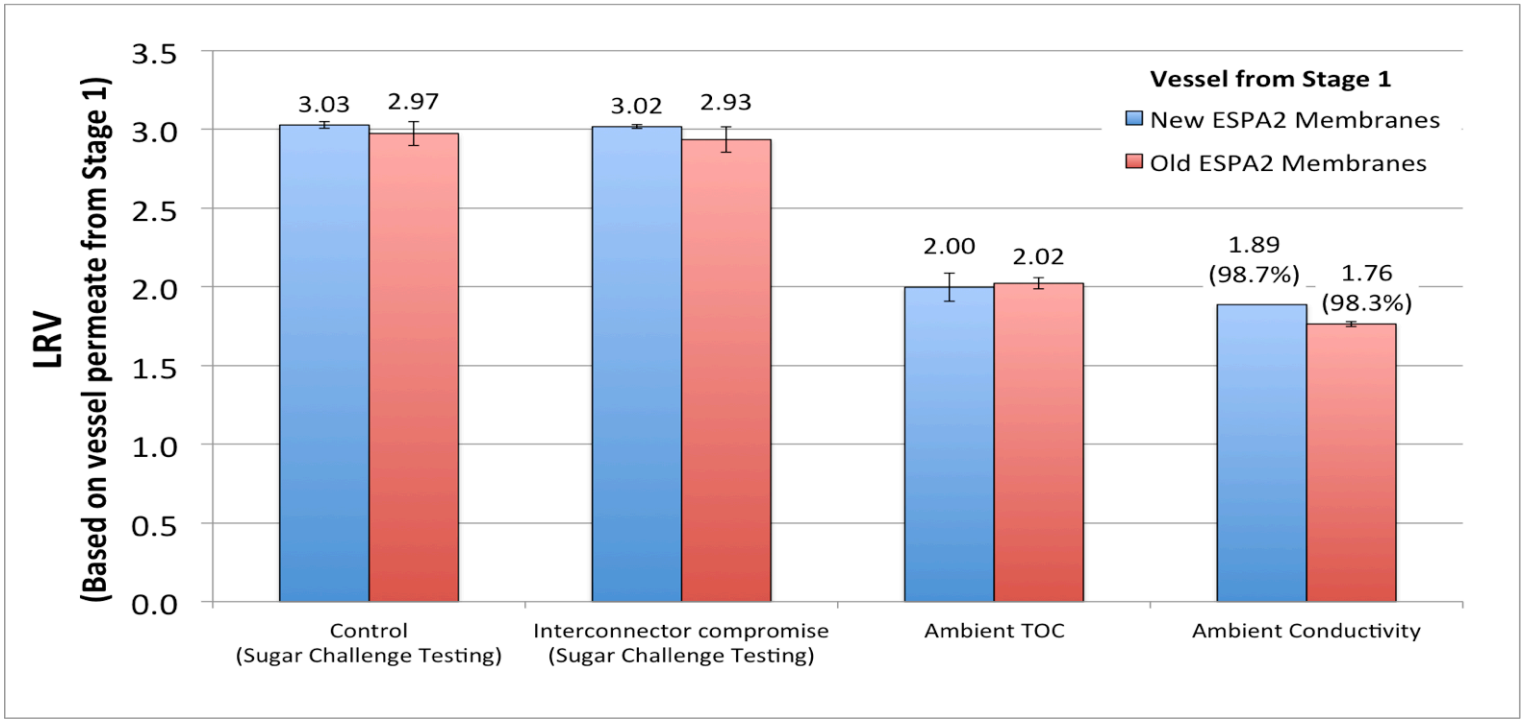
# New versus old membranes

## Preliminary results

- Single vessel replaced with new elements
- Comparison between aged and new membrane

# New versus old membranes

## Preliminary results




- New membranes only *marginally* better on rejection of sugar
- Strontium and MS2 data to be added

- Brief background on RO performance for pathogen removal
- Existing projects receiving RO pathogen removal credit
- EPA Membrane Guidance Manual for RO
- Highlights of project literature review
- Presentation of on-going project results
- **Applicability of project findings in the regulatory context**
- Closing remarks

# Project findings in the regulatory context

- Recall, a membrane filtration system requires:
  - One-time **challenge testing** to evaluate membrane sensitivity
  - Daily demonstration of integrity via **DIT**
  - Real-time indication of membrane integrity through **CIIM**
  - … to secure pathogen removal credit

# Project findings in the regulatory context

- Recall, a membrane filtration system requires:
  - One-time **challenge testing** to evaluate membrane sensitivity
  - Daily demonstration of integrity via **DIT**
  - Real-time indication of membrane integrity through **CIIM**
  - … to secure pathogen removal credit
- Need for a standardized method for RO manufacturer's to be acknowledged for pathogen removal
- *Guidance Manual* mentions turbidity as viable CIIM
  - EC and TOC can also be used

# Project findings in the regulatory context

- Recall, a membrane filtration system requires:
  - One-time **challenge testing** to evaluate membrane sensitivity
  - Daily demonstration of integrity via **DIT**
  - Real-time indication of membrane integrity through **CIIM**
  - … to secure pathogen removal credit
- Need for a standardized method for RO manufacturer's to be acknowledged for pathogen removal
- *Guidance Manual* mentions turbidity as viable CIIM
  - EC and TOC can also be used
- DIT: room for improvement
  - Marker-based tests are far more applicable for RO
  - Marker of choice <u>must</u> be applied to feed per *Guidance Manual* language
  - When already present, current projects have secured credit without needing to spike (i.e. EC, TOC)

# DIT marker contenders

**for securing enhanced pathogen credit**

## RWT
(or other dyes)

High reported LRVs (up to 5?)
Low level of detection (ng/L)
Pulsed-spikes require less dye
& said to resolve adsorption

Dye must be spiked
Adsorption on membranes
(for continuous spikes)

## Strontium
(or other ion/metal)

Notable LRV of 3.5
(UCMR3 method)
No spiking necessary
High enough feed concentration
DIT assessment without being offline

Limited by permeate detection
Hold time > DIT frequency (?)
Rejection mechanism (?)
Rejection affected by fouled elements
(charged constituent)

## Sugar
(or other organic)

LRV 3
Very reproducible
Independent of membrane age
(neutral constituent)

Costly at full-scale (?)
Feed samples must be diluted

# Closing remarks

- Pathogen LRV credit appears to be attainable for RO following LT2ESWTR and Membrane Guidance manual
- Enhanced crediting can be awarded via *marker-based* DIT
  - Strontium and sugar are viable contenders
  - Adsorption on membranes made RWT a questionable choice
    - Discussing with Nalco to perform TRASAR studies
- For potable reuse, there is a need for RO manufacturers to provide pathogen challenge testing to the industry
- TOC and EC may be used as CIIM
  - By the *Guidance Manual*: turbidity would be sufficient

# Questions?

# Appendix F – AWWA International Symposium on Potable Reuse Poster

**Poster title: Achieving Potable Reuse Reliability Using Enhanced Treatment and Monitoring at a 1 MGD Demonstration Facility**

**Date: 01/25/16 to 1/27/16**

**Location: Long Beach, CA (International Symposium on Potable Reuse Poster)**

# Achieving Potable Reuse Reliability Using Enhanced Treatment and Monitoring at a 1 MGD Demonstration Facility

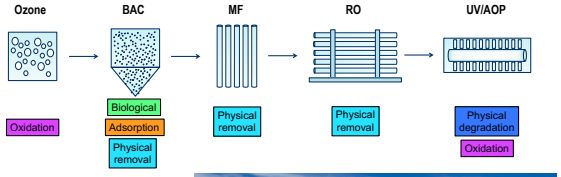
*R. Shane Trussell, Aleksey Pisarenko, Elise Chen, Eileen Idica, Brian Pecson, Rodrigo Tackaert – Trussell Technologies, Inc.* *Bill Pearce – City of San Diego*

## Introduction

This work provides a framework for potable reuse safety, and discusses how these concepts are being implemented in a yearlong demonstration test as part of the WateReuse Project Number 14-12. The strategy for reliability in public health protection uses a framework based on the four "R" words: *R*eliability, *R*edundancy, *R*obustness, and *R*esilience. Reliability is the consistent protection of public health, and is achieved with Redundancy and Robustness contributing to failure prevention and Resilience providing failure response. Redundancy in treatment and monitoring is key as potable reuse moves away from use of an environmental buffer, resulting in shorter storage periods for the purified water between conveyance and consumption. This project is providing comprehensive testing, evaluation, and demonstration of "failsafe" treatment steps for potable reuse without an environmental buffer. Ultimately, this demonstration project will tie together successful existing strategies with key findings from recent research to demonstrate the consistency of potable reuse in the protection of public health.

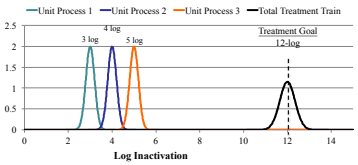
## Advanced Water Purification Demonstration Facility

***at the North City Water Reclamation Plant, San Diego, CA***



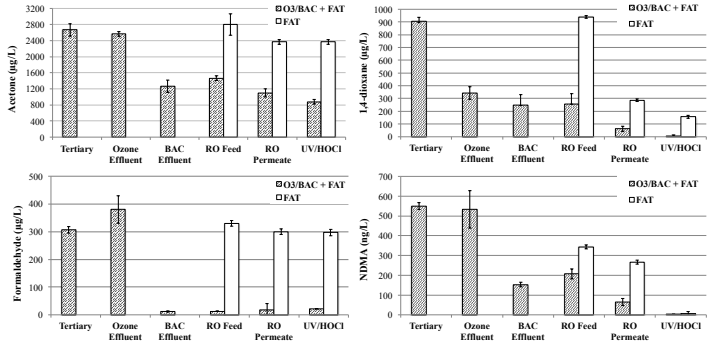

Treatment train provides multiple barriers with a wide diversity of removal mechanisms – this minimizes the probability that a contaminant will pass through.

## Using PDFs to Measure Reliability




To quantify the consistency and degree of performance, performance distribution curves are being developed for each treatment process.

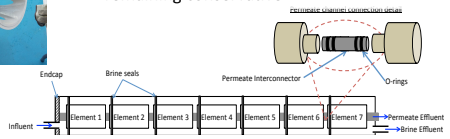
## System Chemical Challenge Tests



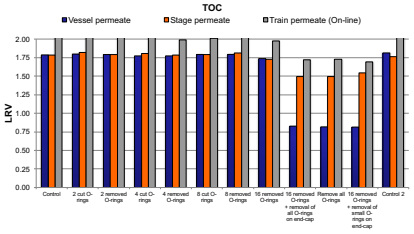

- No single process can adequately address all contaminants of concern
- Spiked compounds selected based on varying levels of treatability by the different processes
- Additional robustness with O3/BAC demonstrated
- UV/HOCl was more effective on 1,4-dioxane removal than UV/$H_2O_2$ (0.5-log removal easily achieved)
- Second round of testing performed for Acetone and 1,4-dioxane to refine results

## Reverse Osmosis Integrity Challenge Tests

- Challenge RO system to establish degree of virus removal
- Identify the surrogate that provides the highest degree or removal credit while remaining conservative



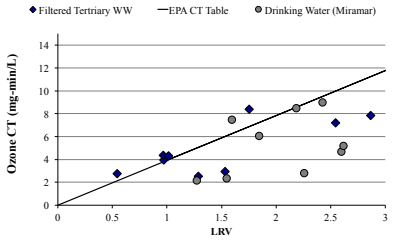

- O-ring compromises chosen based on literature showing the greatest MS2 virus passage with o-ring breaches

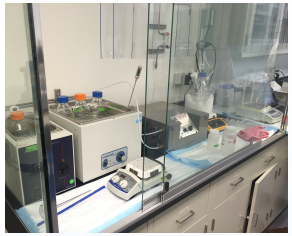



- Conductivity, TOC, sugar, Rhodamine WT dye and ions and metals (e.g., sulfate and phosphate) were tested
- Compromise of end-cap o-ring were most detectable via surrogates
- Next steps include additional testing of surrogates with MS2 virus testing, to ensure virus removal is tracked accurately

## Cryptosporidium Inactivation by Ozone

- Verification that existing EPA ozone CT tables, developed for drinking water, also apply to treated wastewater.
- Additional testing planned to extend CT tables to LRVs higher than 3



## Conclusions and Next Steps

- Individual tests are providing evidence necessary to understand
  - what happens when a potable reuse system faces challenging water quality
  - feasibility of surrogate to allow increased RO virus removal credit
  - application of existing ozone CT and LRV framework to potable reuse
- Combined, these tests contribute to understanding treatment robustness and redundancy, and ultimately the overall reliability of a potable reuse system.
- Quantification of reliability in progress using 10-sec frequency data of routine operations

## Acknowledgements


- WateReuse Research Foundation's financial, technical, and administrative assistance in funding and managing the project through which this information was discovered, developed and presented.
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