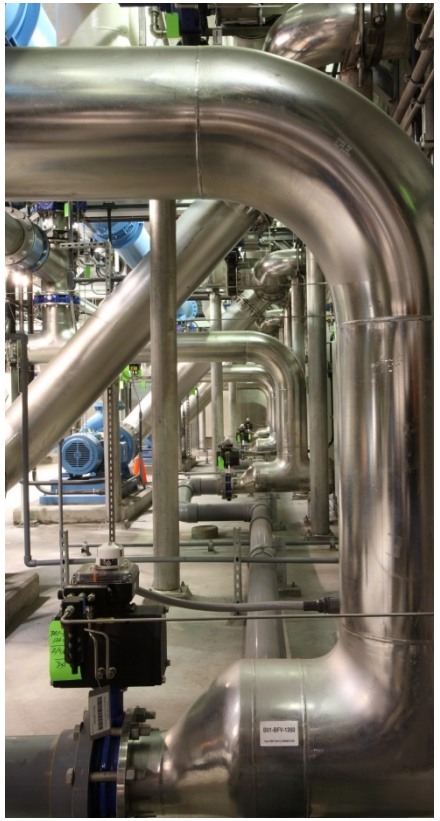
Breaking Down Implementation Barriers for Onsite Non-Potable Water Systems

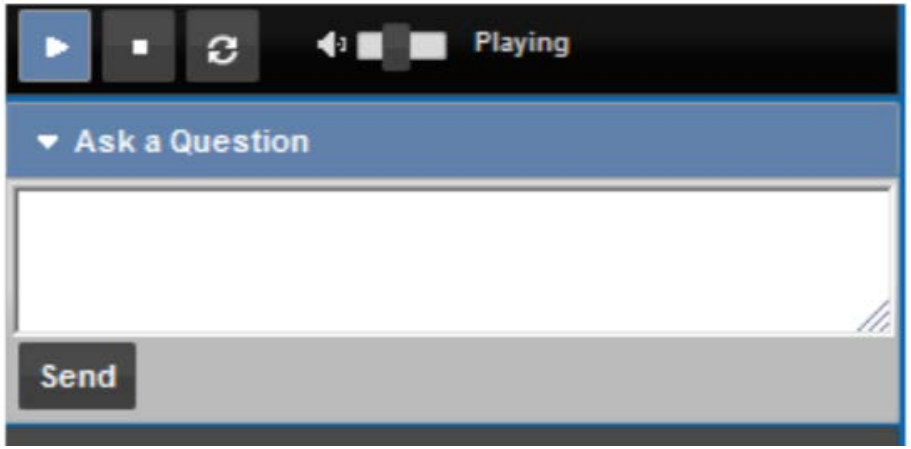
April 15, 2020



WateReuse Webcast Series

A Few Notes Before We Start…

- Today's webcast will be 60 minutes.
- There is one (1) Professional Development Hour (PDH) available for this webcast.
- A PDF of today's presentation will be shared via email
- Please type questions for the presenters into the chat box located on the panel on the left side of your screen.

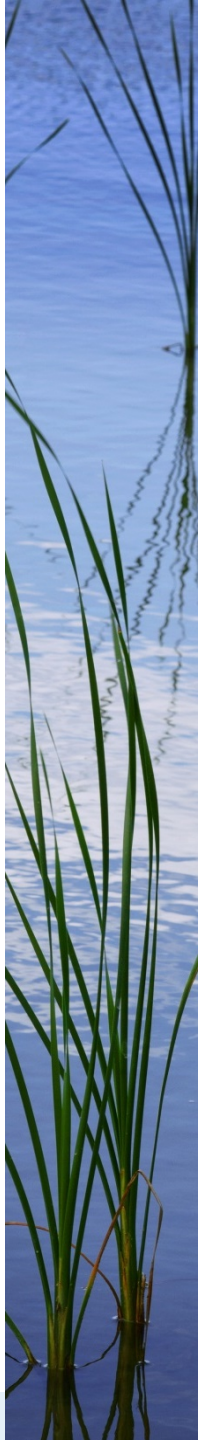


Today's Presenters

Paula Kehoe
Director of Water Resources
San Francisco Public Utilities Commission

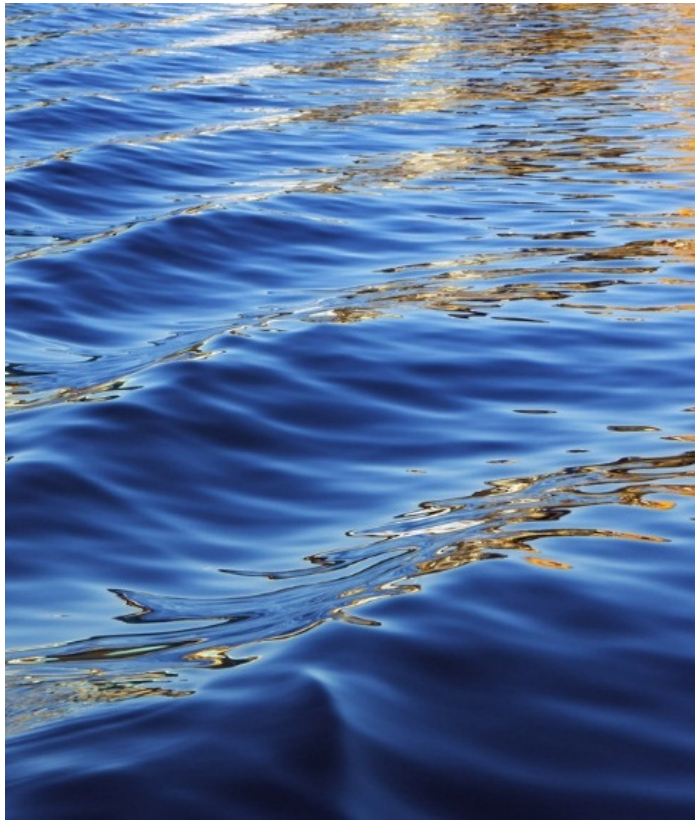
Brian Pecson
Principal Engineer
Trussell Technologies

Brie Post
Senior Engineer
Trussell Technologies

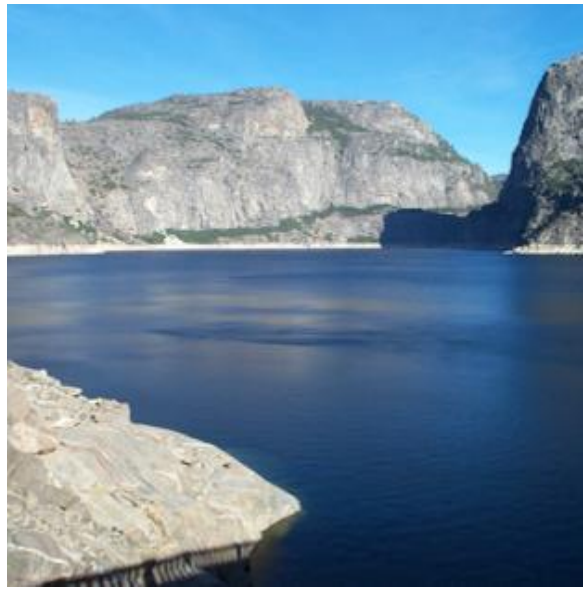


San Francisco
Water Power Sewer
Services of the San Francisco Public Utilities Commission

Paula Kehoe
San Francisco Public Utilities Commission



San Francisco Public Utilities Commission



Water: delivering high quality water every day to 2.7 million people

Power: generating hydropower and solar power

Wastewater: protecting public health and the environment

OneWaterSF: Moved Away from a Linear Approach to Integrated Planning and Implementation

Traditional Resource Management

OneWaterSF

San Francisco's Local Water Program

- Conservation
- Groundwater
- Recycled Water
- Purified Water
- Onsite Water Reuse
- Innovations Program

San Francisco knows the importance of diversifying our water portfolio…
To ensure reliability—particularly in the age of climate change—we need
to use every water resource available.

Harlan L. Kelly, Jr., SFPUC General Manager

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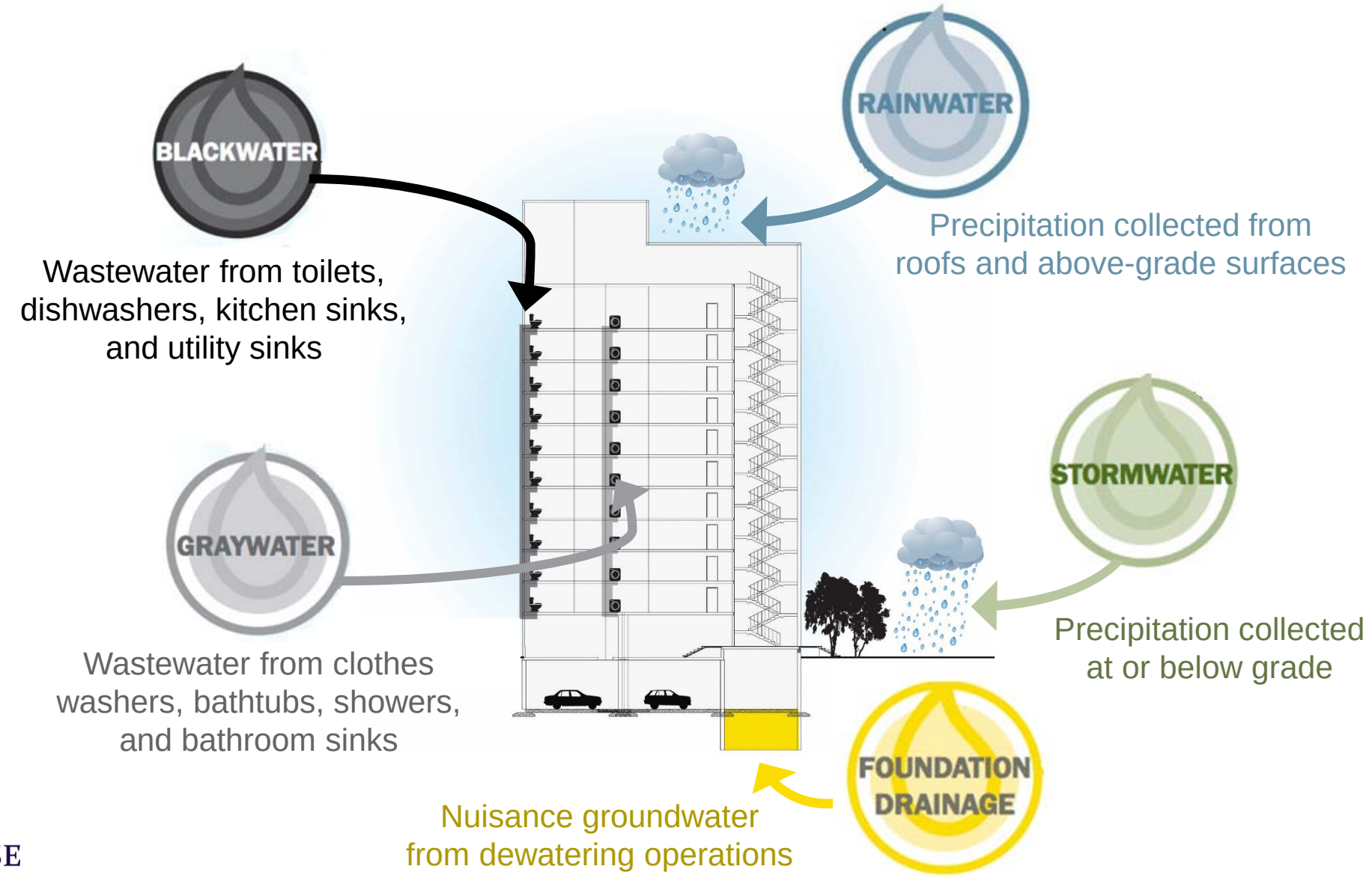
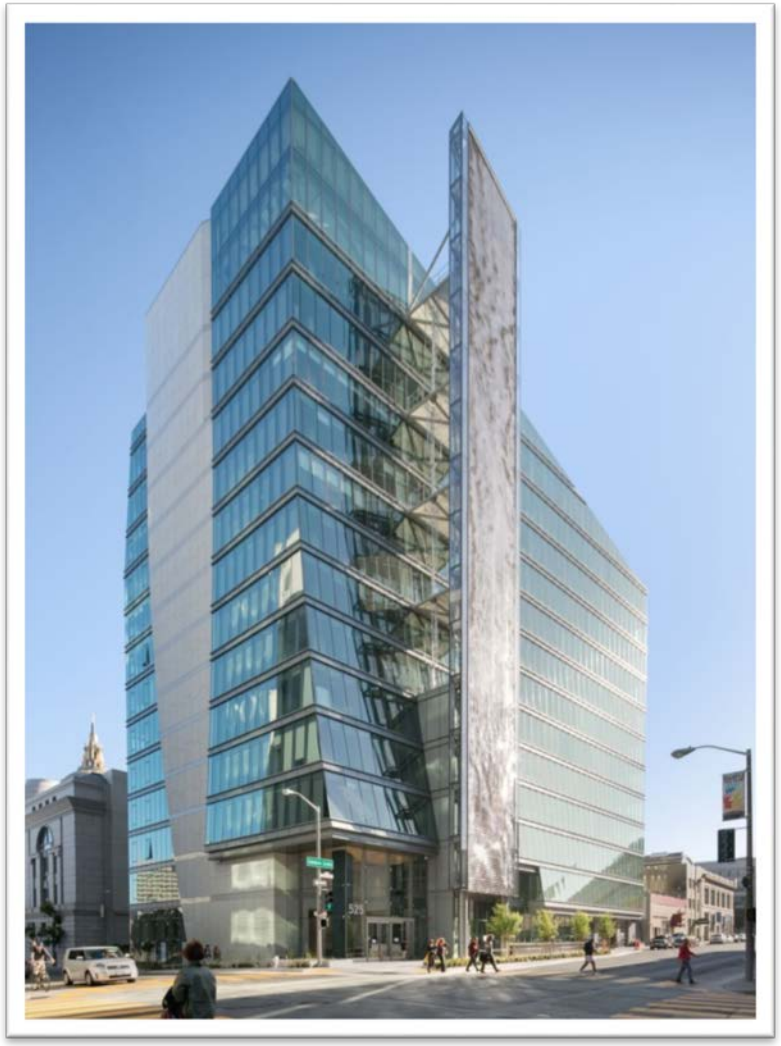
Buildings Generate Resources, Not Waste



Pioneering Onsite Water Reuse at SFPUC Headquarters



San Francisco's Evolving Onsite Water Reuse Program

sfwater.org/np

National Blue Ribbon Commission for Onsite Non-potable Water Systems

Source: San Francisco Public Utilities Commission

National Blue Ribbon Commission Addressing Key Issues

- Create Consistent Water Quality Standards From State to State
- Promote Risk-Based Water Quality Standards
- Encourage Local Oversight and Management Programs
- Forum for Peer to Peer Learning
- Develop Technical Resource Documents

National Blue Ribbon Commission for Onsite Non-potable Water Systems

www.watereuse.org/nbrc

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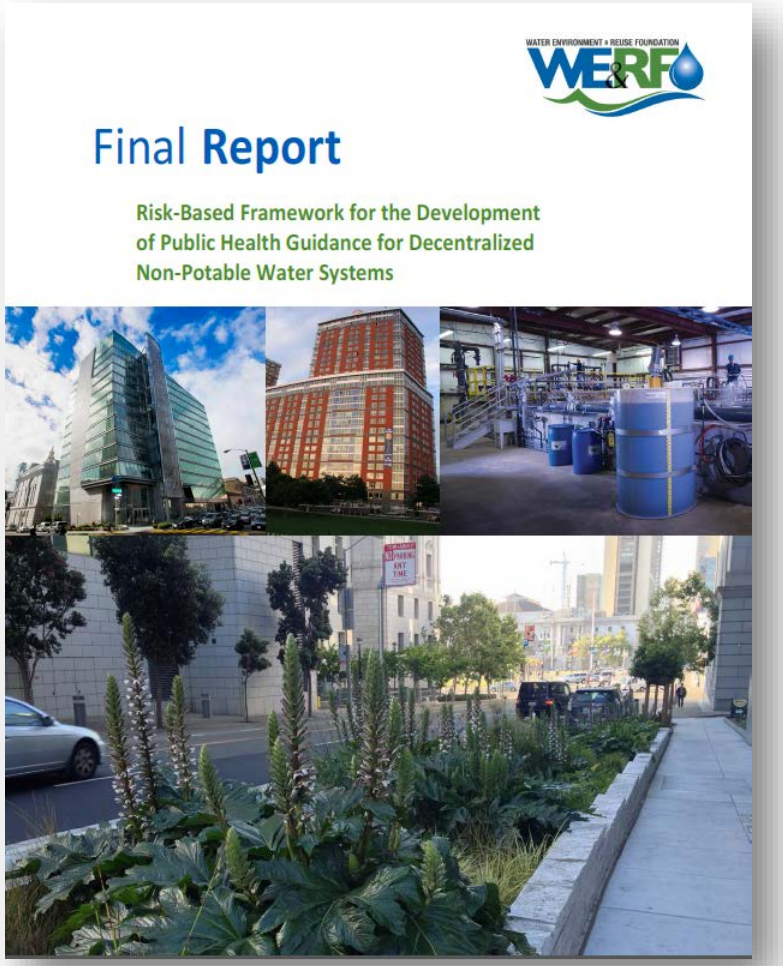
Developed a Risk-based Water Quality Approach



Independent Panel: Developed a risk-based water quality approach for onsite non-potable water systems

Pathogen Log Reduction Targets (LRTs)

↓

Continuous online monitoring

↓

Treated water quality standards

Model Regulations for Consistency Across the US

- San Francisco
- Colorado, Regulation #84
- California SB 966 and Hawaii HB 444
- Minnesota and Washington D.C. Guidelines for Stormwater
- Washington State and Oregon
- Texas and Alaska

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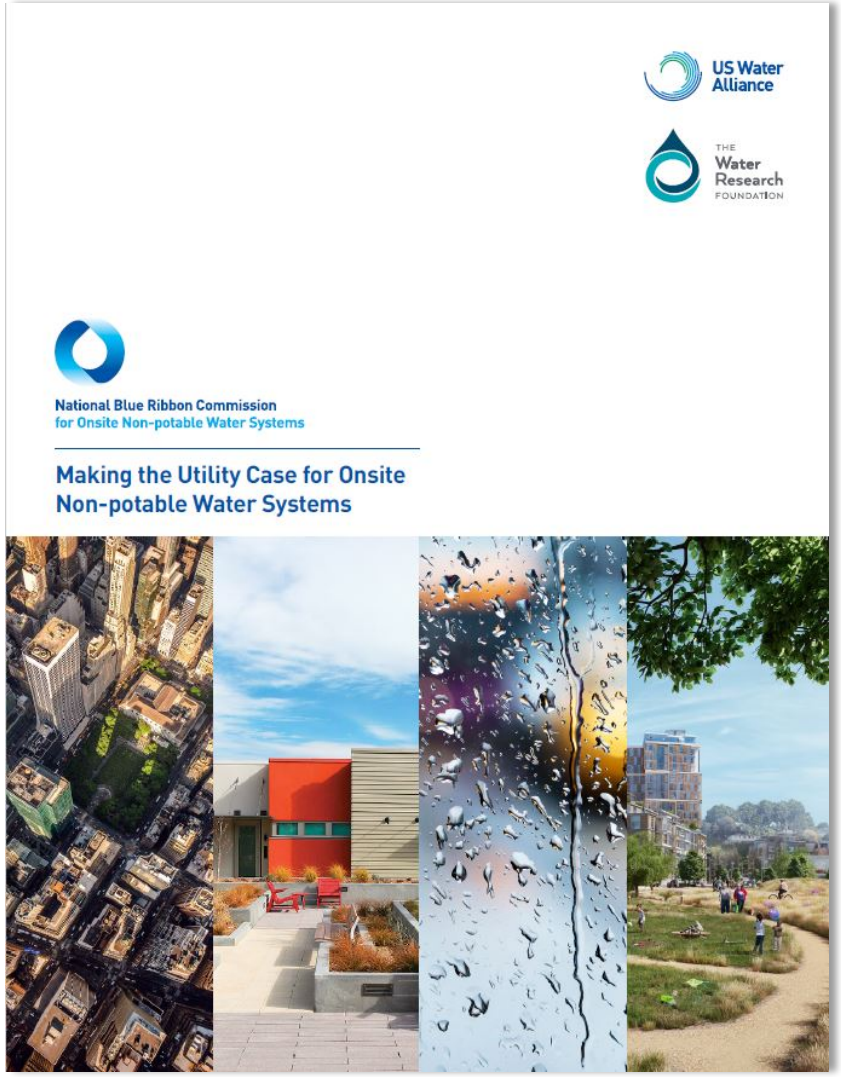
Addressing Utility Considerations

- Stretch drinking water supplies
- Lower energy
- Deferred capital investment in large centralized infrastructure
- Stormwater management
- Wastewater flows and odors



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Source: San Francisco Public Utilities Commission; Jim G. Maloney/Biohabitats, Inc; City of Santa Monica

Key Steps to Develop a Local Program

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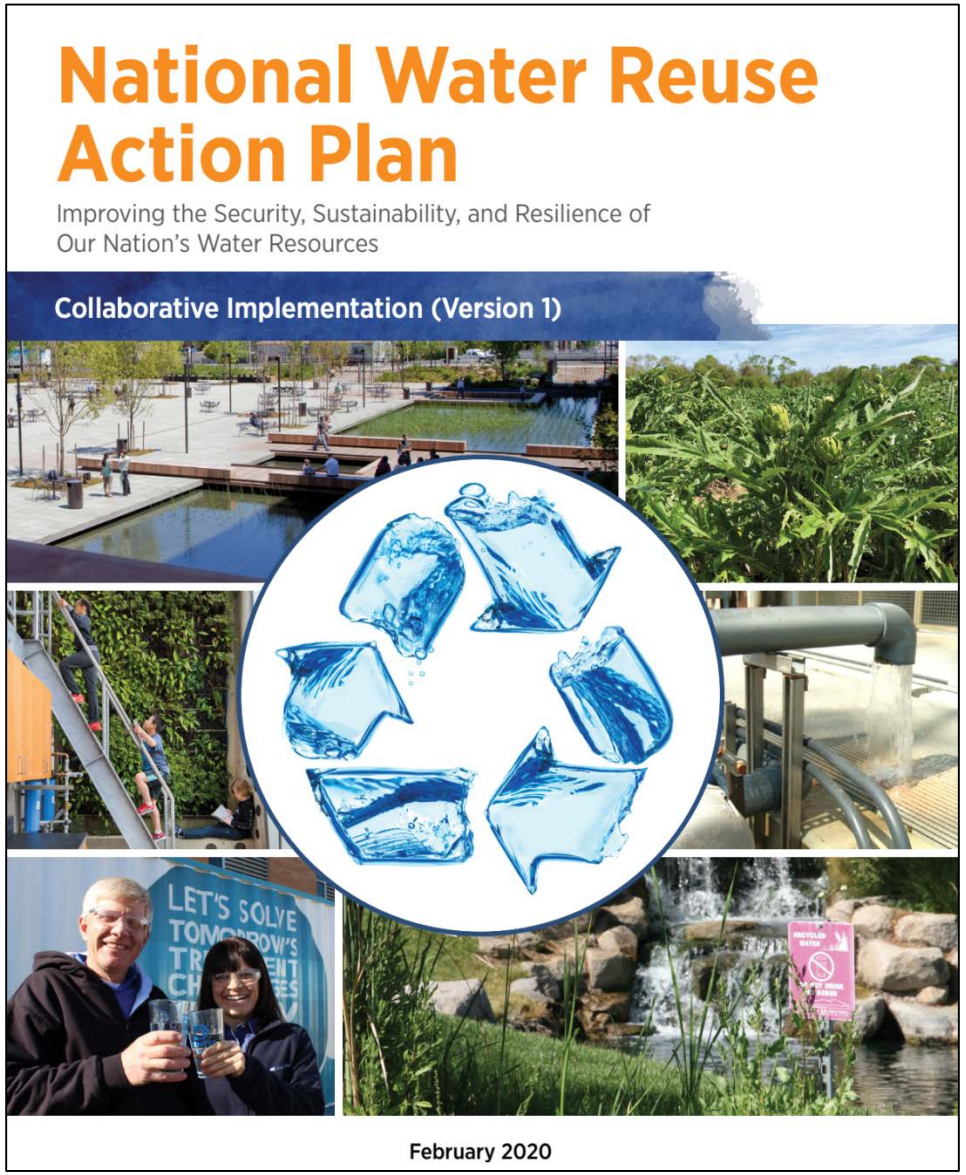
EPA Water Reuse Action Plan



Collaboration is Key to Success!

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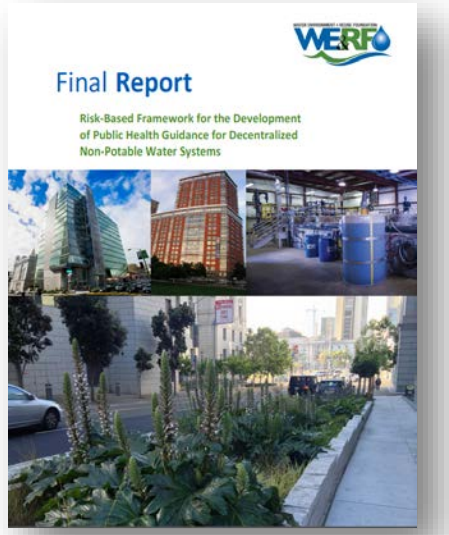
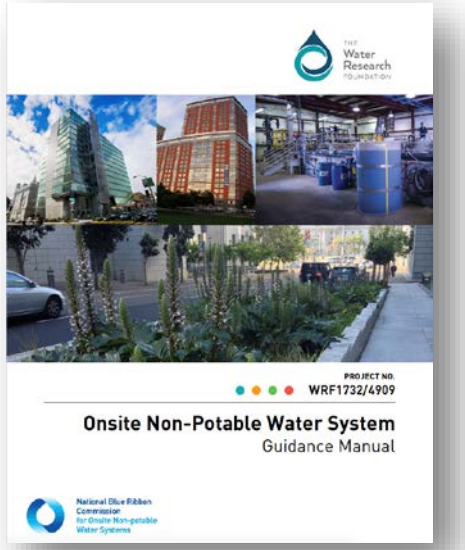
Provide Guidance for ONWS Implementation

- Step 1 – Develop public health goals
- Step 2 – Ensure ONWS programs consistently implement public health requirements
  - Design
  - Permitting, and
  - Operations
- Focus of WRF 4909 – *Development of a Design, Operations and Regulations Guidance Manual and Training Materials for ONWS*





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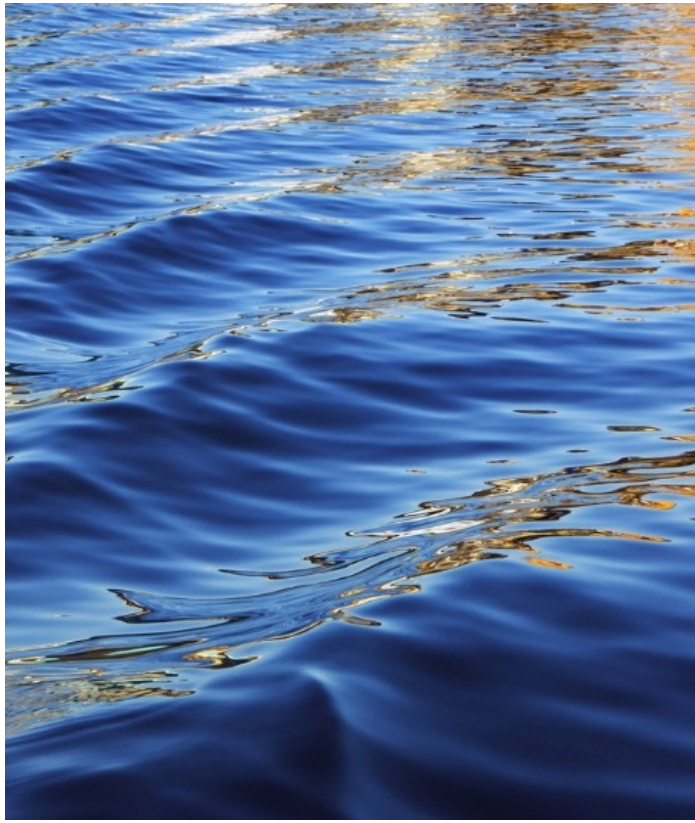
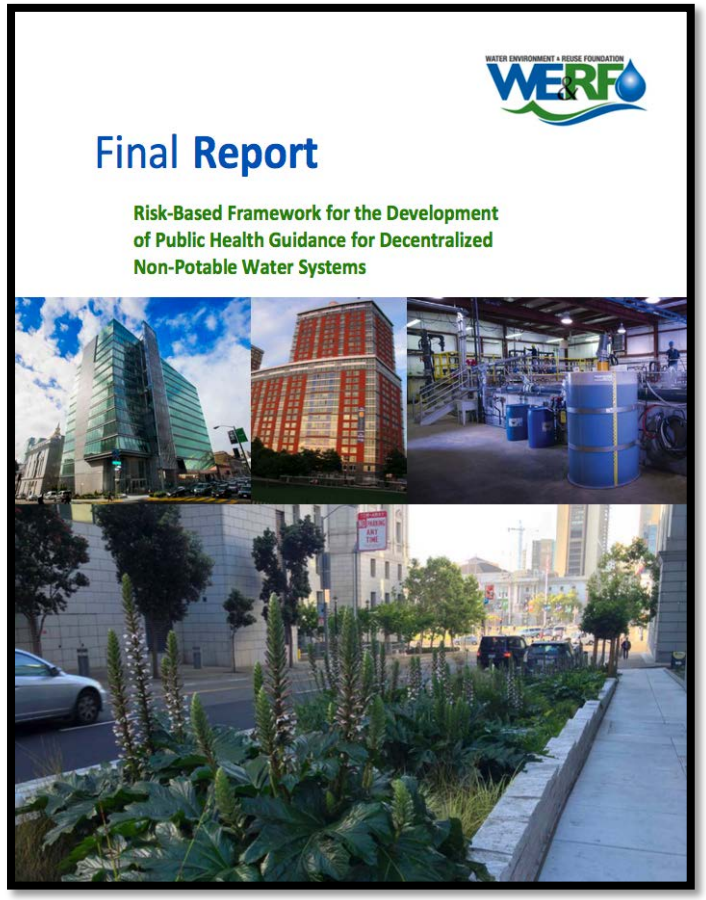
Trussell TECHNOLOGIES INC

Brian Pecson
Trussell Technologies



Purpose of Guidance Manual and Training Modules

- **Expert Panel** determined pathogen reduction for ONWS



The goal of this Guidance Manual is to provide guidance to ONWS stakeholders who are seeking to implement the risk-based public health framework and promote the safe design, operation, and permitting of ONWS systems.

Who are ONWS stakeholders?

DESIGN ENGINEER

REGULATOR

OPERATOR

PROGRAM ADMINISTRATOR

SYSTEM OWNER

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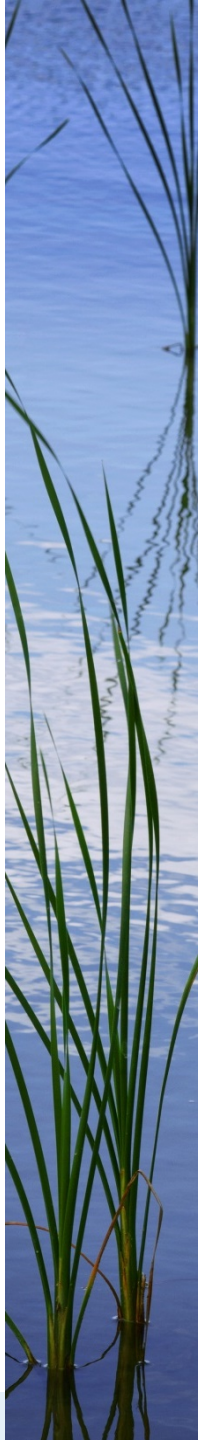
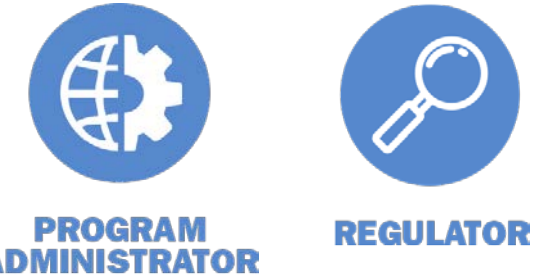
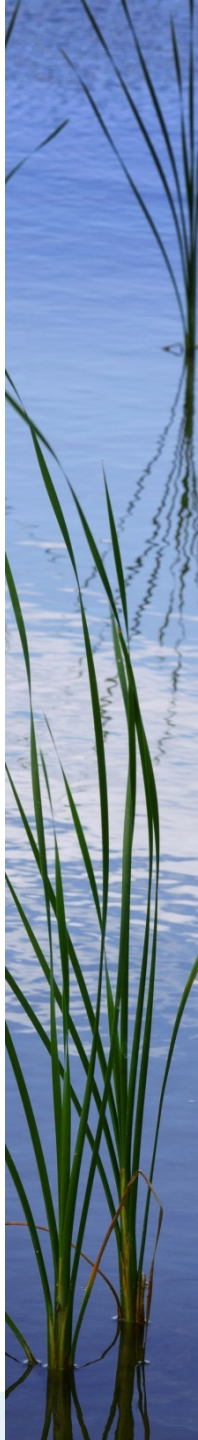


How is a successful program developed?

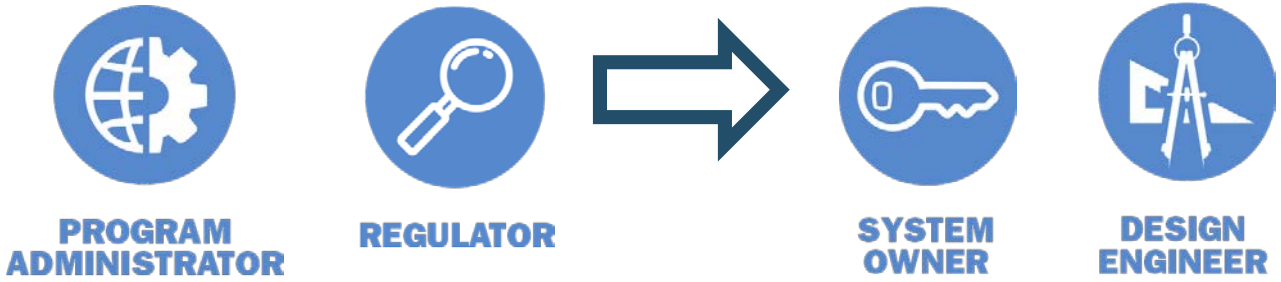
Program Setup





How is a successful program developed?

Program Setup **Project Creation**



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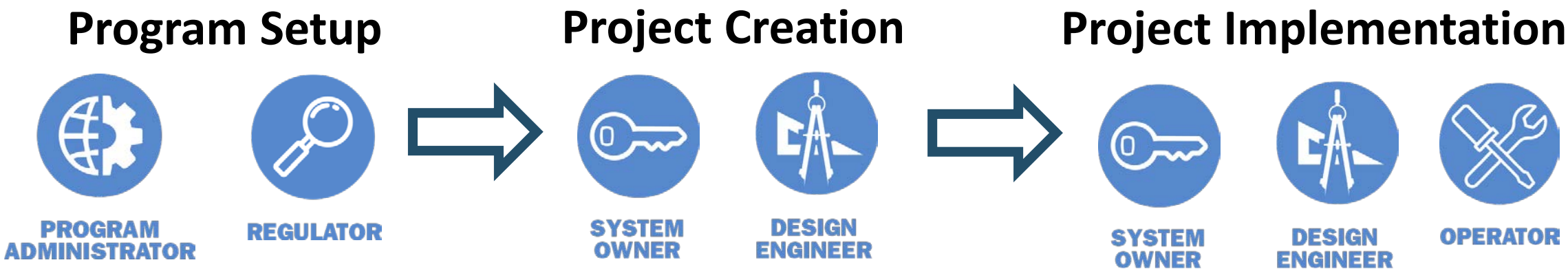

PROGRAM ADMINISTRATOR

REGULATOR

Program Setup and Administration

Project Creation

SYSTEM OWNER

DESIGN ENGINEER

Project Implementation

SYSTEM OWNER

DESIGN ENGINEER

OPERATOR

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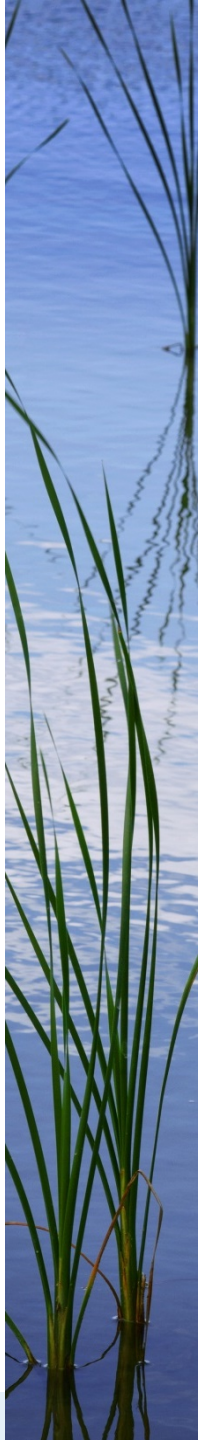
ONWS Stakeholder Learning Objectives

Key Learning Objectives	
DESIGN ENGINEER	• Basic requirements for public health protection in ONWS systems • Importance of pathogen control and LRTs • Need for the protection of water quality in the distribution system • Application of treatment process validation and pathogen crediting • Treatment process design for compliance with LRTs • Benefits of treatment and management barriers for public health protection • Routine monitoring data collection requirements for ongoing LRT compliance • Typical steps in the regulatory process • Key documents needed from Design Engineers for permitting • Importance of interactions with the Regulators
REGULATOR	• Detailed understanding of requirements for public health protection in ONWS • Derivation of LRTs and the importance of pathogen control • Existing pathogen crediting frameworks • Treatment design and monitoring strategies for compliance with LRTs • Evaluation of routine monitoring data for ongoing LRT compliance • Benefits of treatment and management barriers for public health protection • Treatment & monitoring strategies for source and end use combinations • Importance of interface between design, permitting, and operations • Documents for operations, reporting, commissioning, and worker safety • Role in start-up, commissioning, and ongoing monitoring of ONWS systems • Typical steps in the regulatory process • Key documents needed from project team for permitting
OPERATOR	• Key treatment and monitoring concepts • Role of operations in ensuring LRTs are continuously met • Importance of interface between design, permitting, and operations • Role in start-up, commissioning, and ongoing operations of ONWS systems • Documents for operations, reporting, commissioning, and safety • Staffing needs for ONWS systems
PROGRAM ADMINISTRATOR	• Basic requirements for public health protection in ONWS systems • Importance of pathogen control and LRTs • Documents for operations, reporting, commissioning, and worker safety • Typical steps in the regulatory process • Importance of interaction between Regulators and the project team
SYSTEM OWNER	• Basic requirements for public health protection in ONWS systems • Importance of interface between design, permitting, and operations • Benefits of treatment and management barriers for public health protection • Typical steps in the regulatory process • Documents for operations, reporting, commissioning, and worker safety

DESIGN ENGINEER



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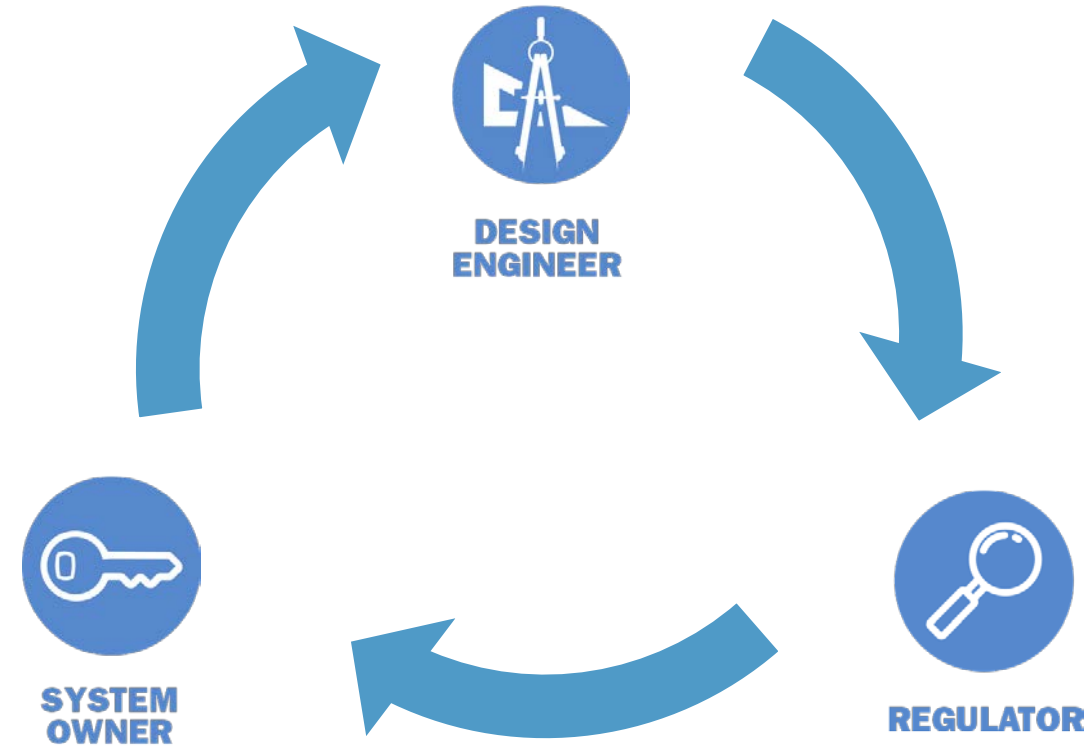
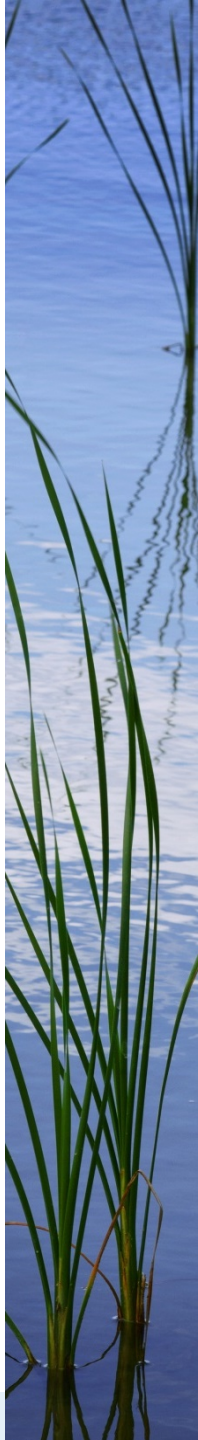
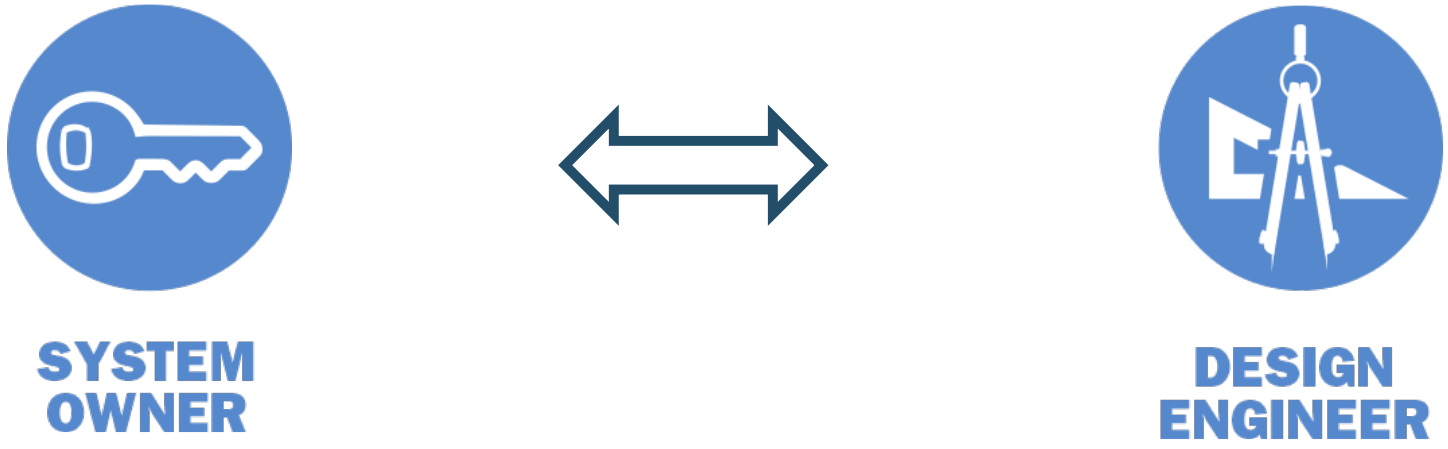


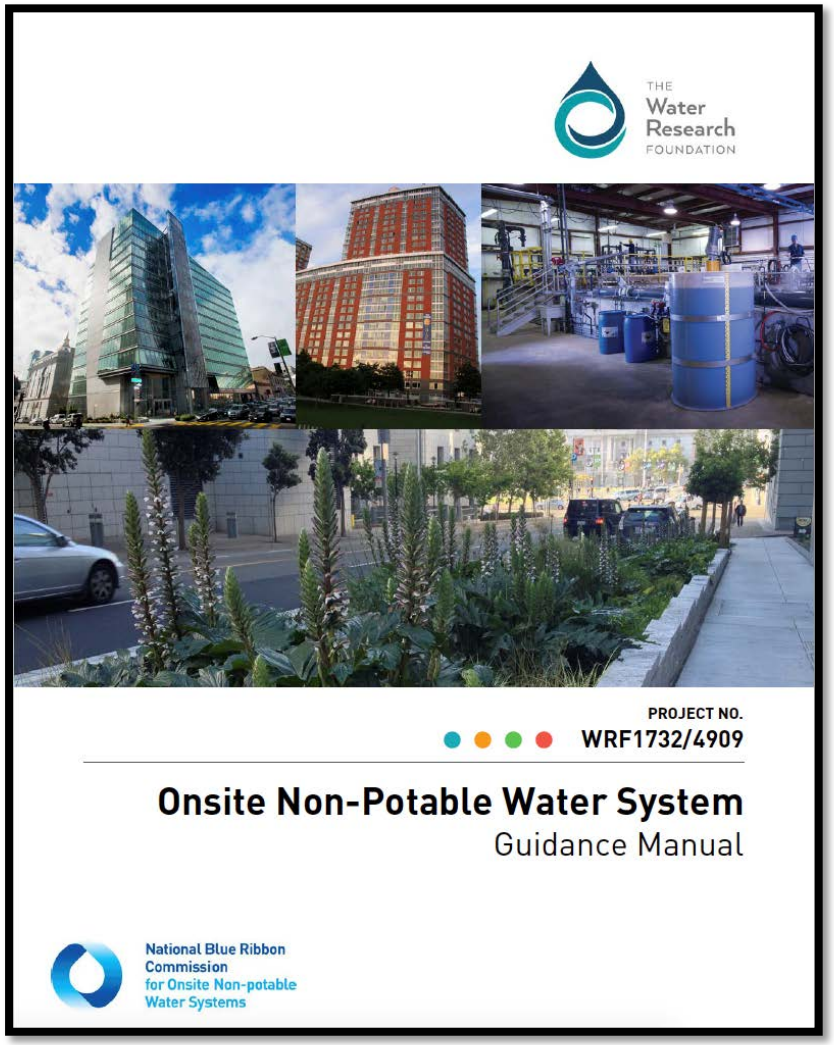


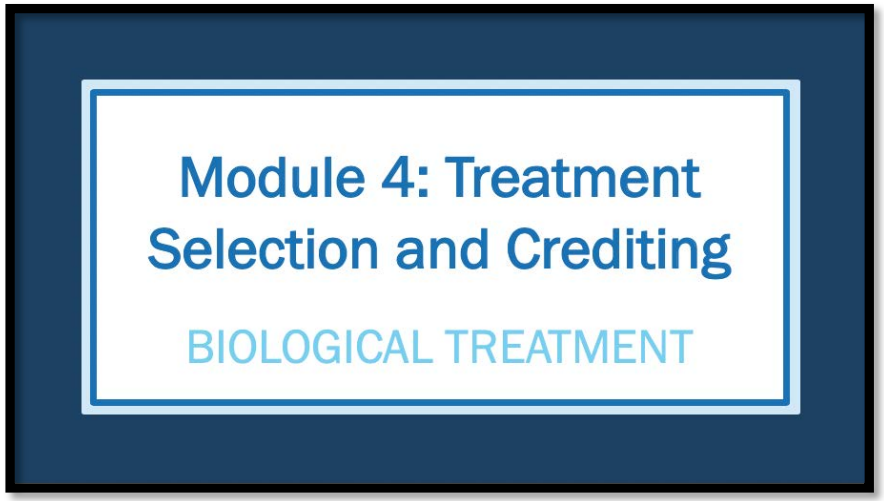
Lessons Learned: Importance of Knowledgeable Owners

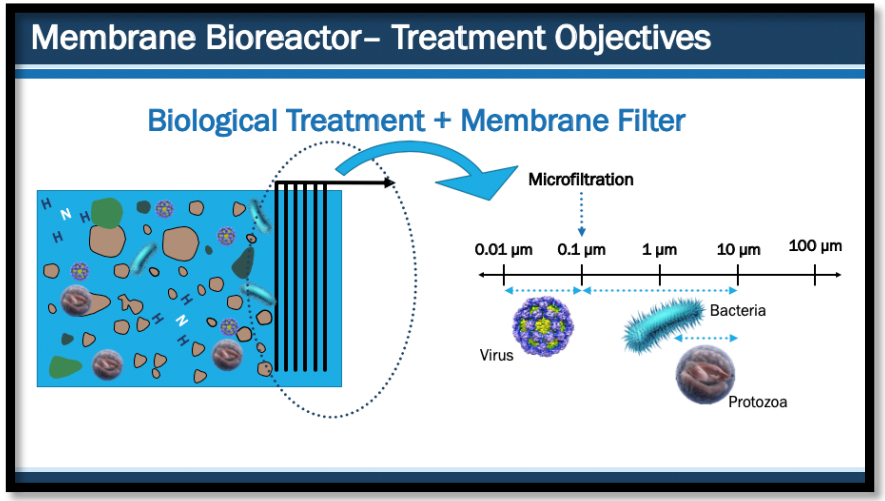


- System Owner is ultimately responsible for proper system design and operation
- Understanding of design approach leads to educated decisions about risk and trade-offs between capital and operating costs

4909 Guidance Materials







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Guidance Manual Overview

CHAPTER 1: **Introduction**	Covers background on ONWS and provides overview of the guidance manual
CHAPTER 2: **Public Health Goals**	Describes the risk-based pathogen reduction targets and the importance of monitoring to verify treatment
CHAPTER 3: **Treatment Selection and Crediting**	Details various forms of treatment and how they can be used for pathogen reduction and water quality targets
CHAPTER 4: **Developing Multiple-Barrier ONWS Systems**	Provides considerations for designing effective treatment trains using multiple and diverse treatment processes to achieve water quality and treatment objectives
CHAPTER 5: **Operations Plan**	Highlights the importance of proper operations and maintenance (O&M) in effective public health protection and the critical elements of an O&M plan
CHAPTER 6: **Regulatory and Permitting Plan**	Describes an overall approach to project permitting with key regulatory interactions at multiple steps of design, construction, start-up, and on-going operations

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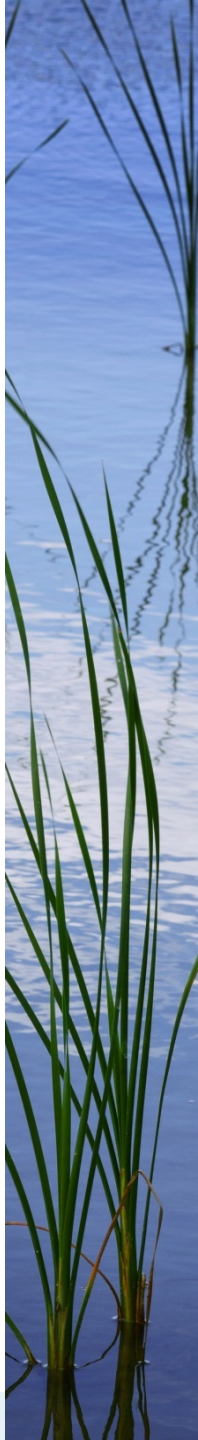

Guidance Manual Roadmap

	Design Engineer	Regulator	Operator	Program Administrator	System Owner
Chapter 1: Introduction	General	General	General	General	General
Chapter 2: Public Health Goals	Detailed	Expert	General	Detailed	General
Chapter 3: Treatment Selection and Crediting	Expert	Detailed	General	General	General
Chapter 4: Developing Multiple-Barrier ONWS Systems	Expert	Detailed	Detailed	General	General
Chapter 5: Operations Plan	Expert	Detailed	Expert	Detailed	General
Chapter 6: Regulatory and Permitting Plan	Detailed	Expert	Detailed	Detailed	General

Knowledge Level		
General	Detailed	Expert

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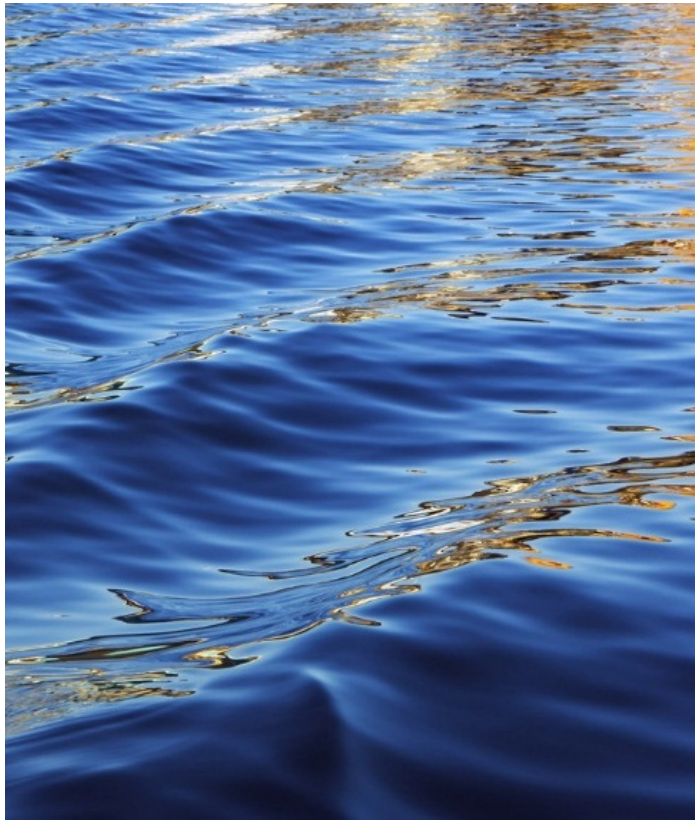
Public Health Goals

Chapter 2



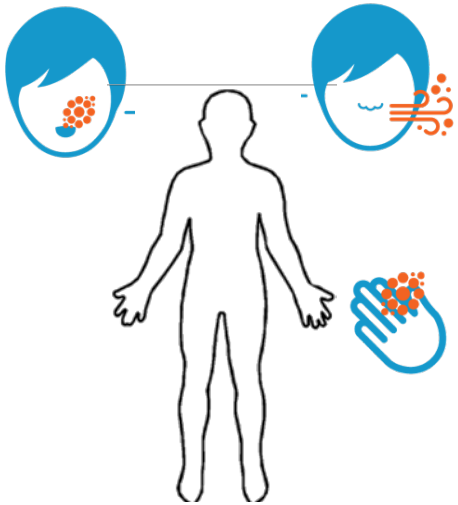
Learning Objectives

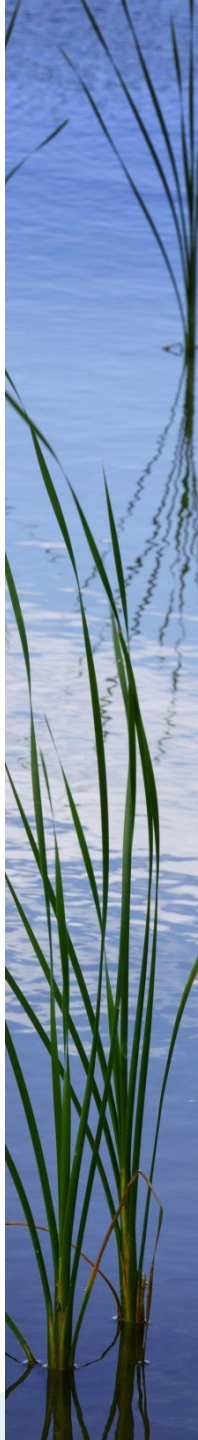
- Understand requirements for public health protection in ONWS
- Identify treatment targets for the control of pathogens
- Discuss importance of water quality in the distribution system

Risk Threshold

10^{-4} infections per person per year

Exposure Pathways





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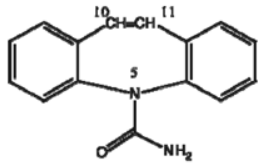
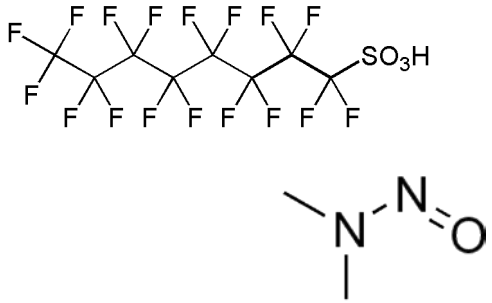
What treatment is required for ONWS?

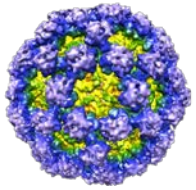
- **What are the typical contaminants of concern found in alternate water sources?**



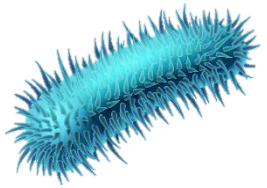


Chemicals

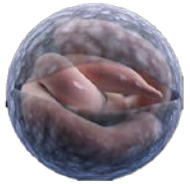
Virus



Bacteria



Protozoa



Pathogens

Pathogens are the main public health concern

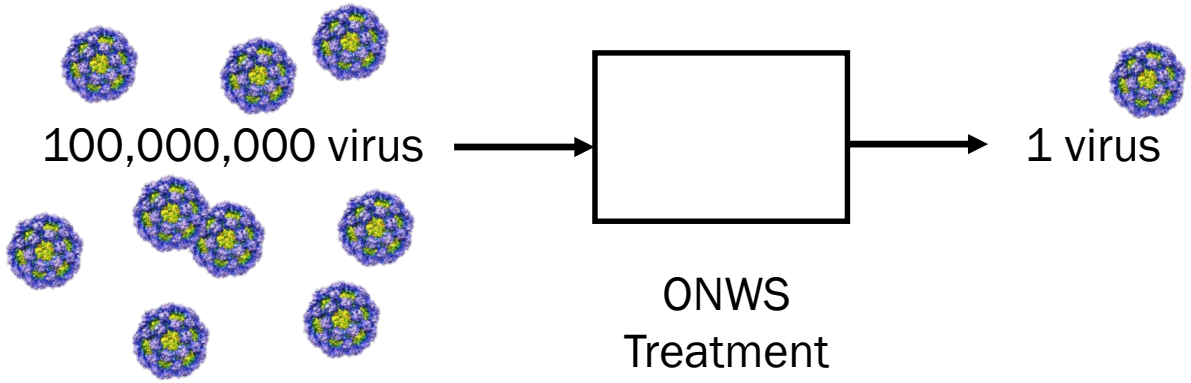
- High likelihood of pathogens in source waters
- May lead to infection from a single exposure
- Even with low exposure, pathogens may be important source of risk

ONWS Expert Panel recommended log reduction targets (LRTs) to protect public health against pathogens

Log Reduction Targets for Source Waters and End Uses

Water Use Scenario	Enteric Viruses	Parasitic Protozoa	Enteric Bacteria
Domestic Wastewater/Blackwater			
Unrestricted irrigation	8.0	7.0	6.0
Indoor use[1]	8.5	7.0	6.0

- 8-log reduction = 99.999999% reduction
- If you start with 100,000,000 virus, there would be 1 left after treatment



Log Reduction Targets for Source Waters and End Uses

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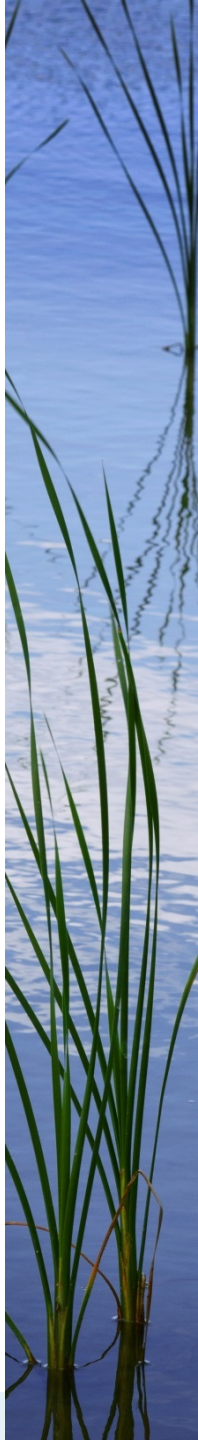
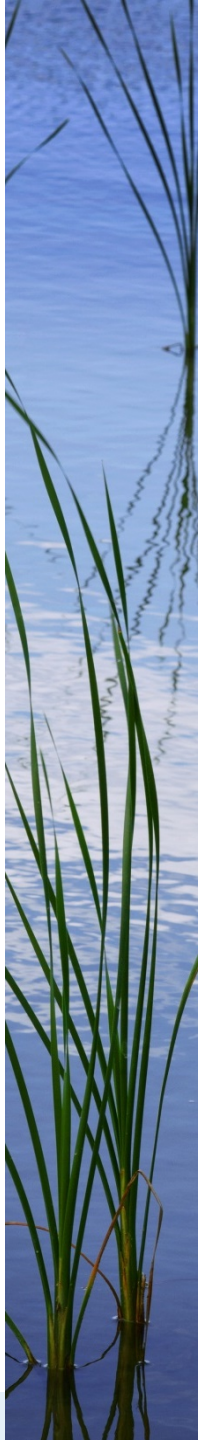
Domestic Wastewater/Blackwater			
Unrestricted irrigation	8.0	7.0	6.0
Indoor use[1]	8.5	7.0	6.0
Graywater			
Unrestricted irrigation	5.5	4.5	3.5
Indoor use	6.0	4.5	3.5
Stormwater (10% wastewater contribution[2])			
Unrestricted irrigation	5.0	4.5	4.0
Indoor use	5.5	5.5	5.0
Stormwater (0.1% wastewater contribution[2])			
Unrestricted irrigation	3.0	2.5	2.0
Indoor use	3.5	3.5	3.0
Roof runoff water			
Unrestricted irrigation	N/A	No data	3.5
Indoor use	N/A	No data	3.5



Example Interactive Question:
True or False?

Blackwater treatment requires higher LRTs than graywater. Therefore, treated blackwater is of better quality than treated graywater.

- **A. True**
- **B. False**



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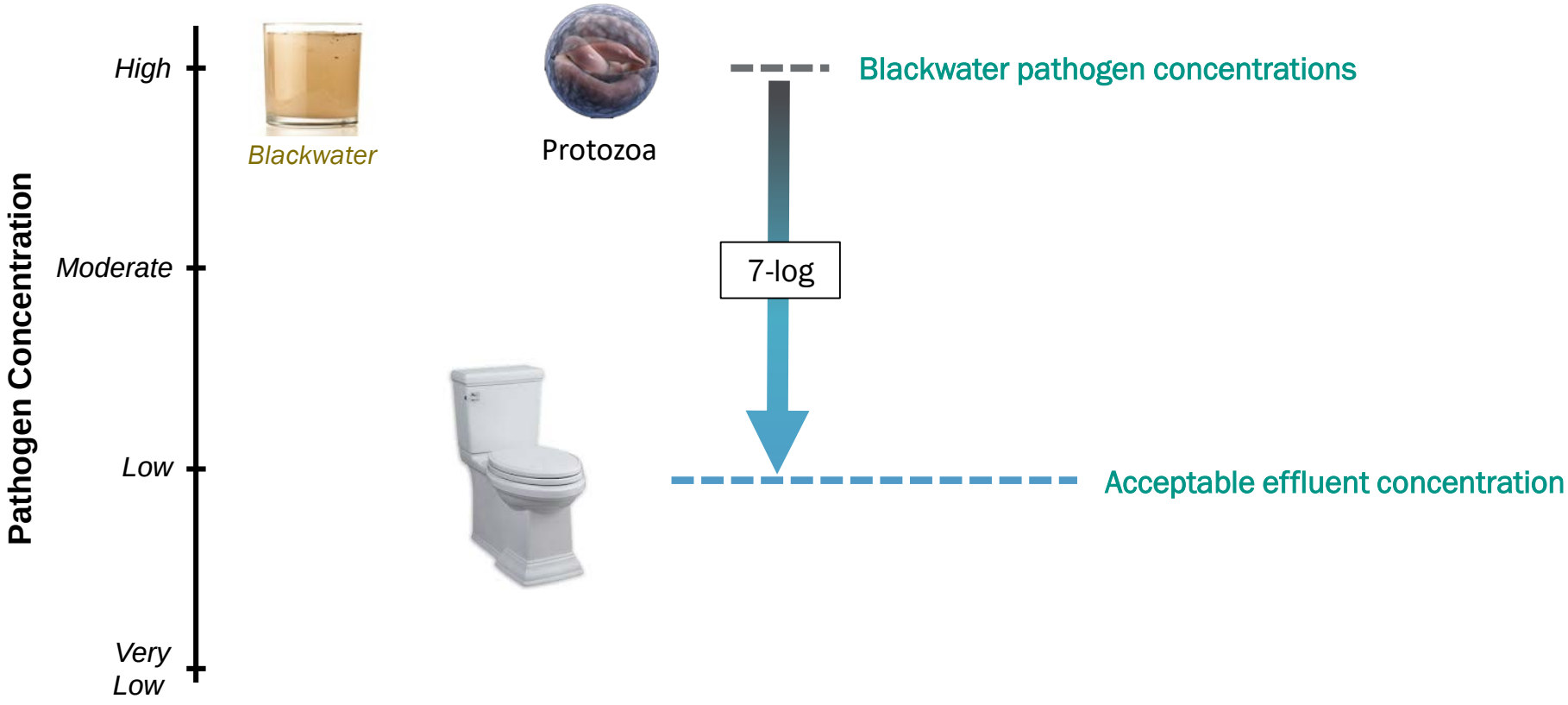
- A. True
- **B. False**



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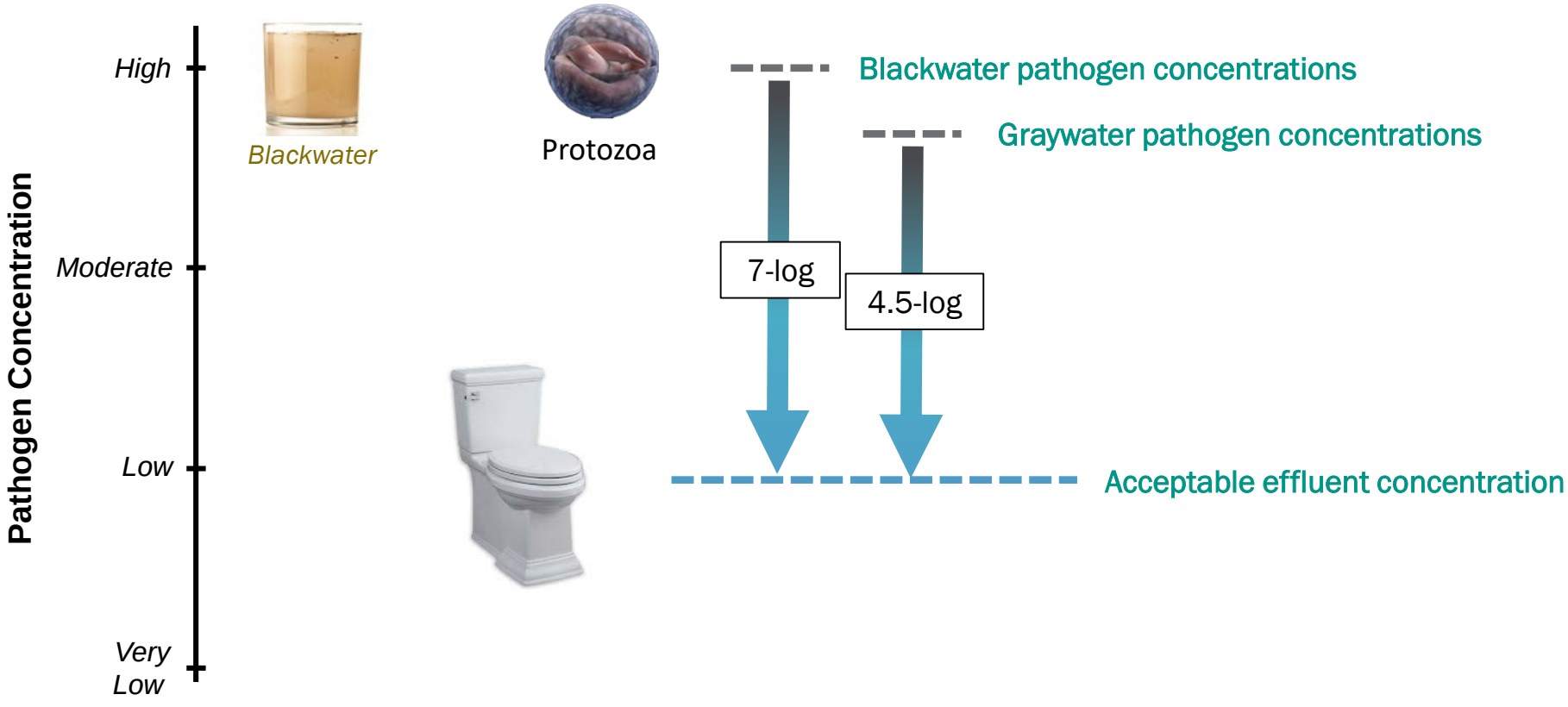
Example Interactive Question:
True or False?

Blackwater treatment requires higher LRTs than graywater. Therefore, treated blackwater is of better quality than treated graywater.

- A. True
- **B. False**



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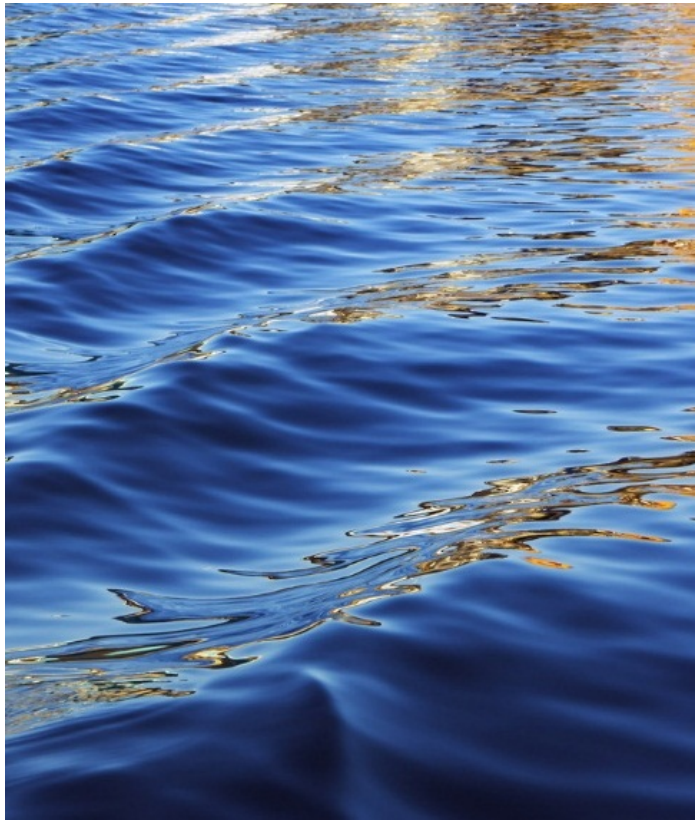
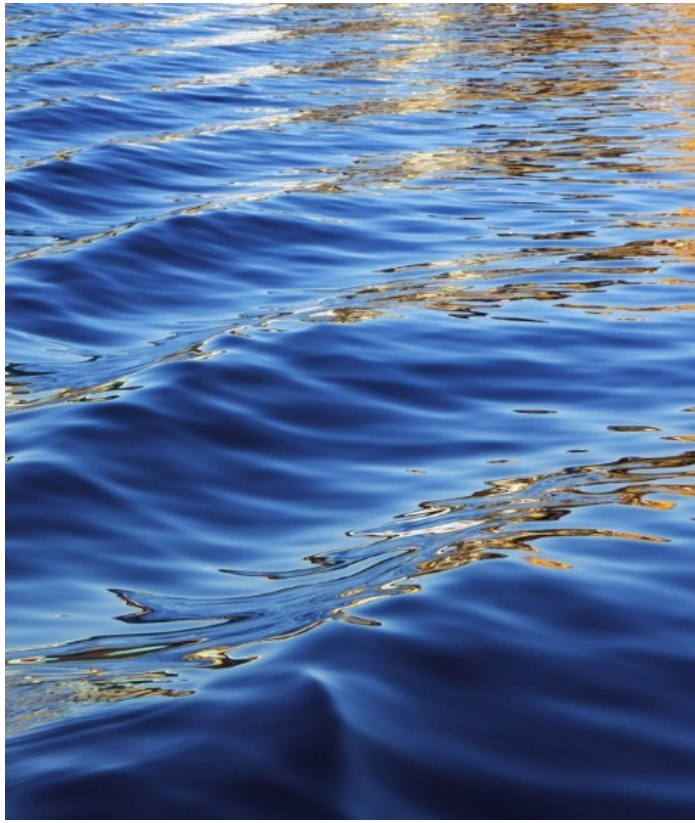
Trussell TECHNOLOGIES INC

Brie Post
Trussell Technologies



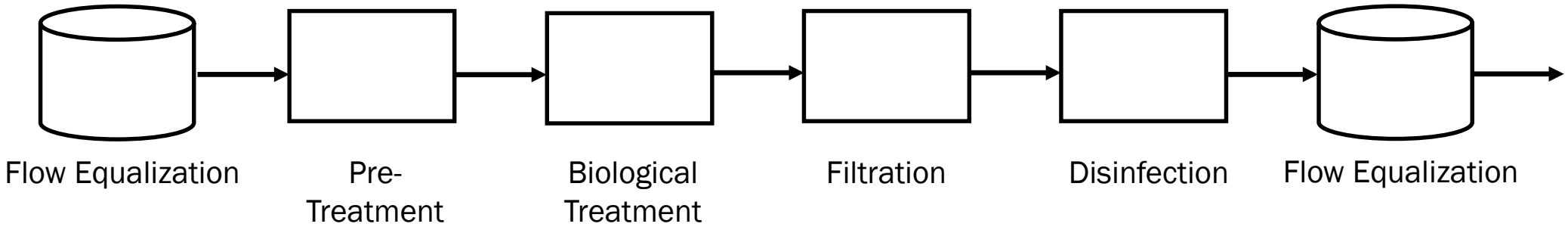
Treatment Selection and Crediting

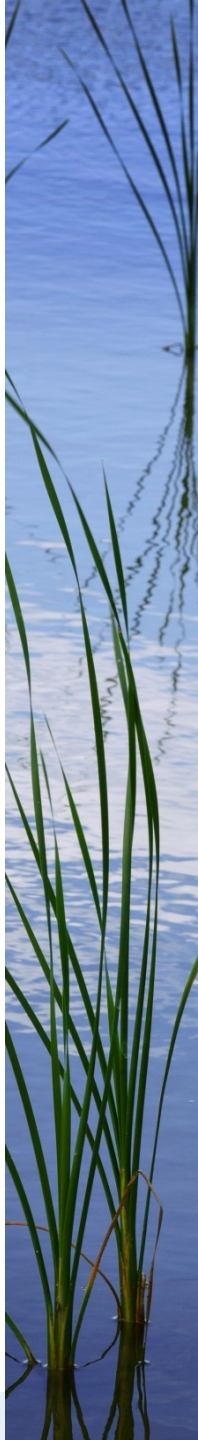
Chapter 3



Chapter 3 Overview

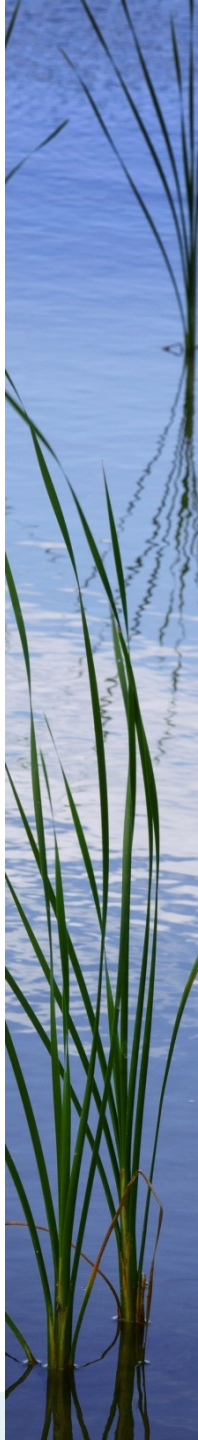
- **Treatment Processes**
- **Pathogen Crediting**





Learning Objectives

- Why is this treatment process important?
- How do we know the system is performing as designed?
- Does this treatment process reduce pathogens—and if so, how do we get credit?



Introduction to Pathogen Crediting

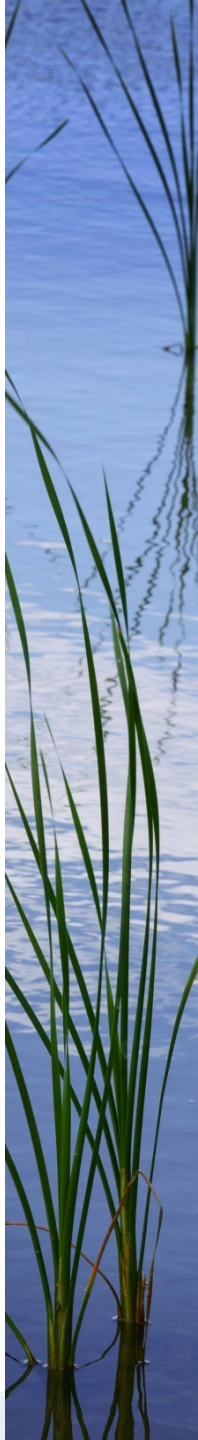
Raw Source Water

How are LRTs achieved?

End Use

Public Health Goals

Log Reduction Targets



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Introduction to Pathogen Crediting

Raw Source Water

Treatment Barriers

Treatment Process #1

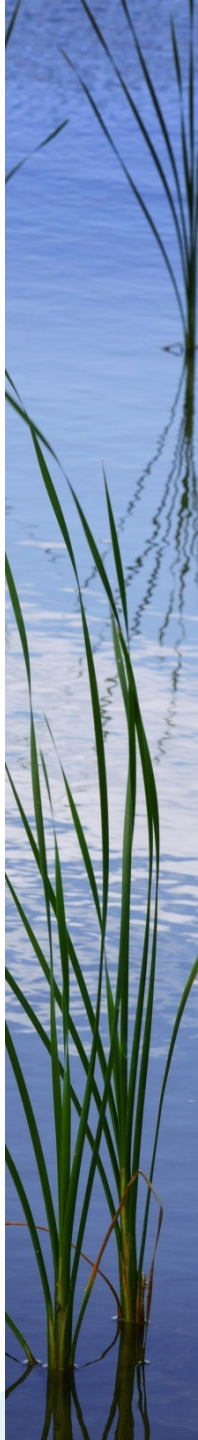
Treatment Process #2

Treatment Process #3

End Use

Public Health Goals

Log Reduction Targets



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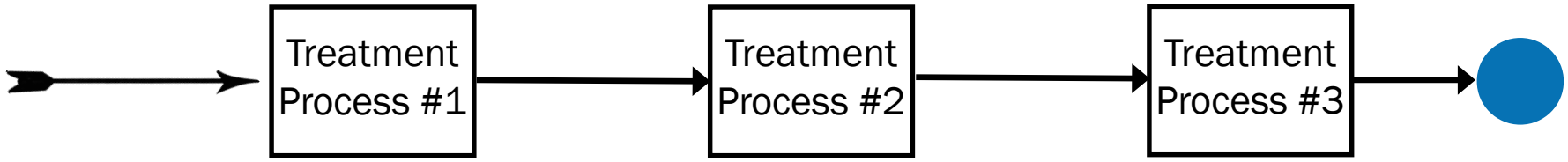
Introduction to Pathogen Crediting

Raw Source Water

Treatment Barriers

Public Health Goals

End Use

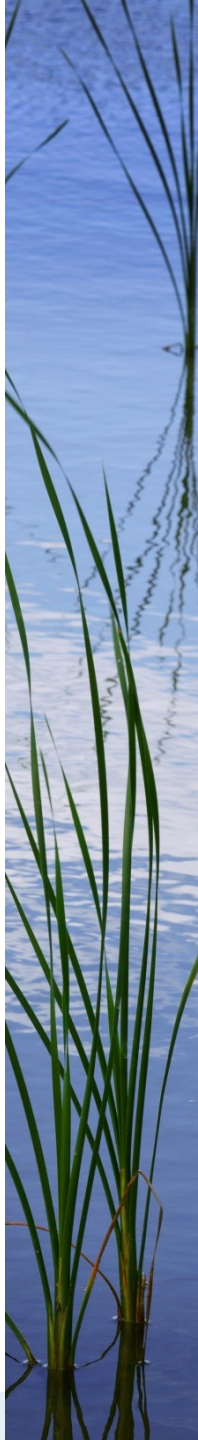


Log Reduction Value = 2

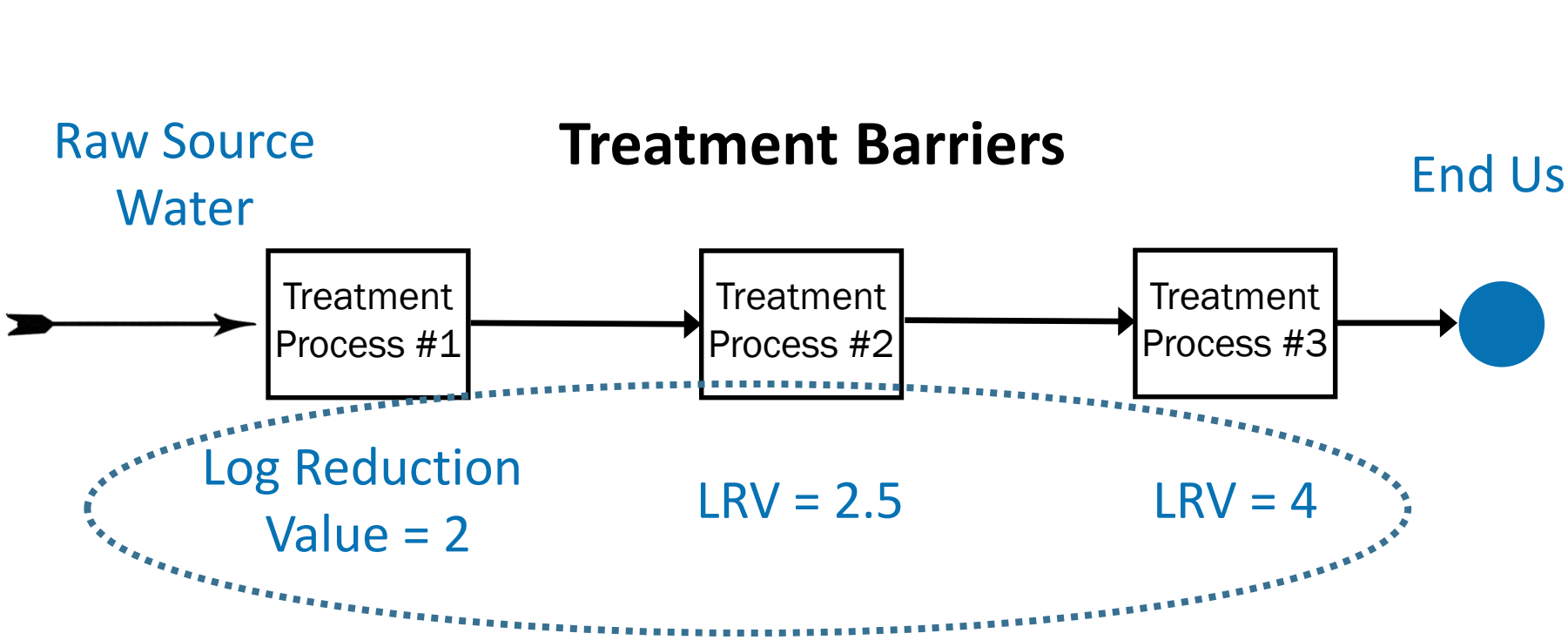
LRV = 2.5

LRV = 4

Log Reduction Targets



Introduction to Pathogen Crediting



Public Health Goals

Log Reduction Targets

How are these specific values assigned?

Pathogen Crediting

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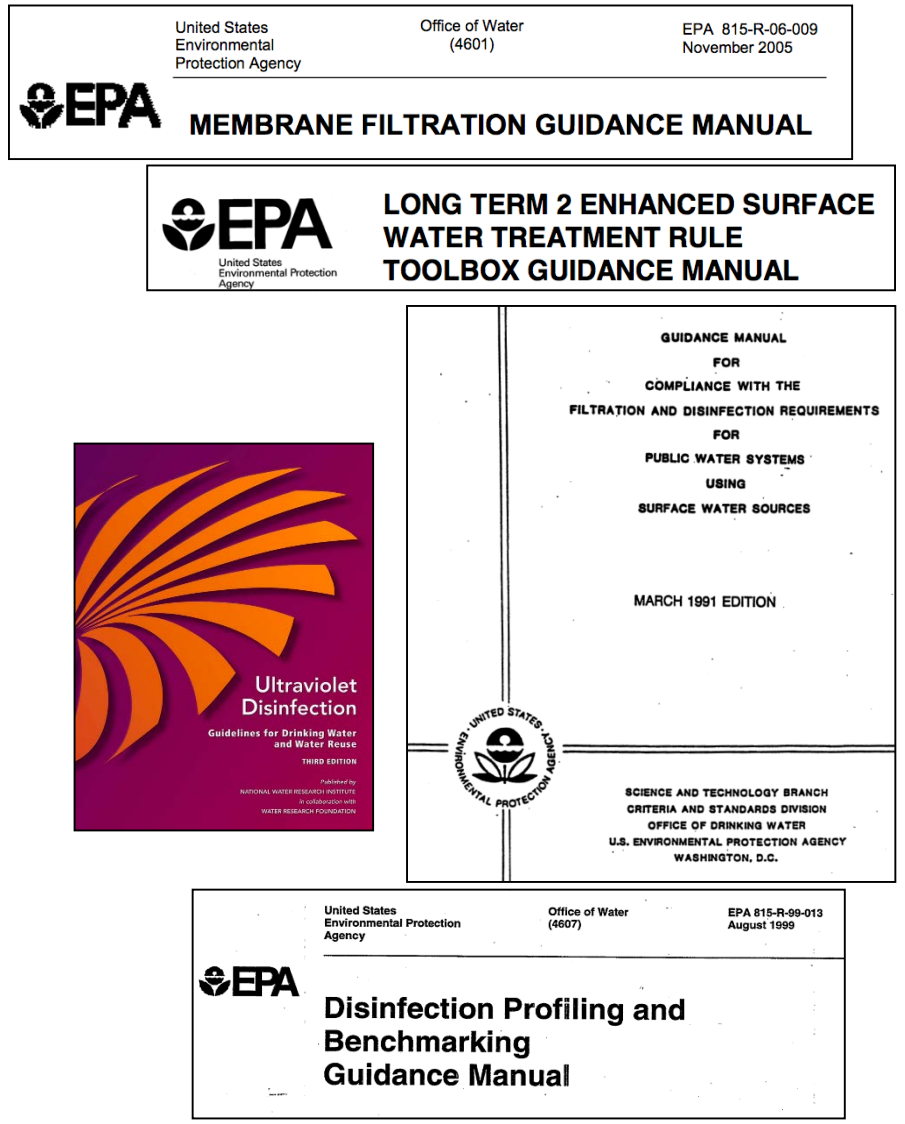
Example Interactive Question:

What is the main objective of pathogen crediting?

- A. Conservatively and consistently quantify the treatment system's ability to meet pathogen log reduction targets
- B. Protect public health
- C. Minimize the risk of *Legionella*
- D. Reduce the level of pathogens in the product water to zero
- E. None of the above



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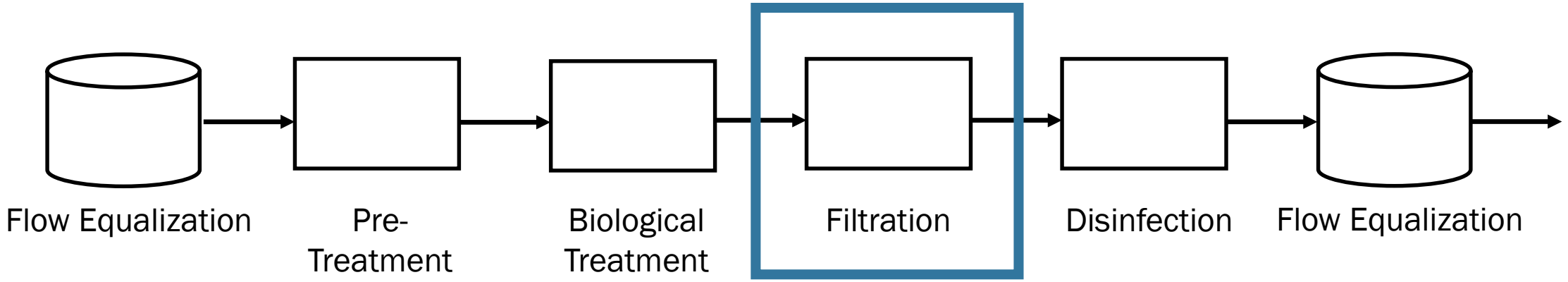
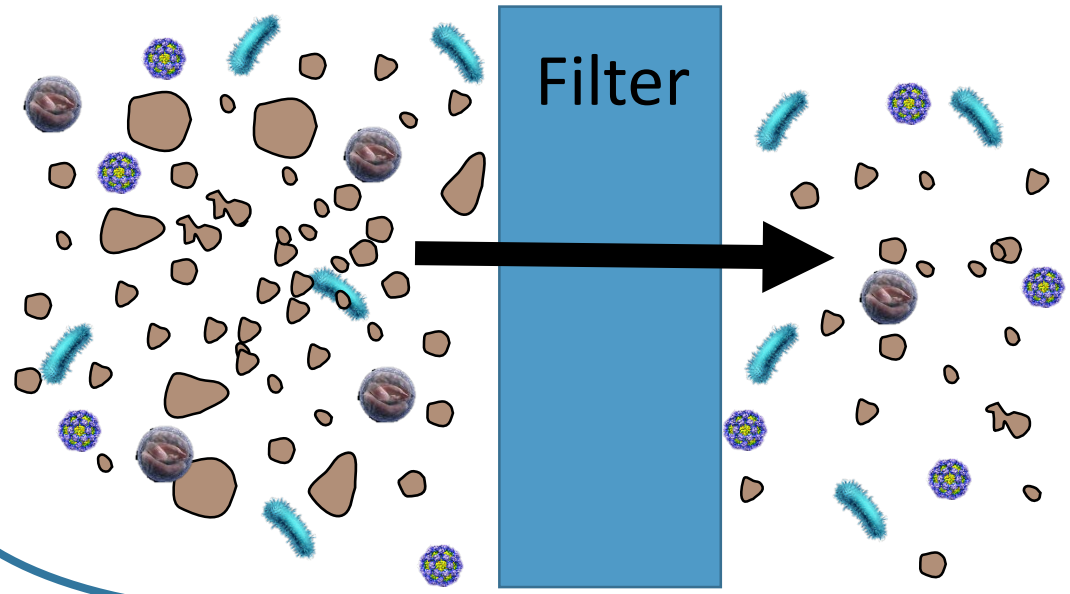
Highlights of a few key treatment processes:
Filtration

- Guidance Manual and Training Modules provide detailed guidance for each treatment process introduced below
- Today, we'll highlight a few key treatment processes



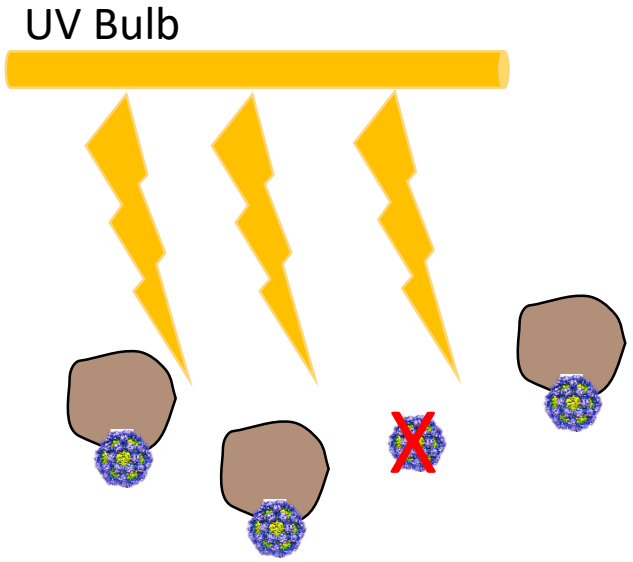
Filtration 101 – Treatment Objectives



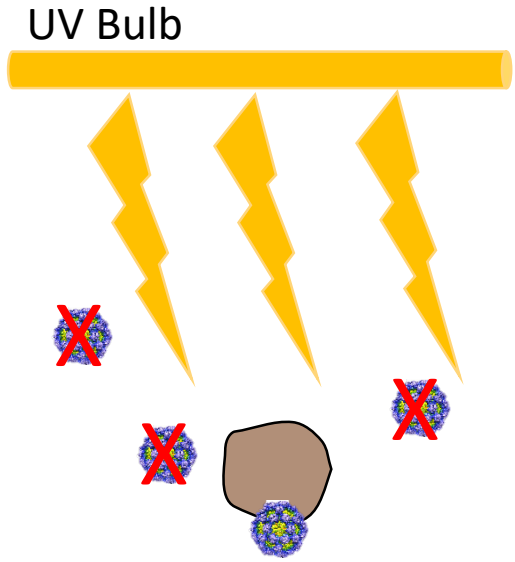
- ✓ Reduce TSS
- ✓ Reduce turbidity
- ✓ Remove some pathogens

Improves downstream disinfection performance

Filtration 101 – Treatment Objectives



Particles can shield pathogens from disinfection



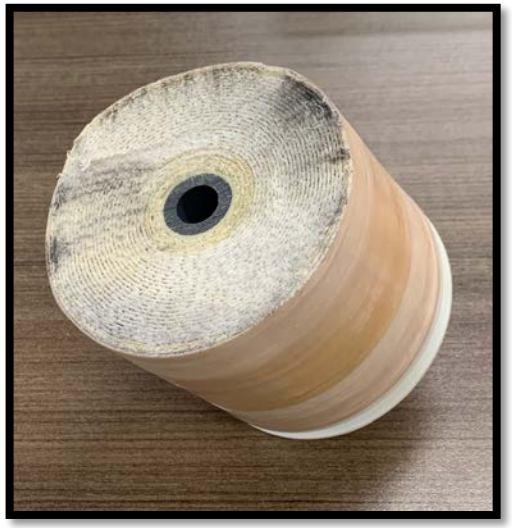
Fewer particles = more effective disinfection

Filtration 101 –Filtration Technologies

Three examples of filters that can meet treatment goals:

Cartridge Filter

Membrane Filter



Reverse Osmosis

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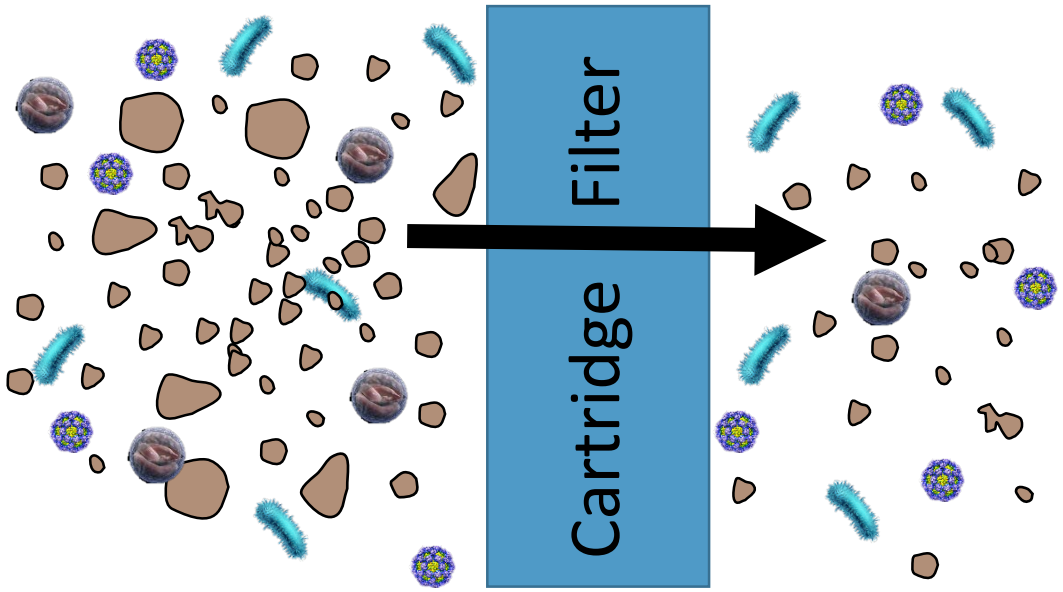
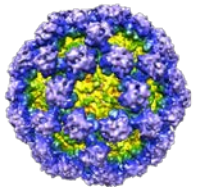
Cartridge Filtration – Treatment Objectives



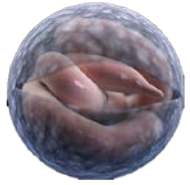
- ✓ Reduce TSS
- ✓ Reduce turbidity
- ✓ Remove some pathogens

Cartridge Filtration – Design Considerations

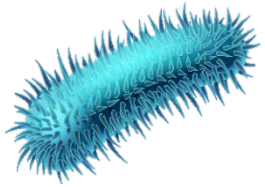
- Crediting framework = EPA's Long Term 2 Enhanced Surface Water Treatment Rule (LT2)
- 2.0- to 2.5-log protozoa credit
- Effluent turbidity requirements should be maintained



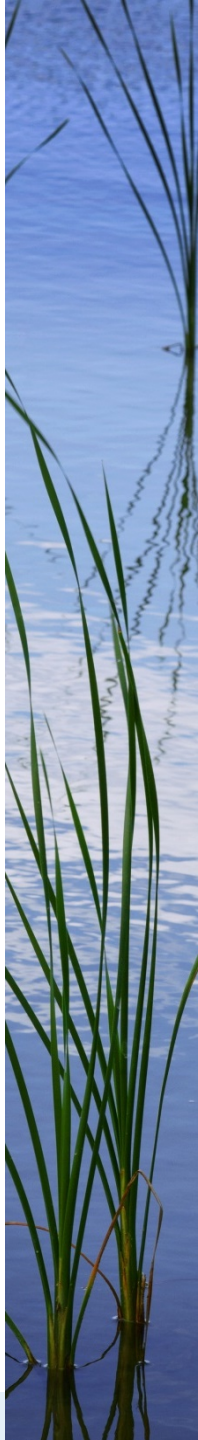
0-log virus



2- to 2.5-log protozoa

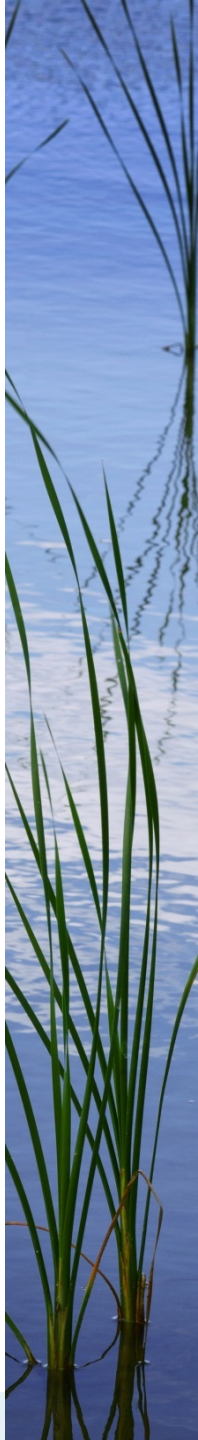


0-log bacteria



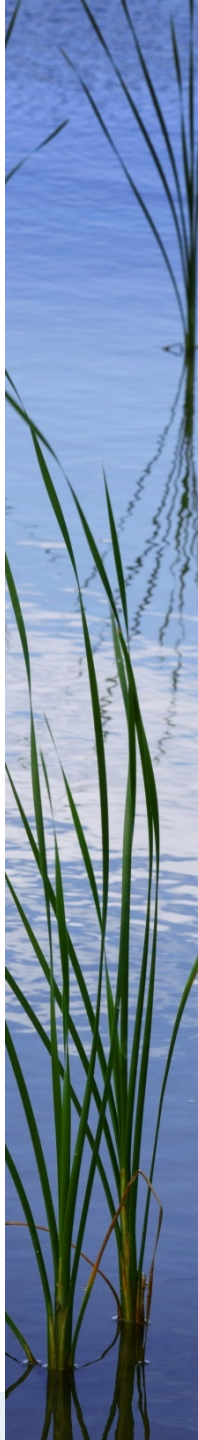
Cartridge Filtration– Summary

Treatment Process	Pathogen Credit	Pros	Cons
Cartridge Filtration	2- to 2.5-log Protozoa	♦ Easy operation ♦ Lowest energy usage	♦ Particulate removal sufficient but less compared to other options ♦ Requires more frequent replacement than membrane filters ♦ Lower pathogen credits



Filtration 101 –Filtration Technologies

	Particulate Reduction	Pathogen Reduction
Cartridge Filter	✓	✓
Membrane Filter	✓ ✓ ✓	✓ ✓
Reverse Osmosis	✓ ✓ ✓	✓ ✓ ✓



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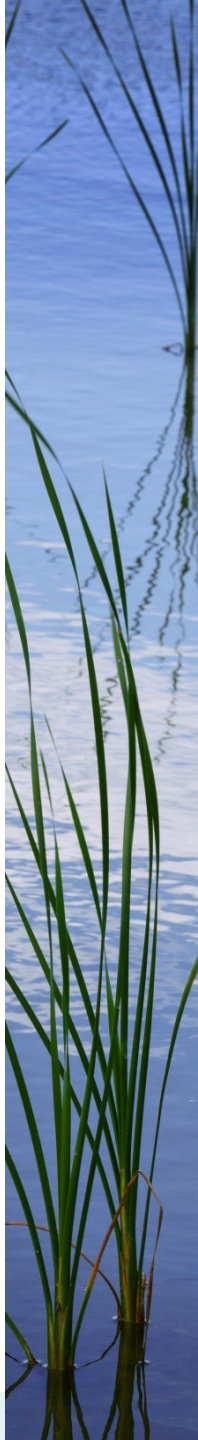
Disinfection– Summary

	Free Chlorine	UV	Ozone
Pathogen Reduction	✓ ✓	✓ ✓ ✓	✓ ✓
Footprint	✓	✓ ✓ ✓	✓
Energy Use	✓ ✓ ✓	✓	✓
Chemical Handling	✓	✓ ✓ ✓	✓



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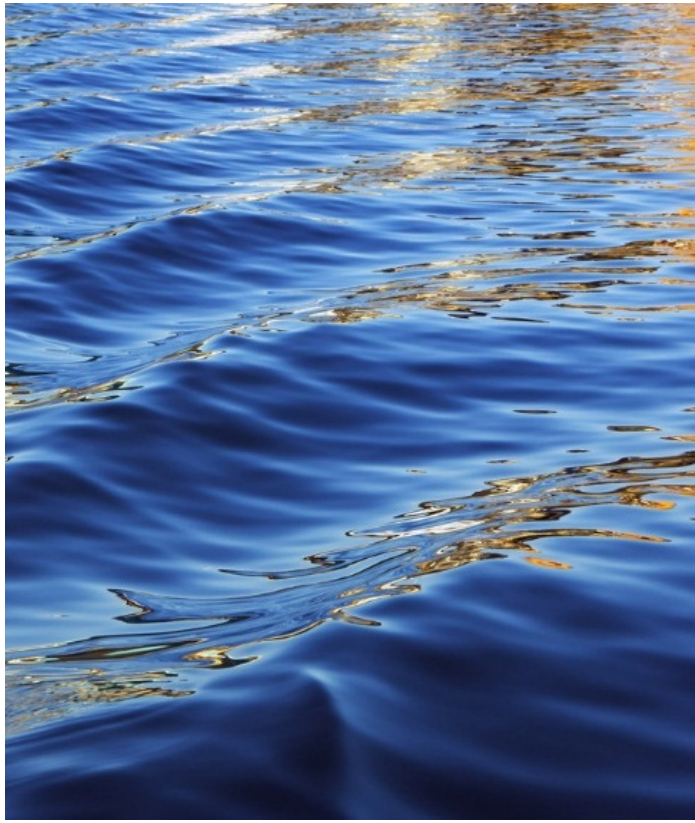
Example Interactive Question:

Choose the treatment objective(s) that is achieved with disinfection:

- A. Reduce dissolved inorganic constituents
- B. Reduce pathogens
- C. Minimize the risk of *Legionella*
- D. Reduce biodegradable organics
- E. Both (B) and (C)

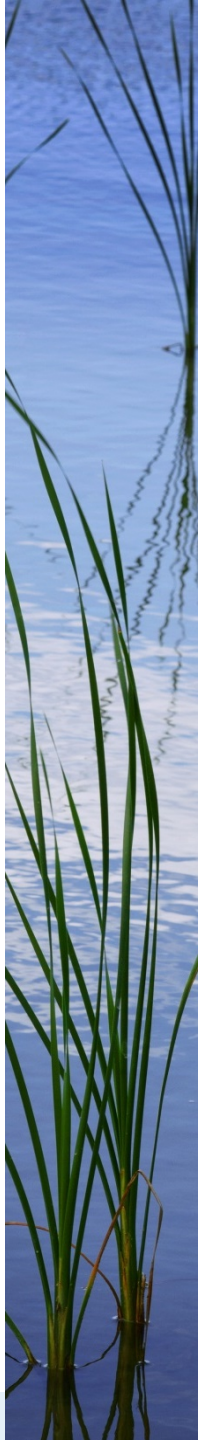
Developing Multiple-Barrier ONWS Systems

Chapter 4



Learning Objectives

- **Why should multiple barriers be considered when designing ONWS?**
- **What are management barriers and why are they useful?**
- **How can an ONWS system be designed with multiple barriers?**

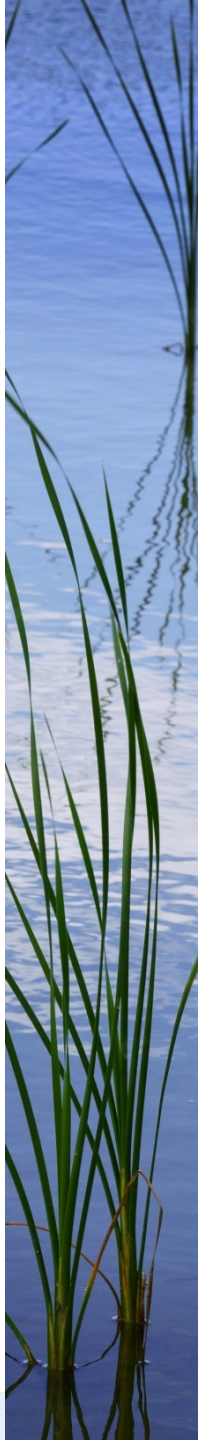


Benefits of Multiple Barrier Trains

Treatment + Non-treatment Barriers

- Ensure **reliability** of public health protection

- Maintain a high degree of **availability**



Benefits of Multiple Barrier Trains

- **Wide diversity of contaminants to remove:**

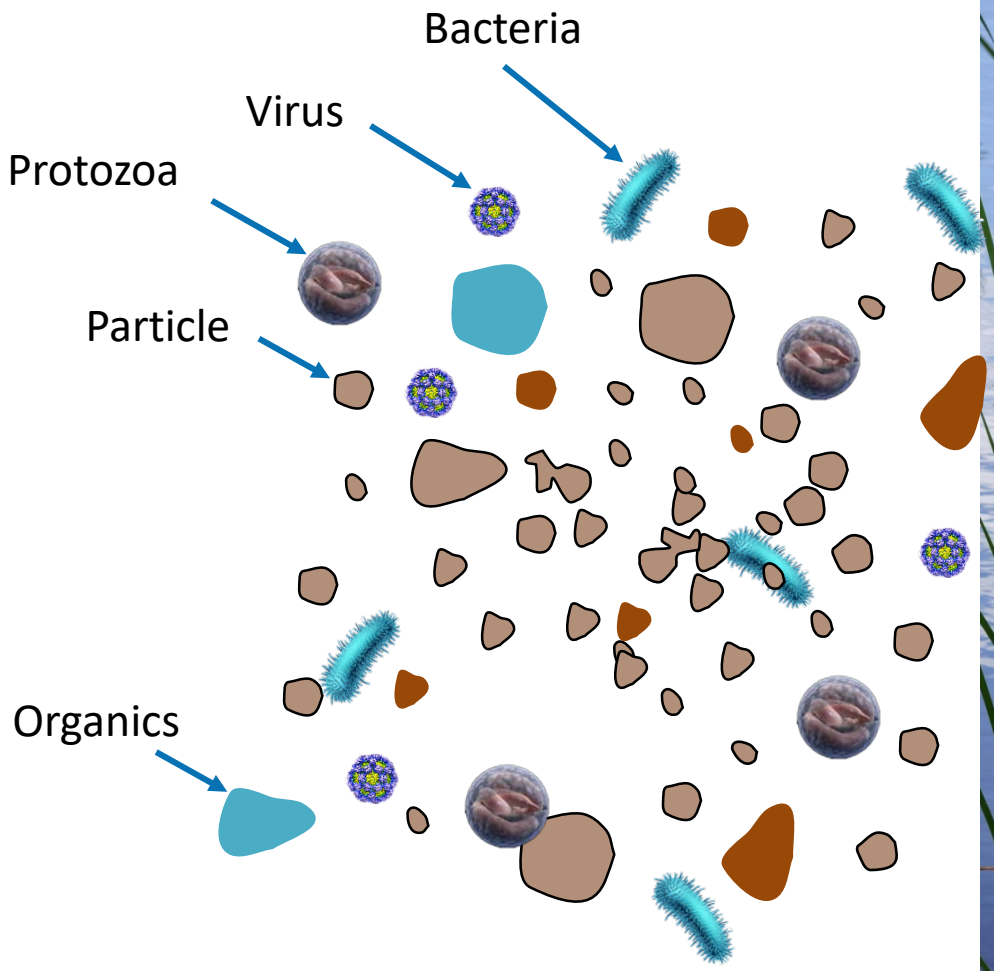
Pathogens

Biodegradable organics

TSS

Color

Odor



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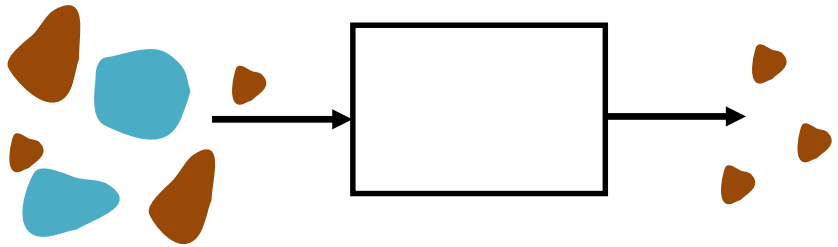
Benefits of Multiple Barrier Trains

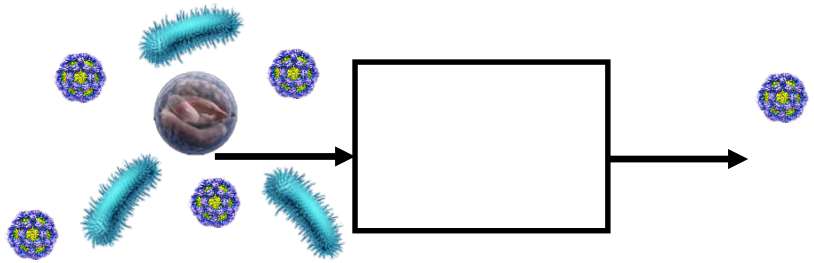
- **Often, one technology doesn't remove everything**



Biological Treatment

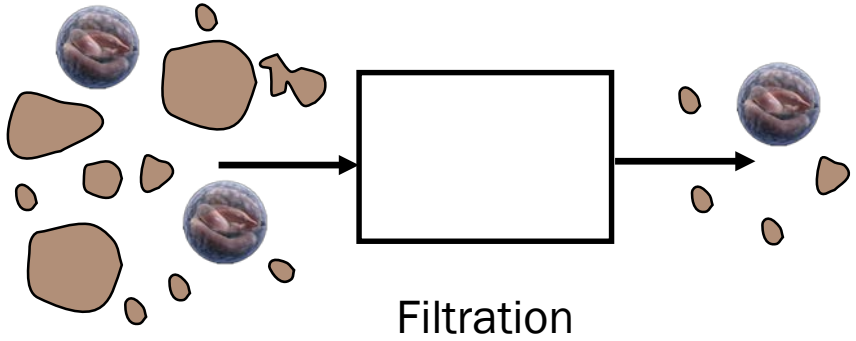
BOD Reduction

TSS Reduction



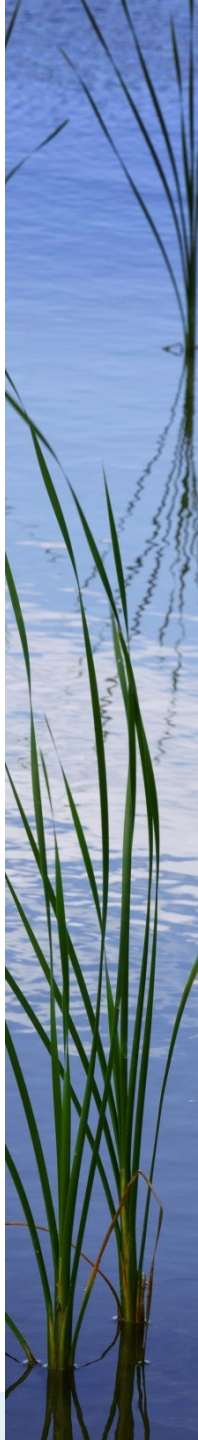
Disinfection

Pathogen Reduction



Filtration

TSS and Pathogen Reduction



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Benefits of Multiple Barrier Trains

Green = effective
Yellow = somewhat effective
Red = not effective

Unit Process	Pathogens			Water Quality		Removal / Inactivation Mechanisms
	Virus	Protozoa	Bacteria	Particulates	Organics	
Biological Treatment						
Non-membrane options						Biodegradation, adsorption, predation
MBR						Same as above plus size exclusion
Filtration						
Granular media filter						Physical removal (e.g., size exclusion, interception, diffusion)
Cartridge filter						
Membrane filter						Physical removal (e.g., size exclusion)
Reverse osmosis						
Disinfection						
UV						Physical degradation
Free chlorine						Chemical inactivation and oxidation
Chloramine						
Ozone						

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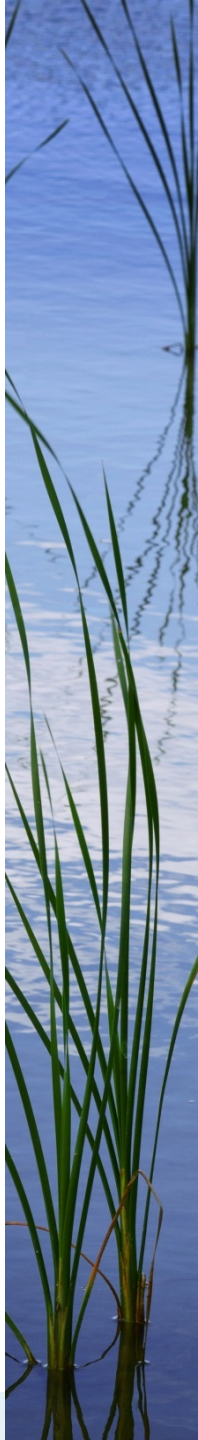
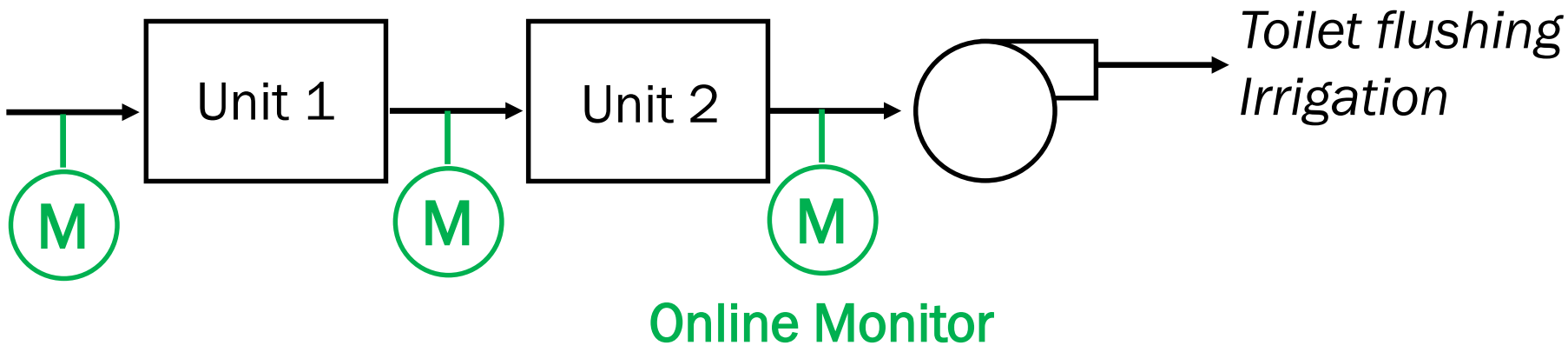
Benefits of Non-Treatment Management Barriers

- **Management Barriers**
  - Source Control
  - Alternative Disposal and Supply Options
  - Flow Equalization
  - Monitoring
  - Operational Optimization
- Promote goals of public health protection and system availability



Management Barriers - Monitoring

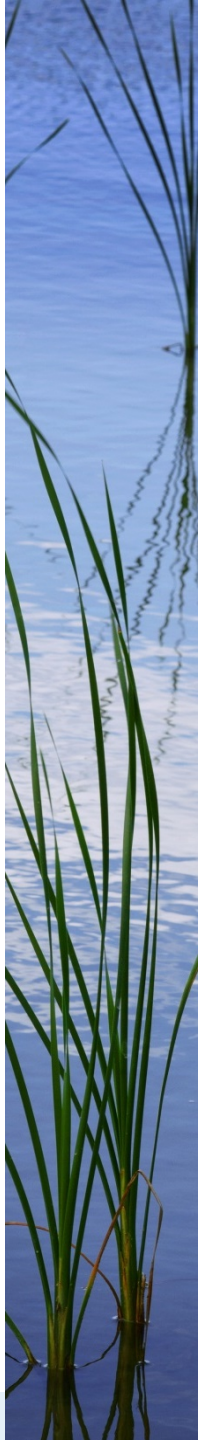
- **Monitoring is an essential element of ONWS**
- Continuous monitoring via on-line analyzers provides on-going assurance of treatment efficacy
- Shortens duration of off-spec operation



Balancing Treatment and Management Elements

Systems designed to utilize best configuration to fit site constraints

Space Limited?	• Less standby capacity • Seek alternate disposal and supply options
Remote Operation Required?	• Use redundant online monitoring • Design system with redundant treatment
No Alternate Supply Available?	• Design redundant and robust system • Include standby capacity



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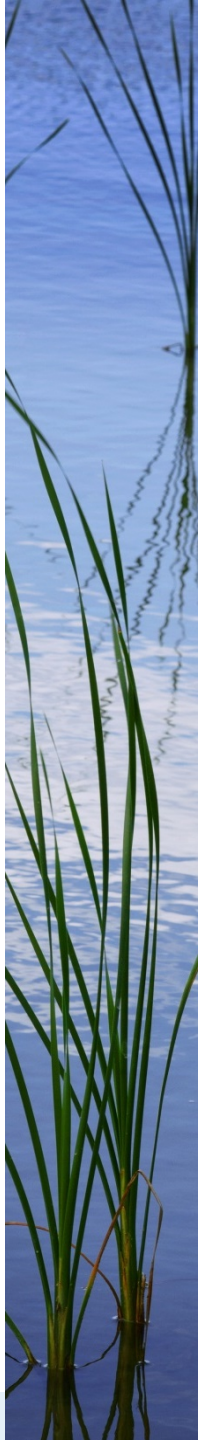
Lessons Learned: Considerations for Designing Multiple Barrier Treatment Trains

DESIGN ENGINEER

Frequent Communication

SYSTEM OWNER

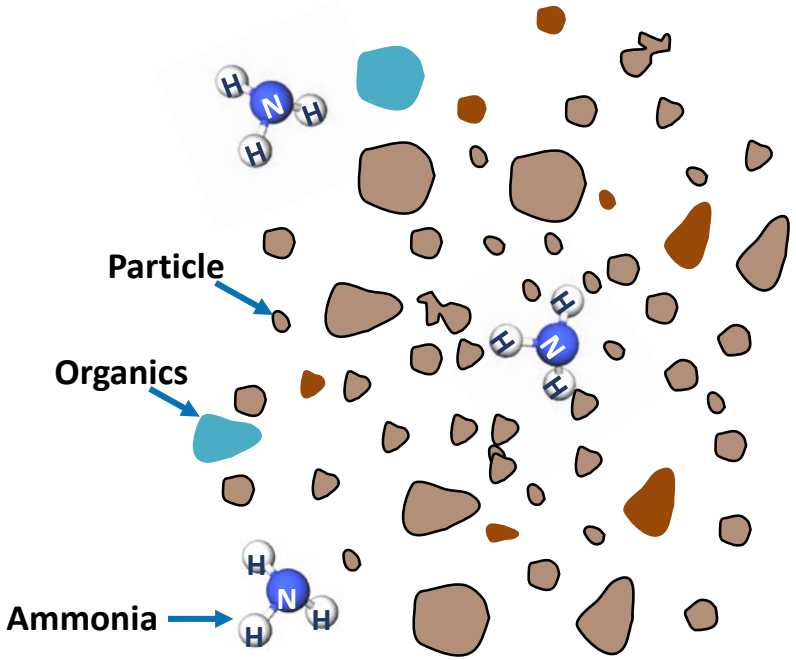
- Regarding assumptions for:
  - Performance
  - Cost
  - Operability
- Balance cost/footprint constraints with operability and uptime



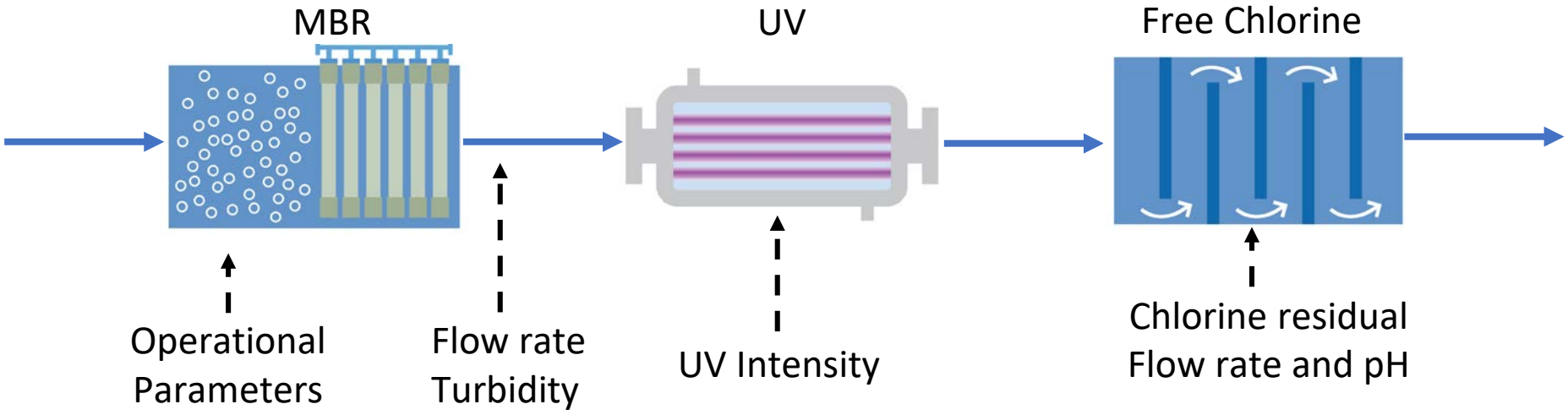
Design and Treatment Goals for Blackwater

- Design system to achieve pathogen reduction for use in ONWS
- Provide assurance that LRTs are being met
- **Decrease organics to create a biologically stable water**
- **Create aesthetically acceptable water (particulates, odor, color)**

Unwanted Constituents in Blackwater and Graywater:



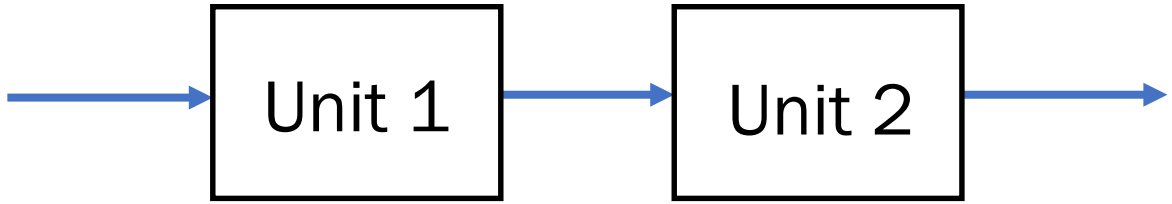
Multiple Barrier Treatment Trains - Blackwater



	Unit Process Pathogen Credits			Total Log Reduction	LRTs for Blackwater
	MBR	UV	Free Chlorine		
Virus	1.5	3.5	5.0	10.0	8.5
Protozoa	2.0	6.0	0.0	8.0	7.0
Bacteria	4.0	3.5	5.0	12.5	6.0

Example Interactive Question:
Graywater Treatment Train Design

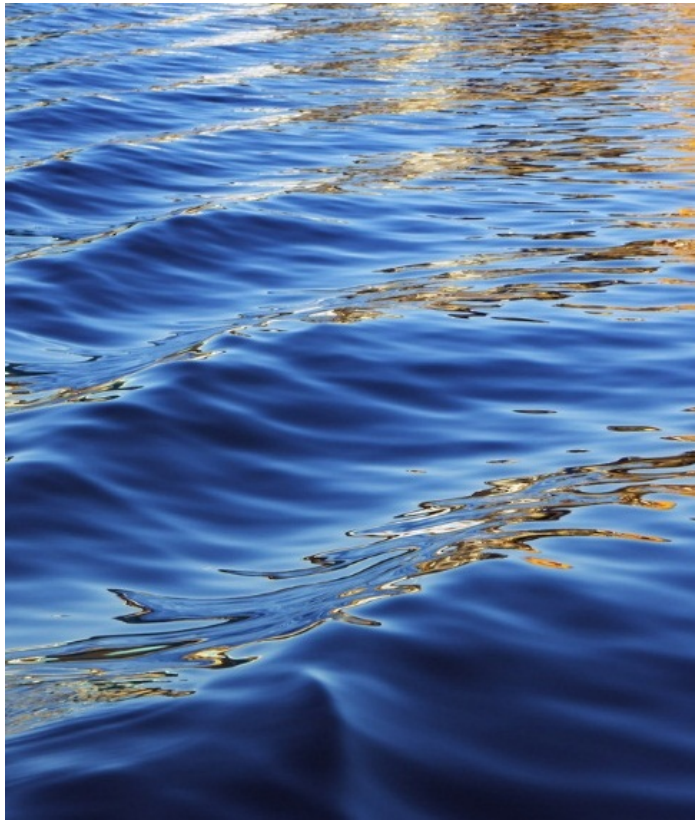
Select two treatment processes that provide the required LRTs:



	Unit Process Pathogen Credits		Total Log Removal	LRT for Graywater
Virus				6.0
Protozoa				4.5
Bacteria				3.5

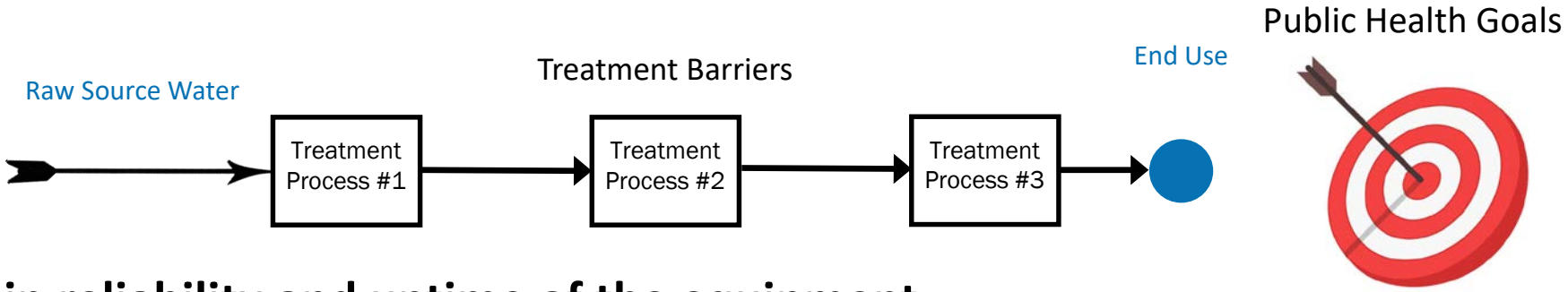
Operations Plan

Chapter 5



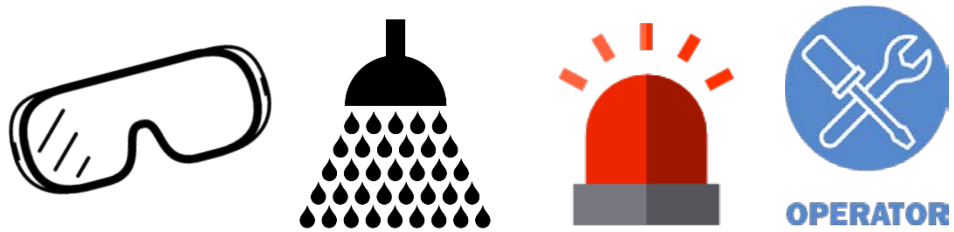
Primary Goals of ONWS Design and Operation

- **Meet or exceed all compliance objectives – protect public health**



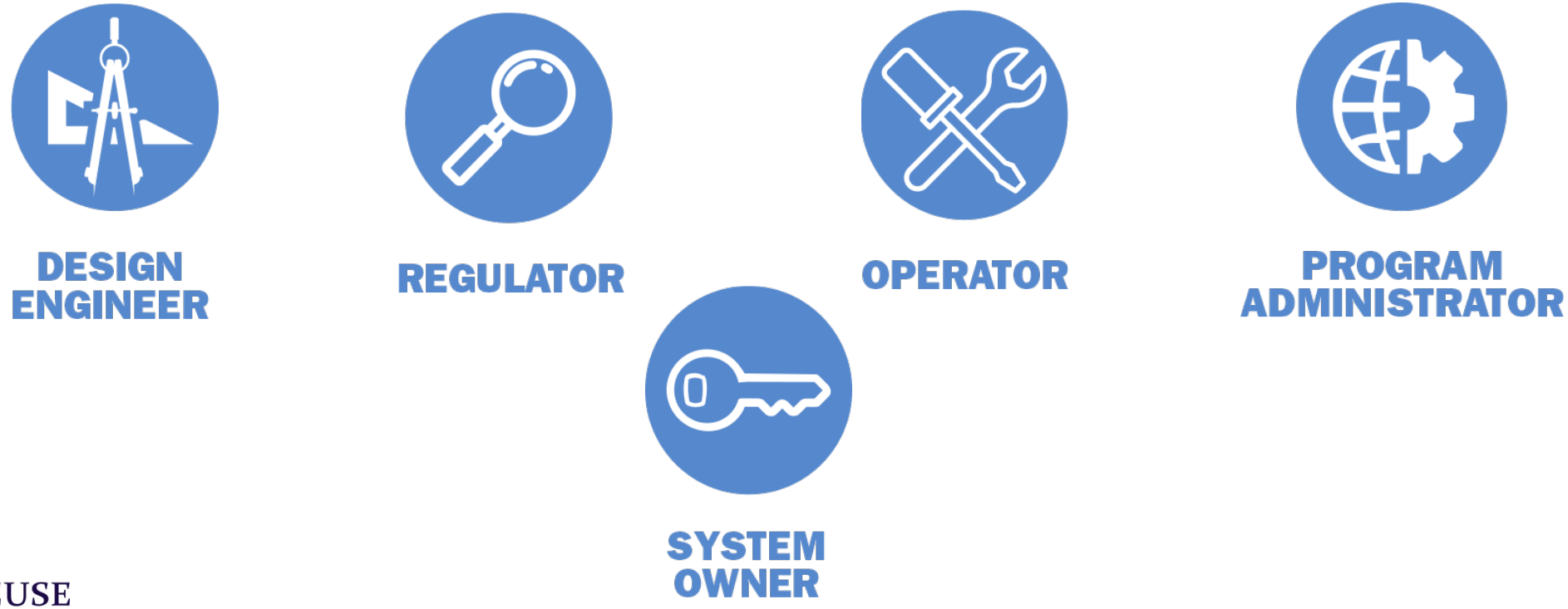
- **Maintain reliability and uptime of the equipment**

- **Ensure the safety of all operating personnel**



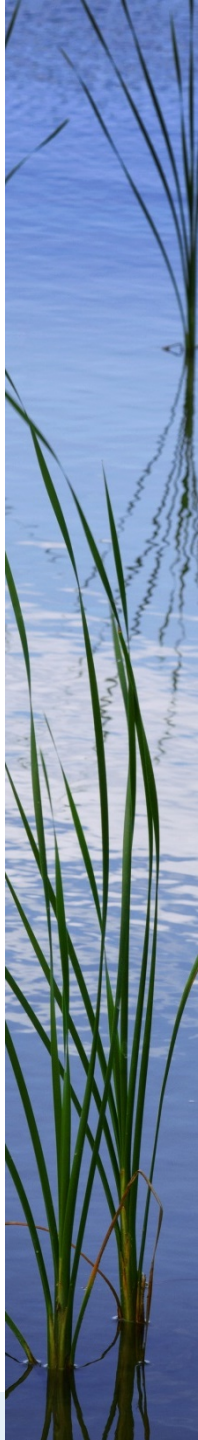
Learning Objectives

- Importance of interface between design, permitting, and operations
- Critical documentation for operating and commissioning ONWS
- Roles for Design Engineers, Regulators, and Operators related to start-up, commissioning, and ongoing operations of ONWS systems



Chapter Overview

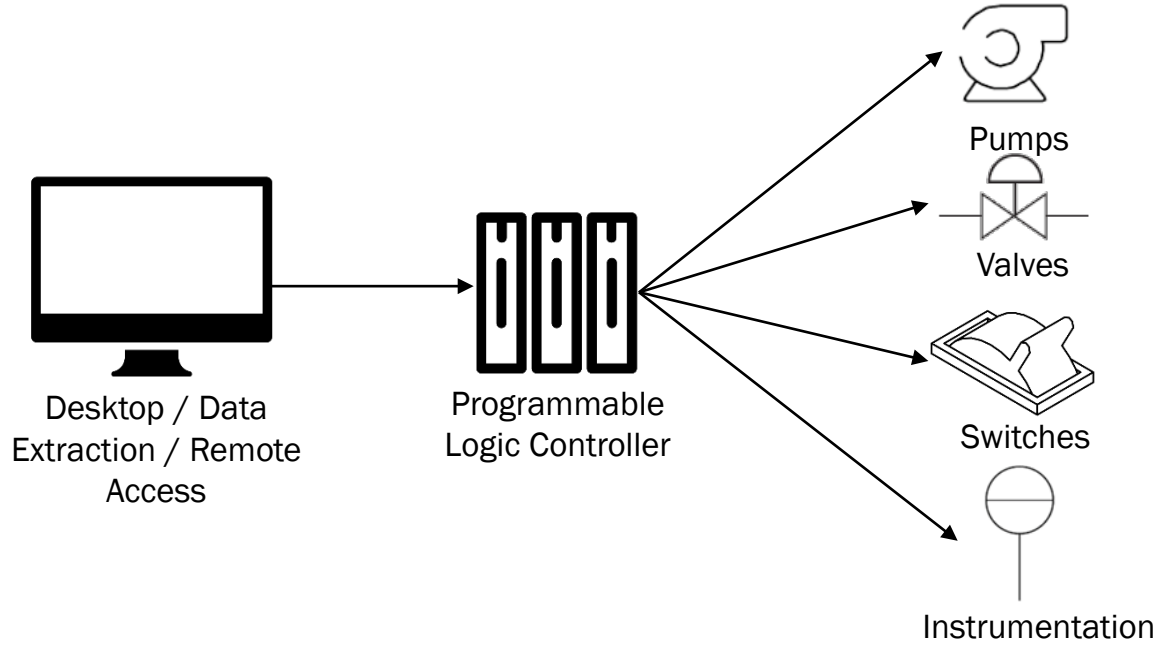
- **Introduction to the essential elements of an Operations Plan:**
  - Process Design and Control Theory
  - Standard Operating Procedures
  - Maintenance Plan
  - Compliance Reporting
  - Environment, Health and Safety Plan
  - Emergency Response Plan
  - O&M Staffing Plan
  - Commissioning and Acceptance Test Plan
  - Process Optimization



Chapter Overview

- **Introduction to the essential elements of an Operations Plan:**
  - **Process Design and Control Theory**
  - **Standard Operating Procedures**
  - **Maintenance Plan**
  - **Compliance Reporting**
  - Environment, Health and Safety Plan
  - Emergency Response Plan
  - O&M Staffing Plan
  - Commissioning and Acceptance Test Plan
  - Process Optimization

System design, operation, and monitoring



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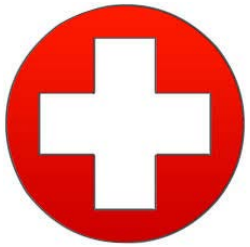
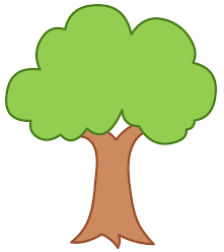
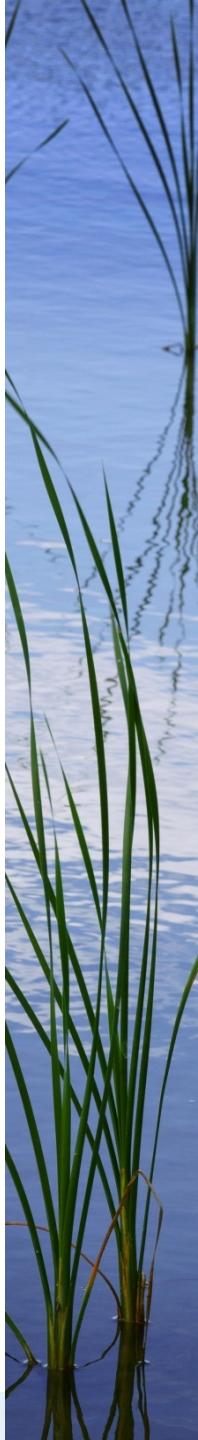
Health, safety, and staffing



Health and Safety



Environmental



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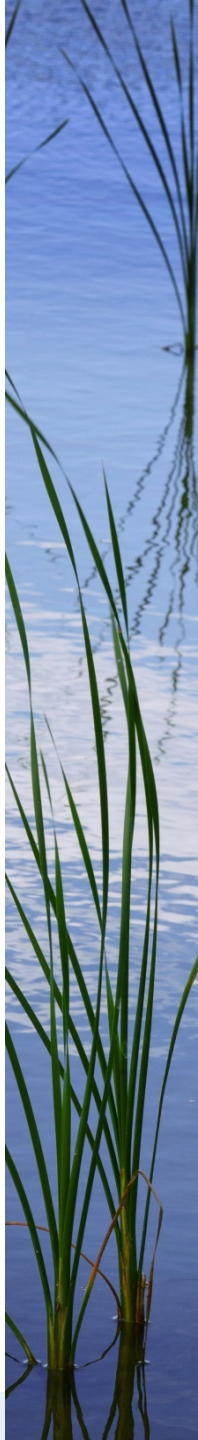
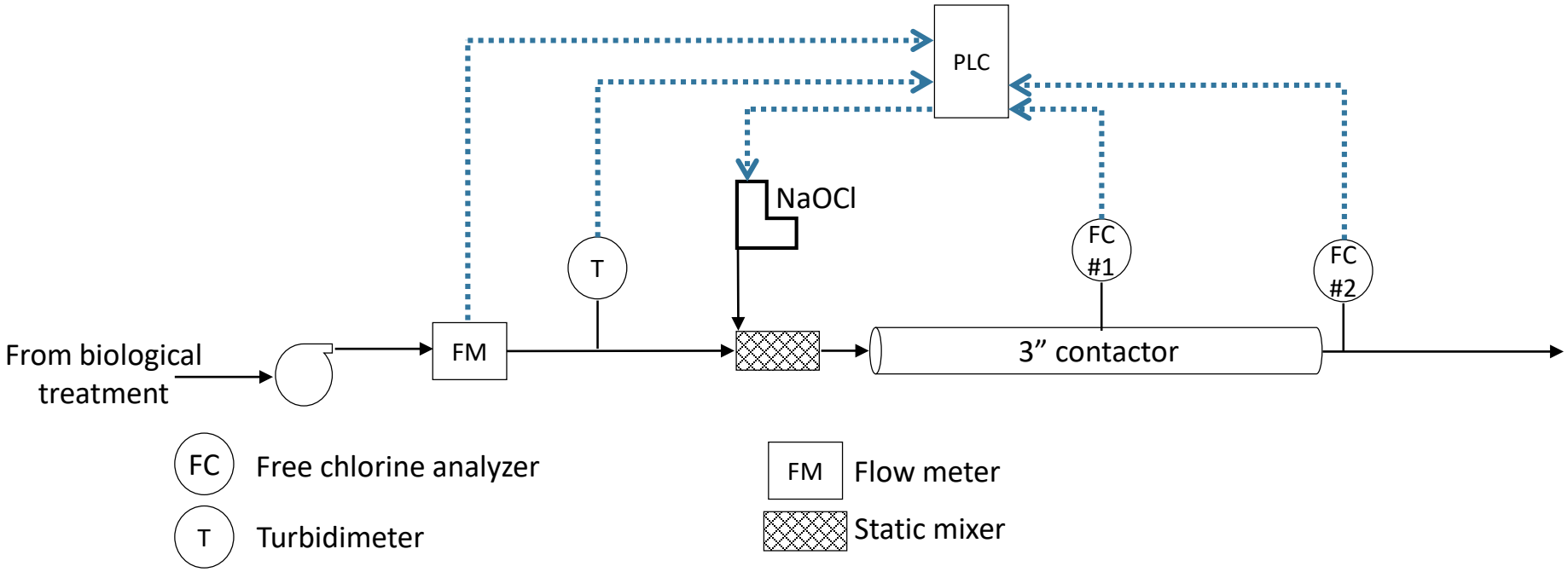
} **Startup and optimization**



Process Design and Control Theory

- **Process Control**
  - Defines how the system *should* be operating
- **Performance Monitoring**
  - Confirms the system is operating as designed
- **Alarms and Notifications**
  - Alerts the operator when a parameter is out of the typical range



Standard Operating Procedures

- SOP = set of **step-by-step instructions** developed to help operators carry out complex or routine operations

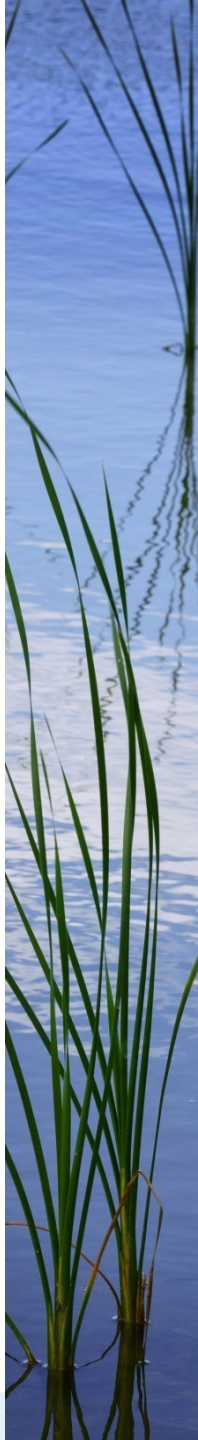
✓Achieves efficient and consistent performance
✓Knowledge transfer among operators
✓Reduces miscommunication and compliance failures

Developed by:

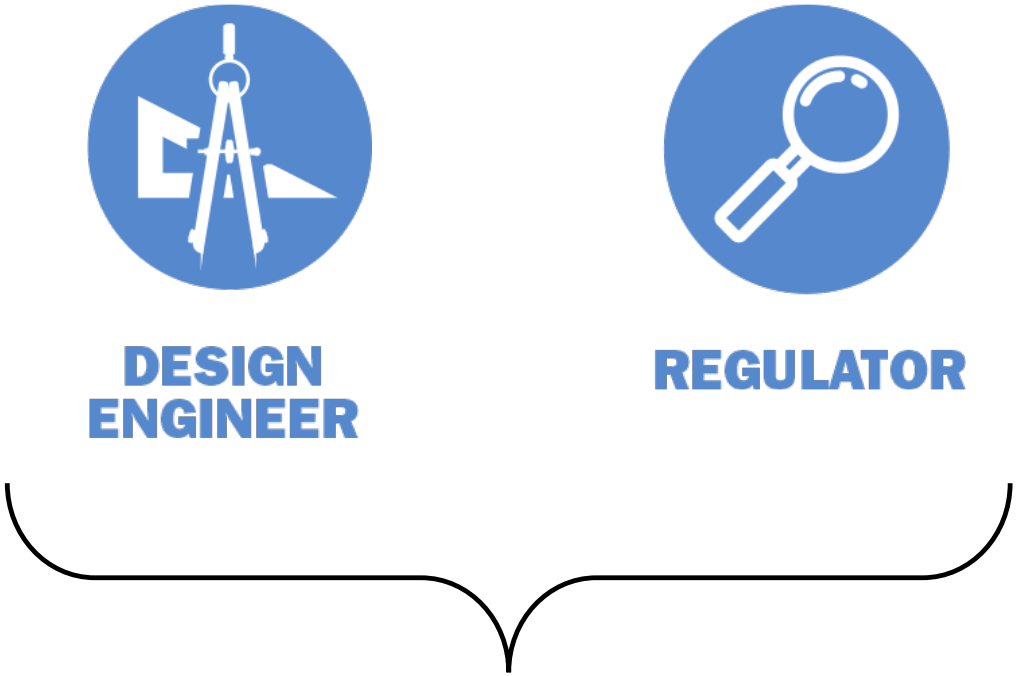
OPERATOR

With input from:

DESIGN ENGINEER



Compliance Reporting



Work together to develop the daily and monthly treatment plant report form. Ideally, compliance and operational reporting needs can be combined in a single report format

Example Interactive Question:
Select impact on staffing needs

Select whether the situation on the left increases or decreases staffing needs:

Staffing Needs:

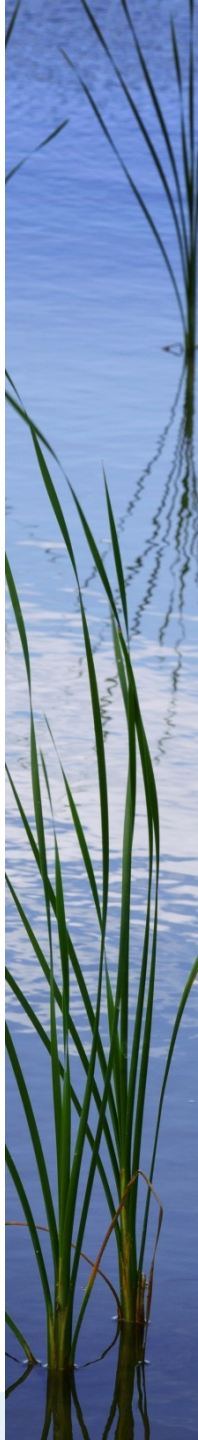
1.  Automation  OR  ?

2.  Maintenance requirements of equipment  OR  ?

3.  Sampling requirements for regulatory compliance  OR  ?

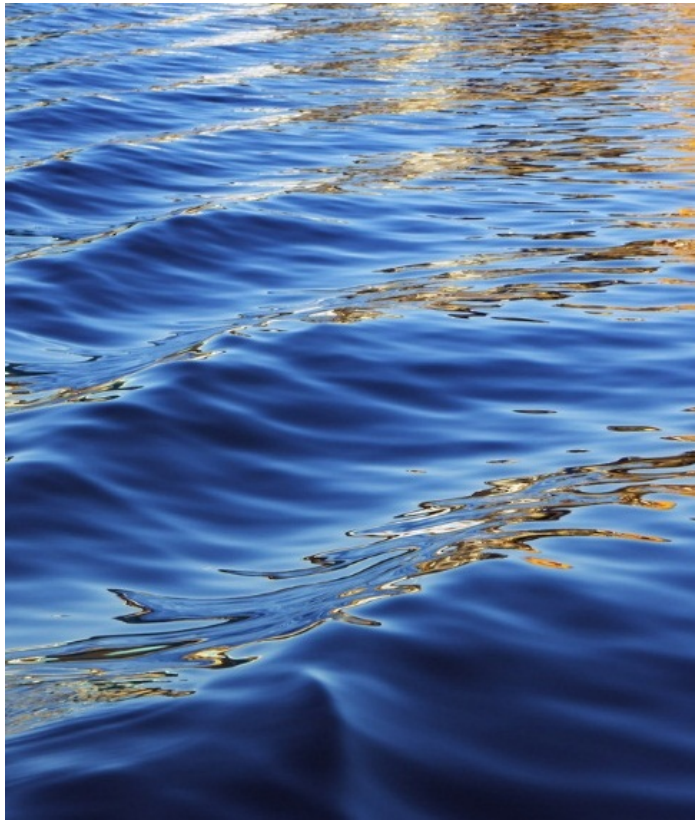
4.  Use of remote monitoring for control and routine operations  OR  ?

WateReuse



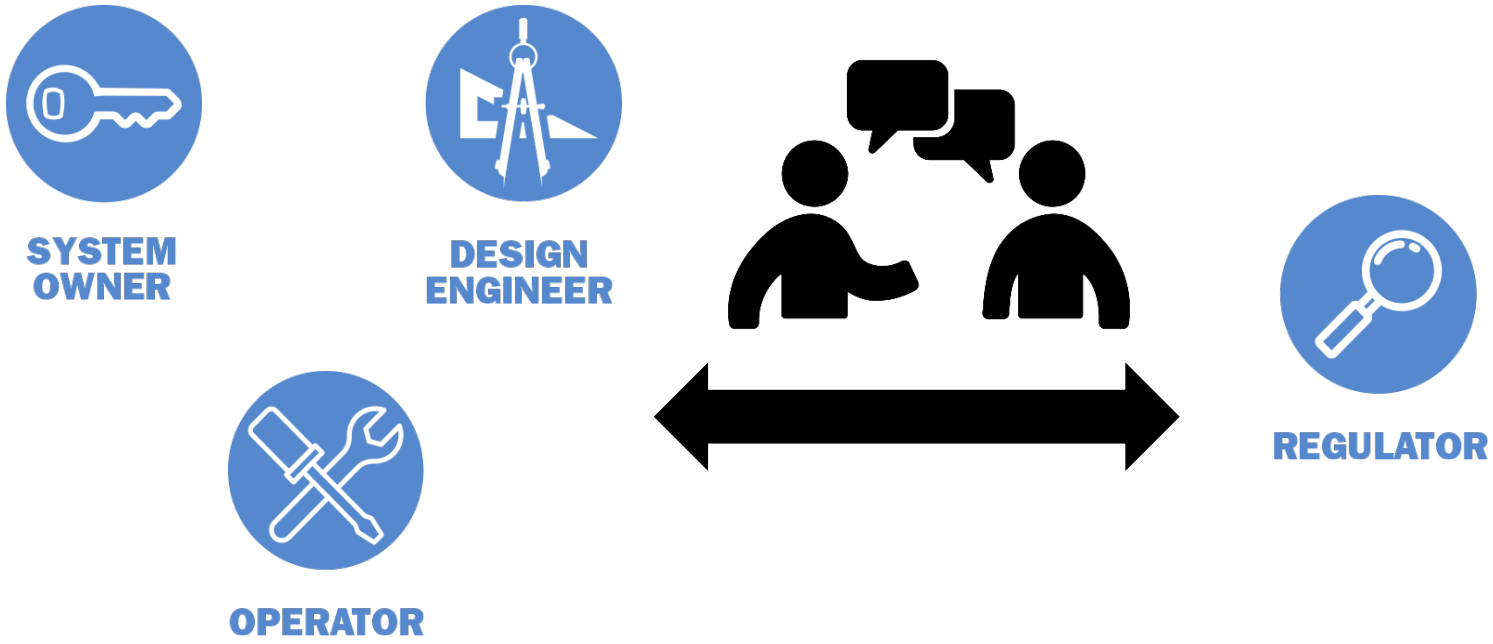
Regulatory and Permitting Plan

Chapter 6



Learning Objectives

- Steps of the regulatory process and how to navigate them
- Key documentation required for regulatory compliance
- Importance of communication between the project team and regulators



PROJECT TEAM	REGULATOR
INITIAL PROJECT DEVELOPMENT	
• Project Application	• Review and approve Project Application
PRELIMINARY DESIGN	
• Engineering Report (Preliminary)	• Review Preliminary Engineering Report
FINAL DESIGN, CONSTRUCTION, AND INITIAL INSPECTIONS	
• 100% Design • Engineering Report (Final) • Operations and Maintenance Plan including Commissioning Plan • Construction • Cross-connection inspection	• Permit to Operate
PROJECT STARTUP	
• Commissioning	• Installation inspection • Permit to Use
ON-GOING MONITORING AND REPORTING	
• On-going monitoring and reporting	• Performance and water quality data review • Inspections and enforcement • Periodic permit renewal

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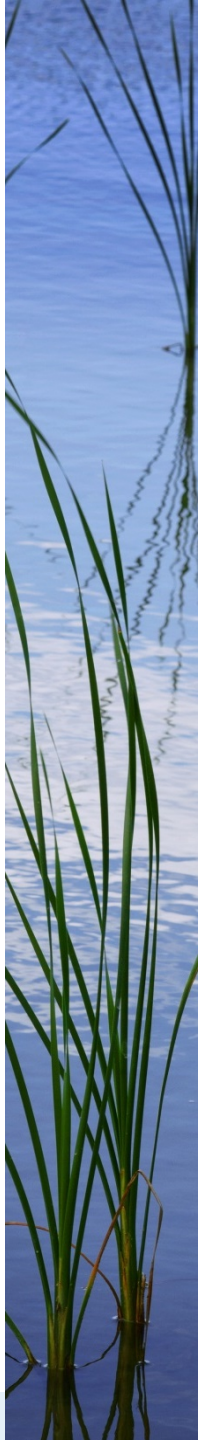
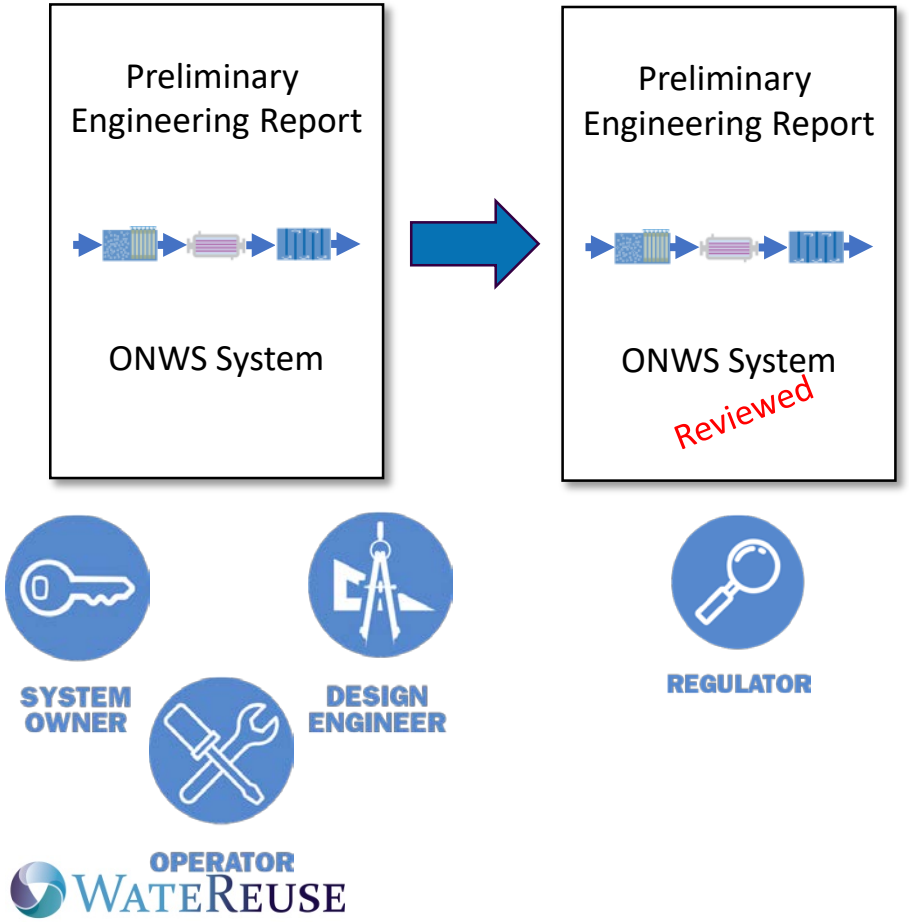
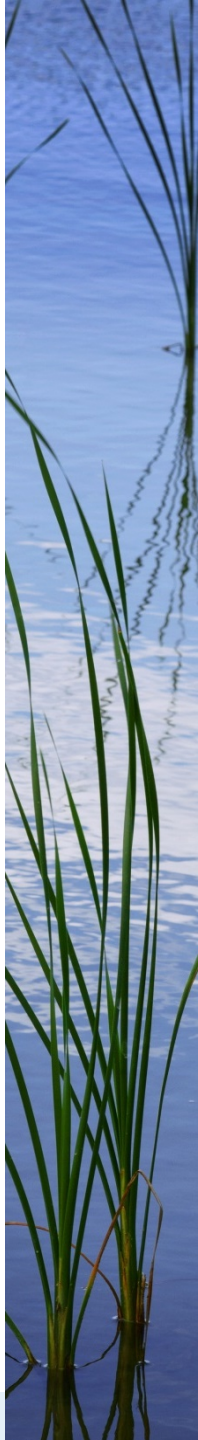


Initial Project Development and Preliminary Design

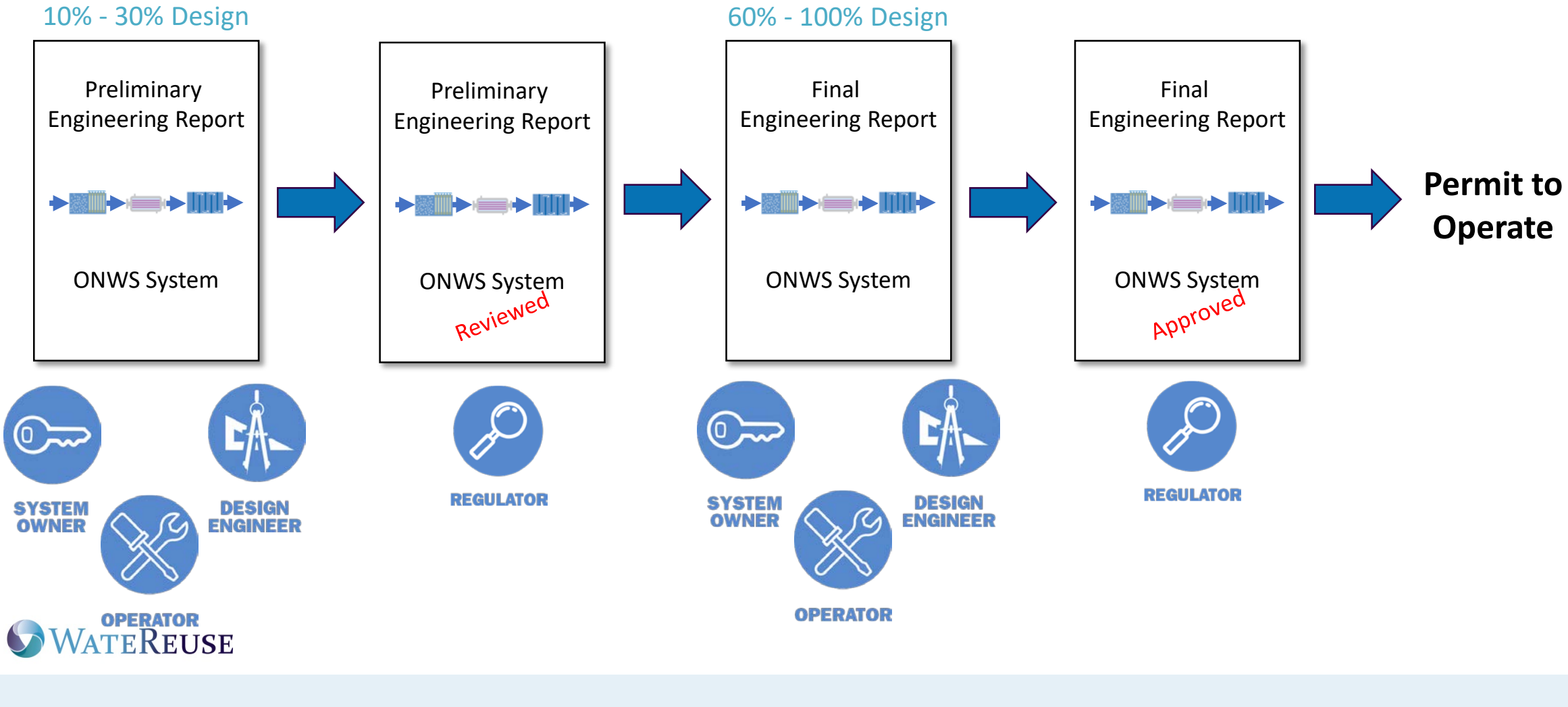
10% - 30% Design



- **Engineering Report** describes how the project meets applicable regulatory requirements
- Submitted at least twice throughout development process—early on and at the end of design



Final Design, Construction, and Initial Inspections



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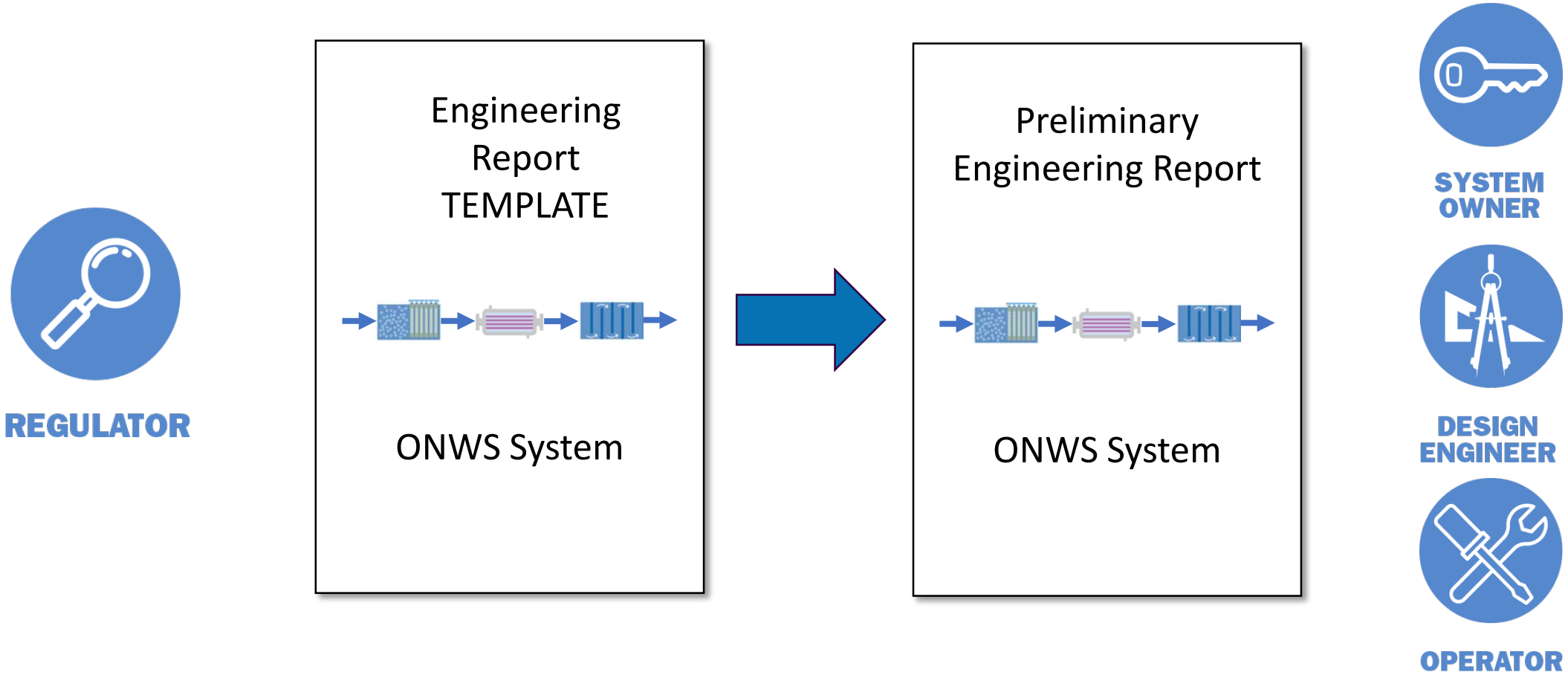
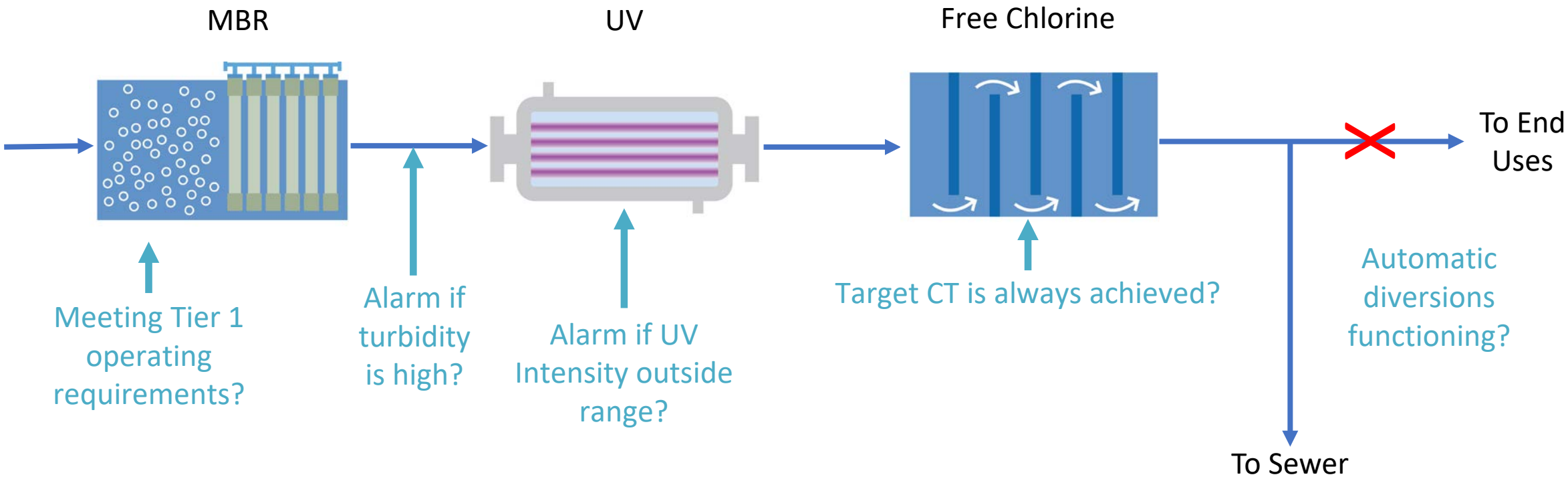
Lessons Learned: Benefit of an Engineering Report Template

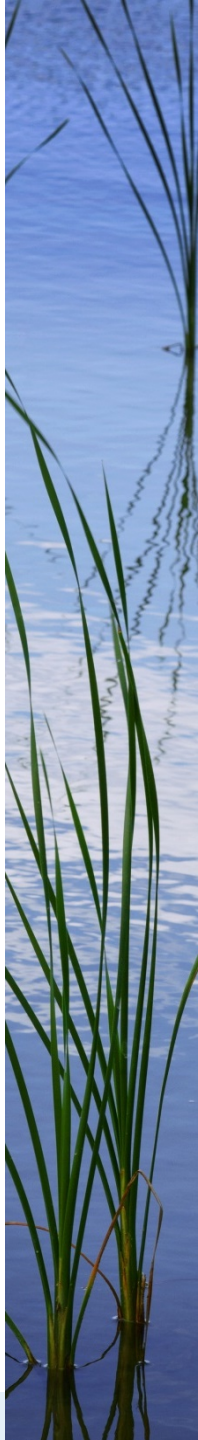
- **Developing an Engineering Report template can streamline regulatory review**



Project Startup and Commissioning

- **Commissioning** to verify proper functioning of system elements to meet performance design





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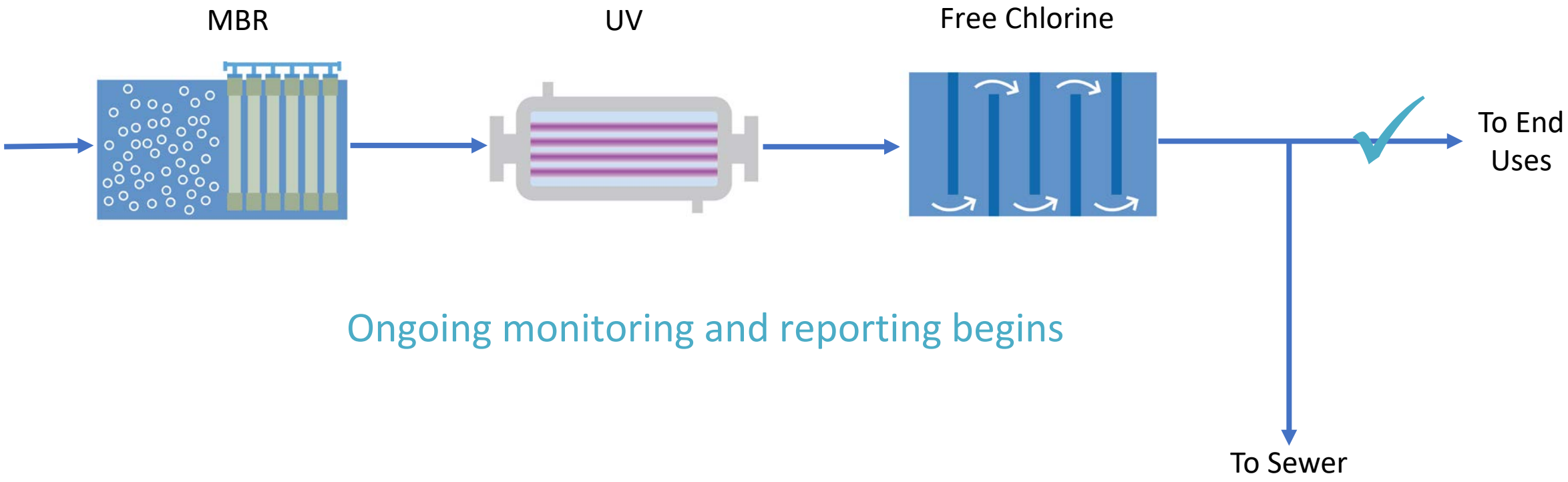
Project Startup and Commissioning

- **Permit to Use** issued after commissioning by the regulator

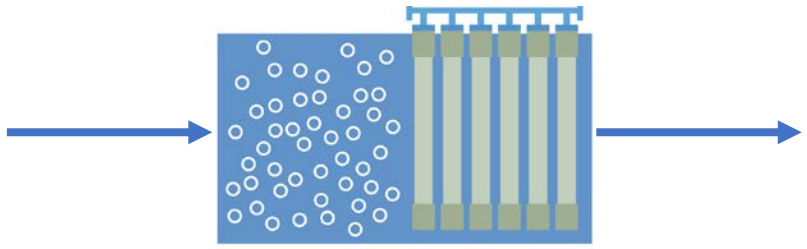


Ongoing monitoring and reporting begins

On-Going Monitoring, Reporting, Inspection, and Enforcement

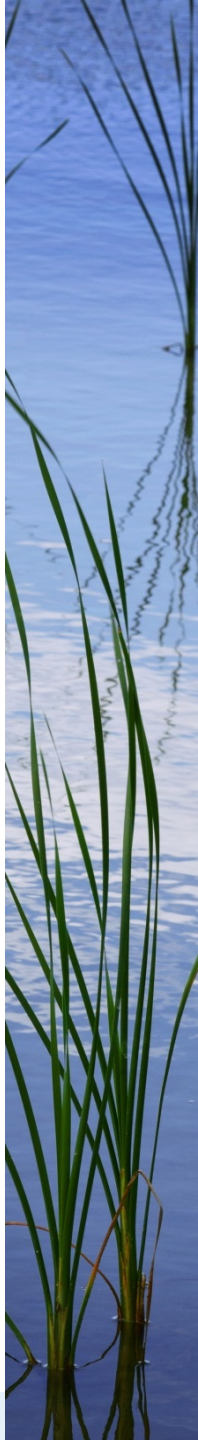
- **On-going Monitoring and Reporting**
  - Evaluation of system performance over time
  - Requirements are specified in the Operations Plan

MBR

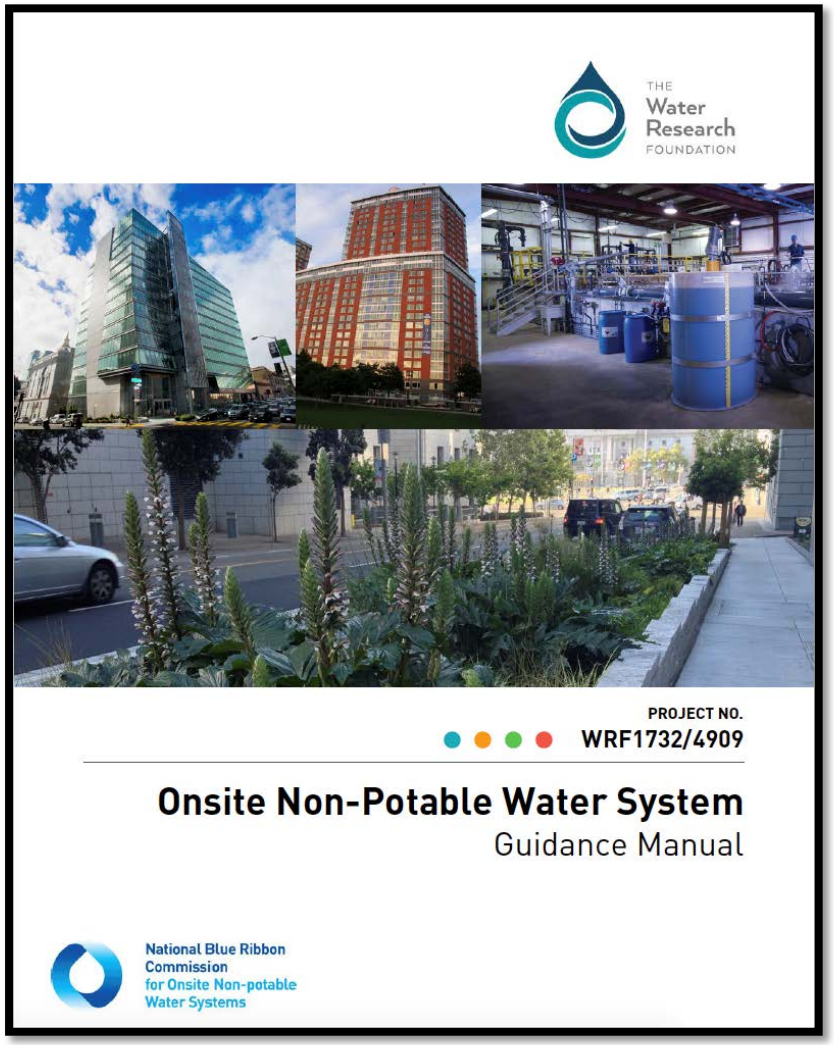


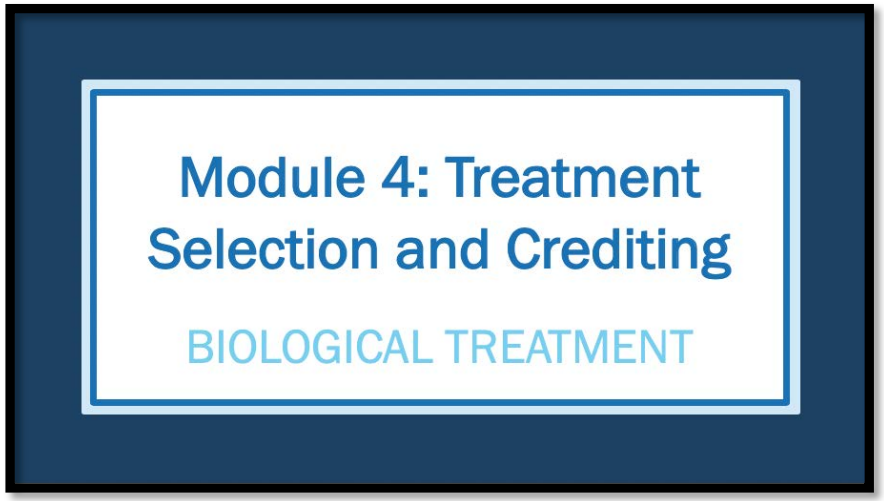
Monitoring Requirements for LRV Credit:

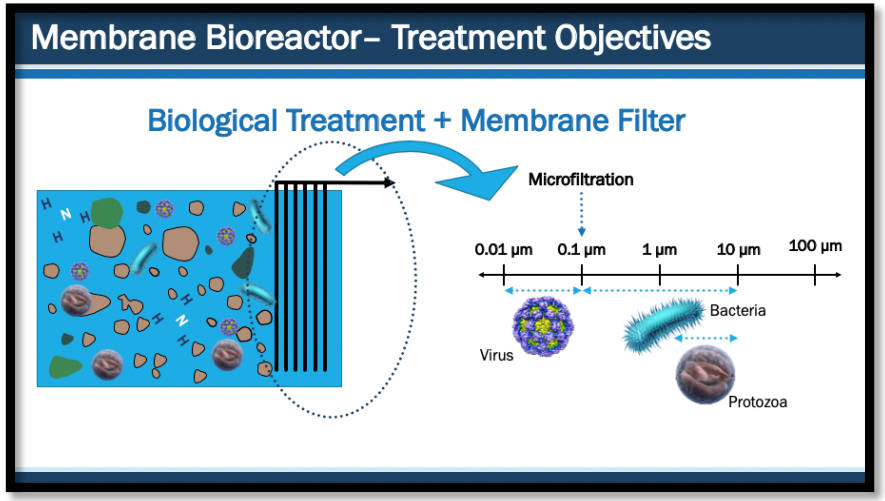
- ❖ Measure turbidity continuously
  - Effluent turbidity always ≤ 0.2 NTU
- ❖ Measure pH continuously
  - 6 < pH < 8



4909 Guidance Materials







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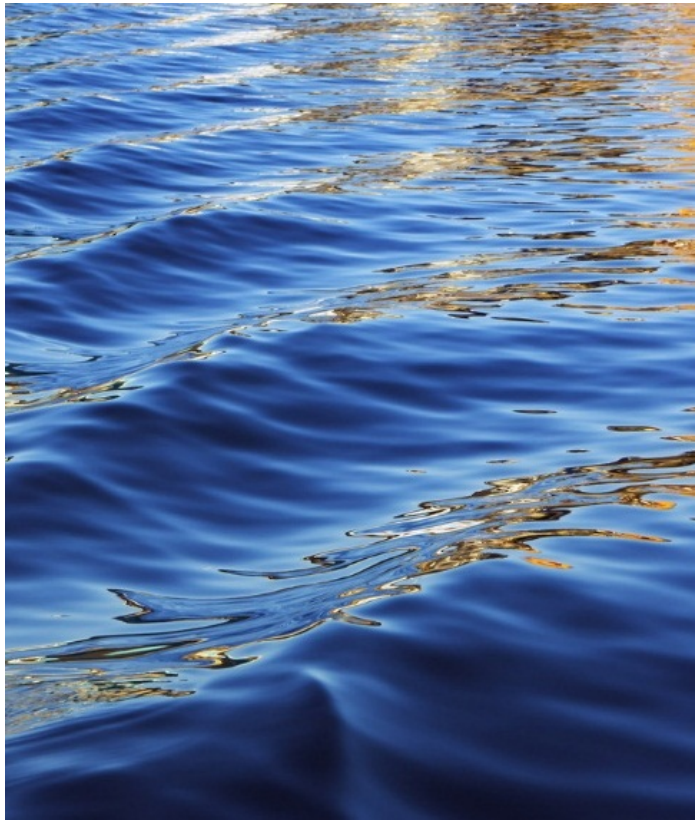
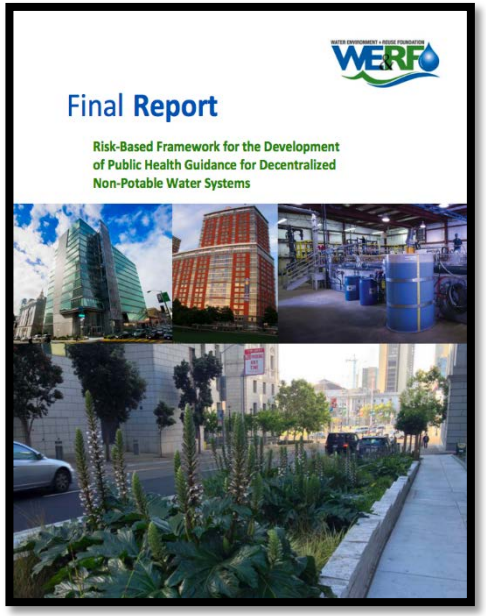
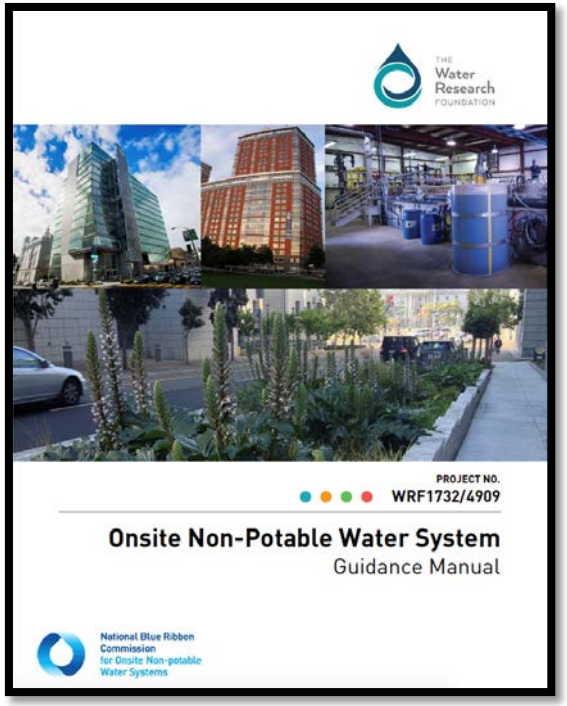
Wrap Up

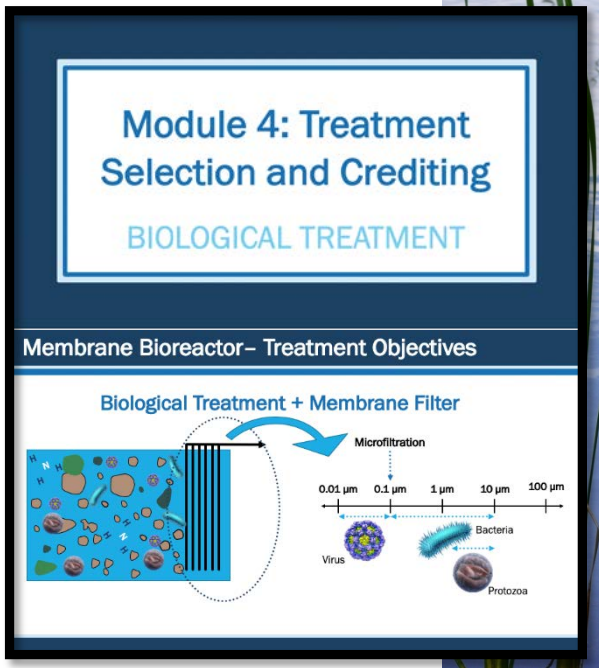


Key Takeaways:

- Guidance Manual and Training Modules cover key concepts to implement safe ONWS programs
- Provide knowledge and lessons learned from first-hand experience
  - Project TAC, Project PAC, National Blue Ribbon Commission, EPA review
- Guidance is broadly applicable to all types of ONWS programs
  - Design, permitting, construction, maintenance, and operation







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Acknowledgements

- Research Team at Trussell Technologies
  - Keel Robinson
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- Technical Advisory Committee
  - Warren Johnson, Aquacell
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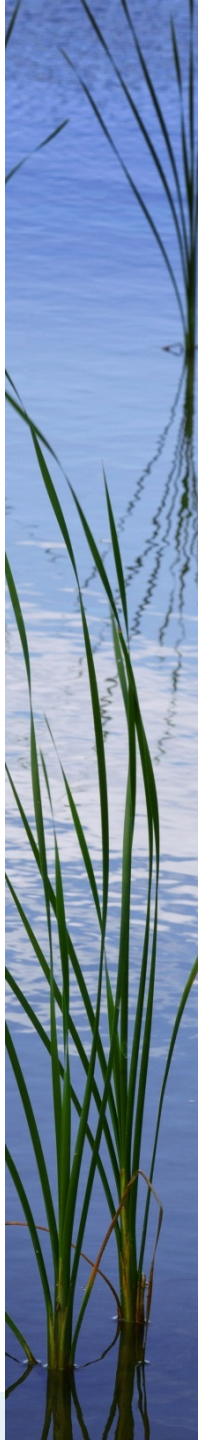
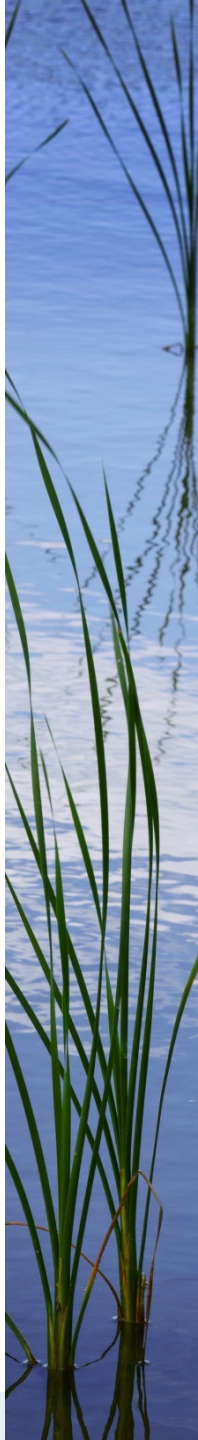
  - Hannah Doherty, New York City Department of Environmental Protection
  - Kyle Pickett and Piper Kujac, Urban Fabrick
- Project Advisory Committee
  - Paula Kehoe, SFPUC
  - Steve Deem, Washington State Department of Health
  - Anita Anderson, Minnesota Department of Health
  - Brian Good, Denver Water



Questions?



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