# Onsite Water Reuse Design & Implementation Tips

This document is intended as a resource to support the design and implementation of onsite water reuse systems in San Francisco in accordance with Article 12C of the San Francisco Health Code (also known as the Non-potable Ordinance, NPO) and its implementing rules and regulations.

This document is not a comprehensive manual for implementation of onsite water reuse; rather, it is a compilation of lessons learned through SFPUC's work administering the Onsite Water Reuse Program. The tips and lessons learned contained in this document are aimed at assisting designers and other stakeholders to further streamline the process of designing, permitting, and operating Article 12C-compliant onsite water reuse systems in San Francisco.

## Planning for Onsite Water Reuse Systems

- Meet with SFPUC Water Resources staff early in planning. Projects can request joint planning meetings with the Non-potable Ordinance (NPO) and Stormwater Management Ordinance (SMO) teams. Email nonpotable@sfwater.org and stormwaterreview@sfwater.org.
- Select and design treatment processes based on anticipated flows, demands, and water quality characteristics.
- Simple designs are best. Remember: someone will have to operate and maintain the system in perpetuity!
- Combining multiple water supplies (e.g. graywater and rainwater) into a single collection tank can help simplify the infrastructure needed.

***Plan early & meet with SFPUC staff***

## Tips for Construction and Ongoing Operations & Maintenance

- The onsite non-potable water system should be built in accordance with the approved Engineering Report (if a permit from San Francisco Department of Public Health is required). If a system is built in a way that differs from the approved Engineering Report, an amendment or updated Engineering Report must be submitted to SFDPH for review and approval with the Construction Certification Letter.
- Ensure all tanks and pipe inlets/outlets are properly sealed to prevent mosquitos.
- The project owner, design engineer, and daily operations staff should coordinate responsibilities for conditional startup and ongoing O&M.

- Ensure all system components that require maintenance are easily accessible (e.g. avoid locating access hatches in vaults or private storage areas).

## Cross-connection Testing Tips

- As a condition of water service, all dual plumbed buildings must have an approved reduced pressure principle assembly installed at the service meter. This assembly is in addition to required backflow prevention wherever makeup water is supplied to a storage tank.
- A cross-connection shut down is test required for all buildings with onsite water reuse systems prior to operating the system.
- Another cross-connection shutdown test is required every 4 years thereafter for blackwater treatment systems.
- Ensure contractors are informed of exactly what fixtures will be installed so the contractors can make accommodations for the cross-connection test.
- All backflow assemblies and air gaps must be tested and/or inspected annually to comply with the plumbing code and Article 12A of the San Francisco Health Code.

## Primary vs. Secondary Disinfection

An important distinction for disinfection in onsite water reuse systems is between primary and secondary disinfection:

- **Primary disinfection:** used to achieve pathogen inactivation. Generally associated with pathogen log reduction credit.
- **Secondary disinfection:** used to maintain a disinfectant residual to prevent contamination as water travels through the distribution system.

***Understand the difference between primary and secondary disinfection***

Most onsite reuse systems will need to provide both primary and secondary disinfection; there are many ways to configure a treatment system to successfully achieve both. A comparison of different disinfectants and their pros and cons for both disinfection steps is provided below in Table 1.

***Table 1.*** *Comparison of pros (✓) and cons (–) of common disinfectant options for primary and secondary disinfection.*

| Disinfection Process | Log Reduction Credit (Primary) | Maintaining Residual in Distribution System (Secondary) | Additional Considerations |
|---|---|---|---|
| **Free Chlorine** | ✓ Smaller footprint required for virus credit because of low CTs needed<br>– Not effective against protozoa[1]<br>– Requires dosing control system to maintain residual | ✓ Effective for controlling biofilm growth<br>– Will need to breakpoint chloramine residual in potable makeup water to maintain free chlorine residual (see Page 4)<br>– Less stable than chloramine | ✓ Color control |
| **Chloramine** | – Requires very large footprint to reach necessary CT values for virus credit<br>– Not effective against protozoa | ✓ Stable residual<br>✓ Easy to blend with existing potable makeup water with chloramine residual<br>✓ Less reactive with organics, may reduce overall chemical usage<br>– Requires chemical storage and handling of chlorine and ammonia on site | |
| **UV** | ✓ Effective against virus, protozoa, and bacteria<br>✓ Relatively simple implementation with pre-validated reactors, with UV intensity and flow rate monitoring | – Not suitable as a secondary disinfectant due to lack of residual | |
| **Ozone** | ✓ Effective against virus<br>– Not effective against protozoa[1] | – Not suitable as a secondary disinfectant due to lack of stable residual | ✓ Color control |

[1] The two major groups of parasitic protozoa are *Giardia* and *Cryptosporidium*. Both free chlorine and ozone can be effective against *Giardia*; however, because they are not effective against *Cryptosporidium*, they have been described here as not effective against protozoa.

## Additional Notes on Chlorine Disinfection

To achieve pathogen reduction credits for chlorine disinfection, calculations must be shown in the Engineering Report to demonstrate CT disinfection, where CT = Chlorine Residual Concentration (C) * Contact Time (T). The configuration of the chlorine contactor is an essential element in receiving CT credit. The contactor must be able to provide both the minimum specified contact time and chlorine residual for all of the water flowing through the system. The following criteria must be met:

***Accurately justify disinfection configuration and CT calculations***

- All water entering the chlorine contactor must be chlorinated prior to entering the contactor.
- Chlorine cannot be added in an internal recirculation loop.
- Chlorine residual must be measured in the contactor effluent.

***Ammonia***

For blackwater and graywater systems, the presence of ammonia can present challenges for free chlorine disinfection. Ammonia and chloramine will consume the free chlorine or convert the free chlorine to chloramine, a weaker disinfectant that is less effective for virus inactivation (see Table 1). A chlorine dosing control system can be used to ensure that a free chlorine residual is present. A control system allows chlorine dosing to be modified in response to changes in the measured chlorine residual; if the residual is too low, the system doses more chlorine, and vice versa.

***Determine the potential impacts of ammonia; consider how to minimize operational complexity***

Ammonia can be removed through biological treatment via nitrification, i.e. the conversion of ammonia to nitrate. If it is anticipated that ammonia will not be fully removed prior to disinfection, consider whether LRTs can be met without the use of free chlorine disinfection to avoid the operational complexities of breakpoint chlorination. Also consider using chloramine as the secondary disinfectant to avoid the need to breakpoint ammonia.

***Free chlorine monitoring***

If CT credit is sought for free chlorine, provide evidence in the Engineering Report that the free chlorine analyzer selected can distinguish between free and combined chlorine. This is important to ensure free chlorine, not chloramine, is present.

***Chlorine contactor configurations***

There are two common configurations for chlorine disinfection in onsite water reuse systems: tank and pipeline. A comparison of these two configurations is provided below in Table 2. Additional examples of potential tank configurations are provided in Figure 1.

***Compatibility of disinfectants***

SFPUC potable makeup water has a chloramine residual. This needs to be accounted for in the secondary disinfection design; chloramine reacts with free chlorine in what is called a breakpoint reaction. When these two chemicals react, both chloramine and free chlorine are consumed, and the net result is an overall lowering of the total chlorine residual present. This reaction will continue until all chloramine is consumed (i.e., until it reaches the breakpoint). After that point, the continued addition of free chlorine will result in a free chlorine residual. Consider using chloramine as a secondary disinfectant to simplify operation during periods of blending and avoid the need to breakpoint the chloramine residual in the potable makeup water.

***Account for impacts of blending with SFPUC potable makeup water, which carries a chloramine residual***

***Water storage and recirculation***

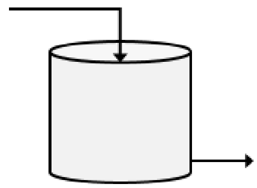
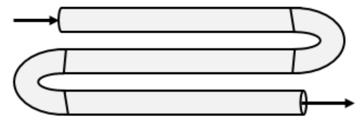
Because demands are not constant for these systems, there may be times when water sits in a treated water storage tank (e.g. overnight and weekends in commercial buildings). Recirculation is an effective strategy for maintaining the concentration of secondary disinfectant, especially when linked to a chlorine dosing control system. Such a system would target a specified chlorine residual, and would use the chlorine residual measurement to determine whether recirculation and/or changes to chlorine dosing are needed to meet the target.

***Consider whether recirculation will be needed to maintain secondary disinfectant residual***

***Chlorine dosing control***

The effectiveness and response time of chemical dosing control depends on the time between chemical dose location and residual measurement. Longer residence times can result in a lag between residual measurement and dose adjustment, which in turns leads to a lag in actually increasing or decreasing the residual concentration.

***Table 2.*** *Comparison of tank and pipeline chlorine contactor configurations.*

| | Tank Contactor | Pipeline Contactor |
|---|---|---|
| **Illustration** |  |  |
| **Pathogen Crediting Approach** | $CT = Cl_2\ residual * Average\ HRT * Baffling\ factor$ | |
| **Default Baffling Factor** | 0.1 | 0.6[1] |
| **Pros** | ✓ Simple design | ✓ Smaller footprint for same CT because of higher baffling factor<br>✓ Easier control due to faster feedback |
| **Cons** | – Larger footprint for same CT<br>– More challenging to control chlorine dosing if tank residence time is long | – More complex design |

[1] Design requirements: Length/diameter (L/D) ratio $\geq$ 40; Reynold's number $\geq$ 4,000 (i.e. turbulent flow regime); no expansions/contractions.
CT = product of chlorine residual (C) and contact time (T); HRT = hydraulic residence time

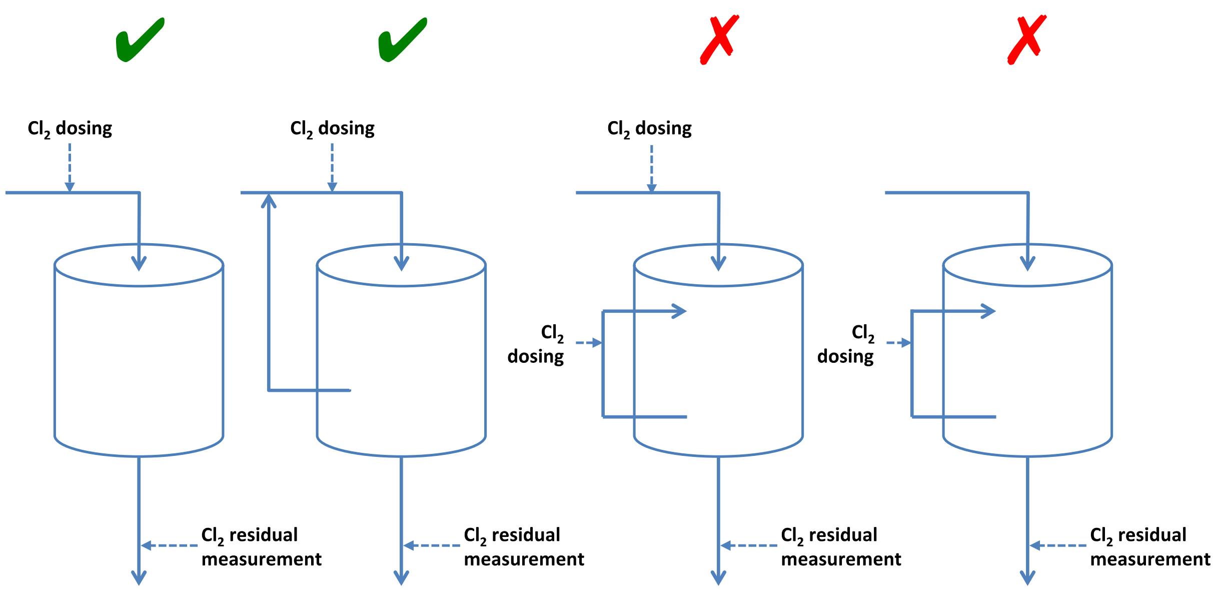



***Figure 1.*** *Examples of proper (✓) and improper (x) configurations for tank chlorine contactors.*

## Additional Notes on UV Disinfection

- Reactor must be validated per accepted framework
  - NSF 55 Class A
  - EPA UV Disinfection Guidance Manual
- A list of validated UV reactors that have been accepted by the California Division of Drinking Water (DDW) is available on the Onsite Water Reuse Program web page under Validated UV List.
- Use the UV reactor validation report to determine the validated operating envelope (flow rate, UV transmittance, UV intensity) within with the desired dose can be achieved.
- Appropriate reactor selection depends on water quality
  - Expected water quality should meet minimum validated UVT
  - The appropriate reactor will vary based on the source water and upstream treatment of a given onsite water reuse system. For example, the UVT of an MBR effluent will be different from that of filtered rainwater. The former will likely require a UV reactor that has been validated down to a UVT of 65 – 75%, whereas the latter may be able to use a UV reactor that has been validated at a UVT of 80% or above.
- With multiple reactors in series, the pathogen credit is based on total dose. See Table 3 below for pathogen credits available for common UV doses.

***Select validated and approved UV reactors that are compatible with anticipated water quality***

***Table 3.*** *Pathogen log reduction credit for validated UV reactors. Credits apply for reactors validated using MS2 as the challenge organism.*

| Validated Dose ($mJ/cm^2$) | Virus | Protozoa | Bacteria |
|---|---|---|---|
| 40 | 2 | 3 | 2 |
| 80 | 3.5 | 6 | 3.5 |
| 120 | 5 | 6 | 5 |
| 150 | 6 | 6 | 6 |

## Membrane Bioreactor Pathogen Crediting

An MBR can achieve 1.5-log virus credit, 2-log protozoa credit, and 4-log bacteria credit if the MBR is operated within the Tier 1 operating envelope as defined in the AWRCE, *Membrane bio-reactor*, WaterVal validation protocol. See Table 4 below for the Tier 1 operating envelope.

***Table 4.*** *Summary of MBR operating envelope for Tier 1 default pathogen reduction credits.*

| Parameter | Units | Minimum | Maximum |
| --- | --- | --- | --- |
| Bioreactor pH | pH units | 6 | 8 |
| Bioreactor dissolved oxygen | mg/L | 1 | 7 |
| Bioreactor temperature | C | 16 | 30 |
| Solids retention time | d | 11 | -- |
| Hydraulic retention time | h | 6 | -- |
| Mixed liquor suspended solids | g/L | 3 | -- |
| Transmembrane pressure | kPa | 3 | -- |
| Flux | $L/m^2/h$ | -- | 30 |
| Turbidity | NTU | -- | 0.2 |

## Conditional Startup Period Operations for Blackwater and Graywater

Blackwater and graywater onsite water reuse systems need to divert treated water to the sewer during conditional startup and must account for this in their design. These systems must be designed to be able to achieve the following simultaneously:

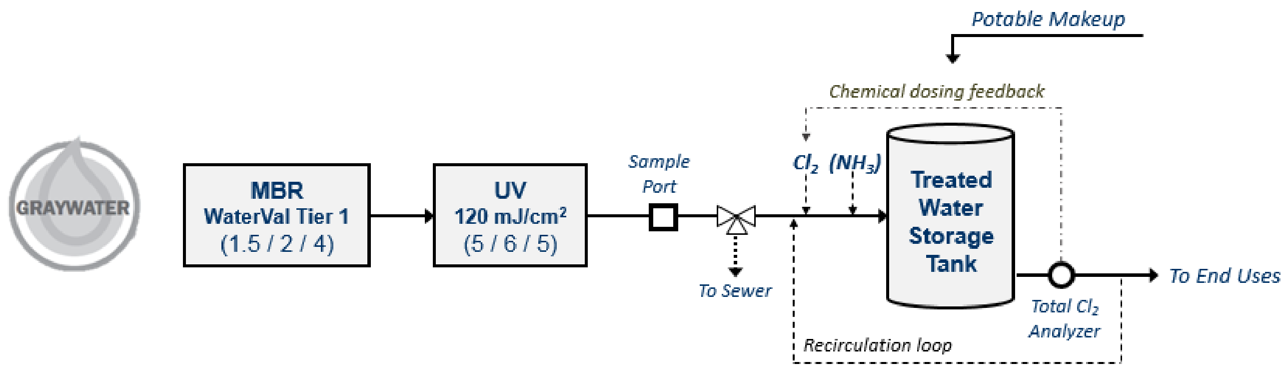
- Verify that all log reduction targets are met
- Verify compliance with water quality standards – BOD, TSS, turbidity, and total coliform
- Divert treated water to sewer
- Supply end uses with potable water
- Operate in final plumbing configuration with an approved cross connection test completed

***For graywater and blackwater, plan for diverting treated water to the sewer during conditional startup***

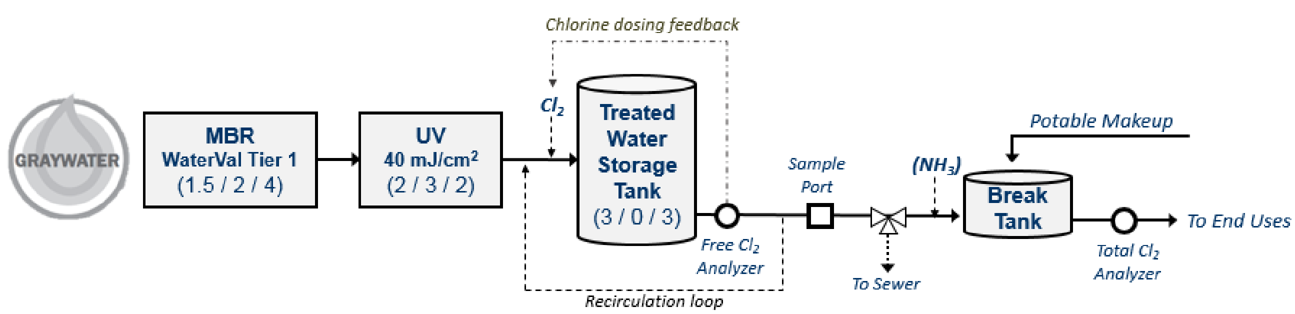
## Example Graywater and Blackwater Treatment Train Designs

Several designs are summarized in the figures below. **These are provided as examples and are not intended to be prescriptive or exhaustive. SFPUC does not endorse any design. All designs must be prepared by a qualified licensed engineer**. Pathogen log reduction credit is shown in the format (Virus / Protozoa / Bacteria). This document does not describe the continuous online monitoring and other design elements that would be needed for each unit process to obtain the specified log reduction credit.

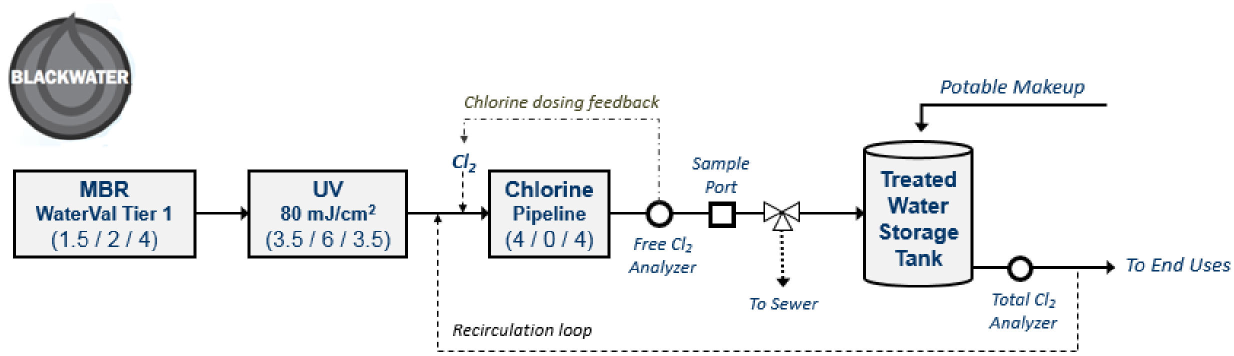
In some treatment trains below, the option for ammonia addition is included in the form ***($NH_3$)***. In each case, either free chlorine or chloramine could be used as the secondary disinfectant; the benefits of chloramine would be a more stable residual, and it would eliminate the need to breakpoint the chloramine residual in the potable makeup water.



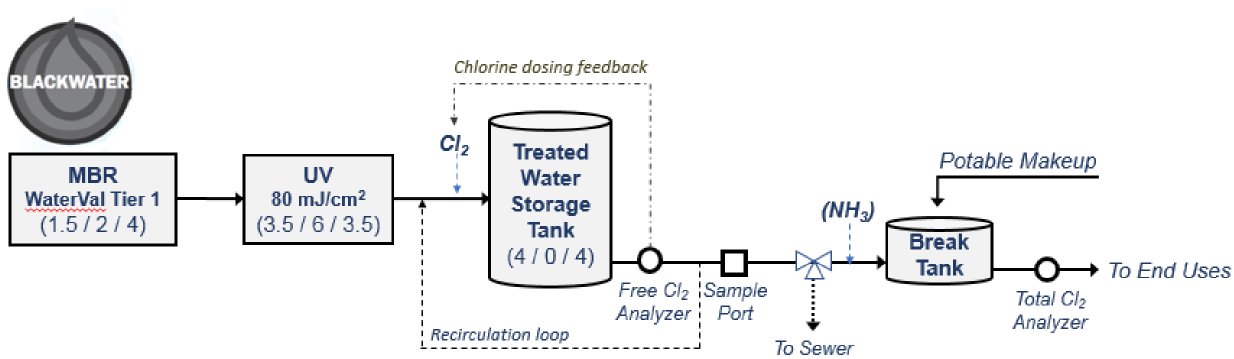

| Benefits | Drawbacks |
| --- | --- |
| ✓ Single final tank<br>✓ Ammonia bleed-through would not impact primary disinfection performance<br>✓ Requires single total chlorine meter after treated water storage tank<br>✓ Easy to implement recirculation for periods of low demand<br>✓ ***(If adding $NH_3$)***: Stable chloramine residual for secondary disinfection, and simpler blending with potable makeup water | – Can't test chlorine dosing on treated water during startup period<br>– Breakpoint chloramine residual in potable makeup water |



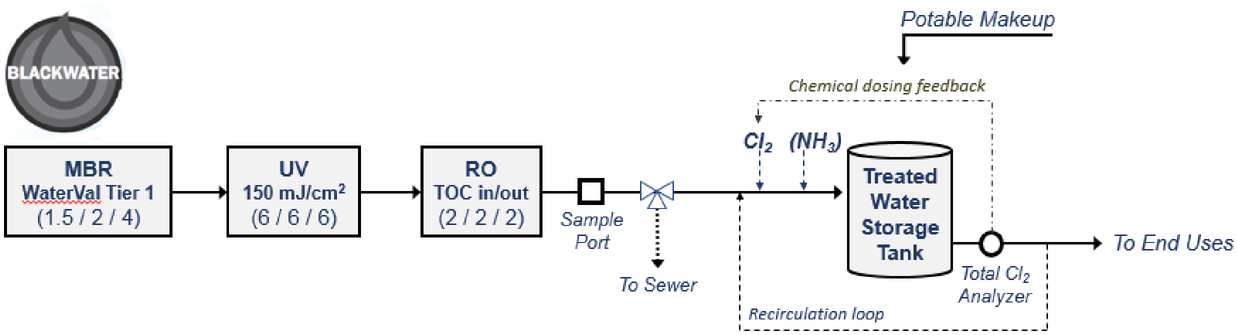

| Benefits | Drawbacks |
| --- | --- |
| ✓ Flexibility to troubleshoot chlorine dosing system independently of serving end uses<br>✓ ***(If adding $NH_3$)***: Stable chloramine residual for secondary disinfection, and simpler blending with potable makeup water | – Requires consistent nitrification performance and chlorine dosing control system<br>– Small additional footprint of break tank<br>– Requires free chlorine meter (after treated water tank) and total chlorine meter (after break tank) |




| Benefits | Drawbacks |
| --- | --- |
| ✓ More control over free chlorine process for disinfection and color control due to use of pipeline contactor<br>✓ Flexibility to troubleshoot chlorine dosing system independently of serving end uses | – Additional footprint of separate chlorine contactor<br>– Requires consistent nitrification performance and chlorine dosing control system<br>– Would have longer feedback time to increase chlorine residual in recirculation loop |




| Benefits | Drawbacks |
| --- | --- |
| ✓ Save footprint by not needing separate chlorine contactor and treated water storage tank<br>✓ Can include chlorine recirculation loop to maintain chlorine residual during periods of low demand<br>✓ Potential benefits for color control if tank has long residence time<br>✓ ***(If adding $NH_3$)***: Stable chloramine residual for secondary disinfection, and simpler blending with potable makeup water | – Less control over free chlorine residual if tank has long residence time<br>– Requires consistent nitrification performance and chlorine dosing control system |




| Benefits | Drawbacks |
|---|---|
| ✓ RO provides consistent color control<br>✓ Does not rely on sophisticated chlorine dosing control system for log reduction credit<br>✓ Can include chlorine recirculation loop to maintain chlorine residual during periods of low demand<br>✓ ***(If adding $NH_3$)***: Stable chloramine residual for secondary disinfection, and simpler blending with potable makeup water | – High energy use and operational complexity of RO |

## Rainwater Harvesting Planning

- If rainwater harvesting is used for NPO compliance, it may also provide benefits for complying with the Stormwater Management Ordinance (SMO). For more information regarding the SMO, refer to www.sfwater.org/smr.
- Consider both capital costs and life cycle (O&M) costs when planning for rainwater harvesting.
- Ensure the rainwater cistern size matches the intended end use to avoid an oversized tank for minimal demand or minimal supply for large demand.

***Size rainwater cisterns to match intended use***

## Rainwater Harvesting System Design

- Routing rainwater collection through a rooftop planter or green roof may impact treatment downstream by causing turbidity issues.
- Plumb potable make-up water connection (with approved backflow protection) into final treated water storage tank.
- Reduced pressure principle assemblies are allowed on the potable makeup water connection to the final treated water storage tank in a rainwater system.
- Consider how to maintain rainwater collection cistern in dry months.
- Add appropriate pretreatment to design (e.g. first flush diverter).
- Ensure passive overflow (or 3-way failsafe bypass valve) is designed to avoid flooding the basement during power failures or peak storm events.

- Rainwater harvesting is optimal in commercial/office buildings that don't produce enough graywater to meet 100% of the building's non-potable water demands.

## Estimated Lab Costs for Water Quality Analyses

Water quality analyses are required for some onsite water reuse systems. The following information is intended to help plan for ongoing O&M costs. The costs specified do not include the cost of collecting and transporting samples to a certified lab.

***Table 5.*** *Estimated costs for laboratory analysis of total coliform, BOD, and TSS*.*

| Parameter | Estimated Cost per Sample |
|---|---|
| Total Coliform | $35 – $55 |
| BOD | $35 |
| TSS | $20 |

* Does not include costs for collecting and transporting samples.