Hazen

HORIZONS

water environment solutions

SPRING 2019

Planning for a Sustainable Future

Asset management processes and tools enable utilities to make defensible, data-driven decisions and find the right balance between timely funding of critical needs and maintaining reserves for long-term capital expenditures.

UC Santa Barbara Campus at Goleta
UCSB PHOTO

Like many wastewater utilities, Goleta Sanitary District (GSD) in California is facing a need for significant capital investment for rehabilitation and replacement of aging infrastructure to reliably maintain operations.

New utility leadership initiated an asset management program (AMP)—developed with Hazen and Sawyer—to help guide this investment. The program would set a sound foundation for development of the District's annual budget, ensure its finances are adequate for delivery of services, and provide a transparent basis for communicating fiscal requirements with the public and other stakeholders.

The District was using its Geographic Information System as a data repository for collection system assets but needed a system to centralize data for facility assets. Due to the sheer number of assets involved and the disruptive culture change that can come with rigorous asset management, a proof-of-concept pilot project was proposed as part of a phased approach. The project team selected the GSD wastewater treatment plant (WWTP) influent pump station for the pilot because it included a range of mechanical, electrical, and structural assets and could produce a scalable program that could be expanded to the entire plant.

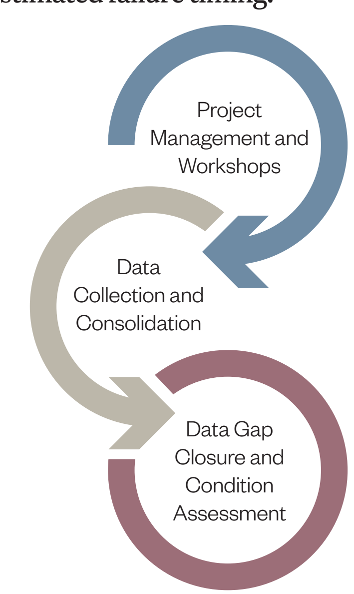
At the core of this otherwise traditional asset management project was a set of customized analyses designed to inspire higher confidence in the timing and cost of asset failures and provide a tool for calculations as new data becomes available. Hazen developed a computerized asset management model to streamline calculations and visually elevate key operational and financial information in dynamic dashboards, enabling the District to drill down to asset-level source data, or roll up high-level data for reader-friendly, visual reports.

Desktop Inventory and Condition Assessment

A centralized database provided the foundation for customizing the District's AMP, grounded in the contributing assets/over-arching process hierarchy that allows the District to "zoom" in and out as analysis and reporting requires. Data from various sources was consolidated into the database and an onsite field inventory and condition assessment closed data gaps. WiFi-enabled mobile devices with electronic data collection forms reduced collection and quality review time by approximately 25 percent, while also improving data quality and consistency.

Customized Analysis

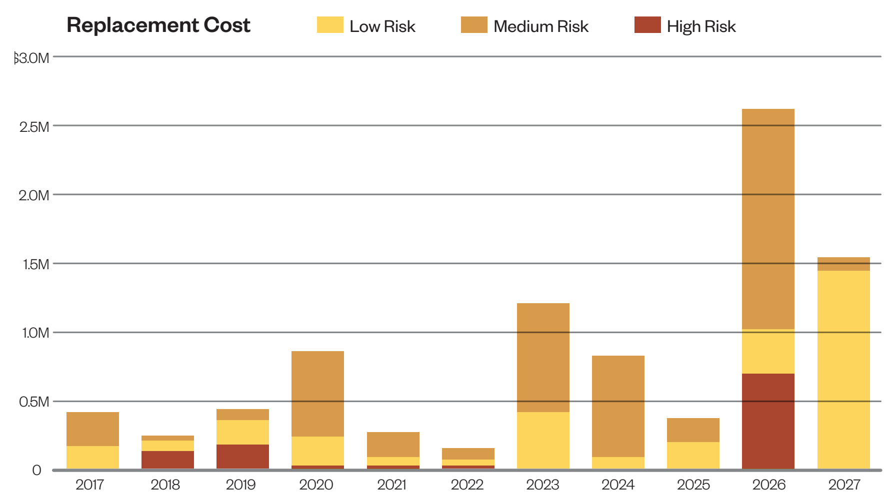
Long-term asset management requires determining remaining useful life, operational criticality, and long-range funding requirements for each asset. The project team calculated estimated lifespans for each asset class using industry best practices as defined by the Water Environment Research Foundation, American Water Works Association, and the U.S. EPA, coupled with experience from similar projects, onsite condition assessment, and maintenance history. Condition assessment provided insight into the nature and timing of possible asset failures, which can be impacted by operating environment, operational history, maintenance procedures, construction quality, material quality, and external stresses. By customizing the expected useful lifespan of assets based on their historical performance, the project team increased confidence in estimated failure timing.



Translating Data into Dollars

The next step was determining the financial requirements associated with rehabilitation and replacement, beginning with assessing the current replacement cost of each asset. The project team developed a cost library for efficiency and to allow review and updates of cost assumptions as updated information becomes available. Replacement and rehabilitation costs contributed to asset-specific management strategies that identified likely needs, timing, and associated costs. Using the timing of failure, replacement costs, and lifecycle cost logic, Hazen identified the budget year in which each asset is likely to require investment along with how much.

Determining Where to Spend



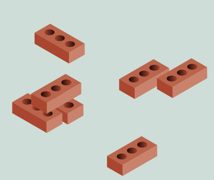
To optimize the return on investment, a risk assessment methodology was developed to calculate the business risk exposure score of each asset. Business risk exposure has two components: probability of failure and consequence of failure. Probability of failure (POF) is a function of asset condition and helps measure how likely it is for an asset to fail, while consequence of failure (COF) quantifies the impact of asset failure on the main functionalities of the WWTP.

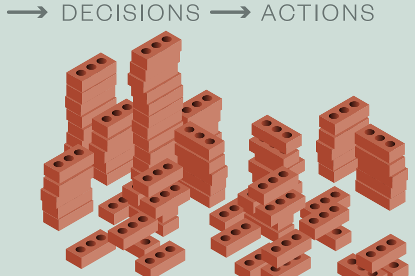
Through workshops with the Hazen team and GSD operations and maintenance, a two-tier approach— process level and asset level—was utilized to develop COF. The process level consequence followed a triple bottom-line methodology evaluating the impact of major process failures from environmental, social, and economic perspectives. The asset level consequence considers the main functionalities of each process. Assets within the influent pump station were scored exclusively on how they support the main functionality of the pump station. The multiplication of process level and asset level scores resulted in the overall COF score for each asset.

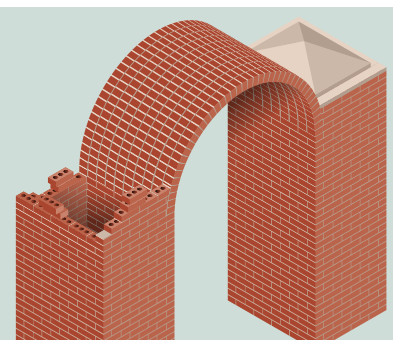
The Hazen team assembled the risk assessment results and visualized them in various formats, including risk matrices categorizing assets based on their level of risk by count and replacement values. Hazen then created an intuitive map to visualize the risk exposure of each major process component based on the analysis of POF and COF for 2,300 assets. The results indicated 15 assets are considered high risk and have a total replacement cost of about $1 million, or roughly 1% of the total valuation of the WWTP. The risk assessment results helped the District prioritize annual investments and focus first on rehabilitation or replacement of critical path assets.

The Journey from Data Poor to Knowledge Rich

INFORMATION ⟶ INSIGHTS ⟶ DECISIONS ⟶ ACTIONS







Data Poor

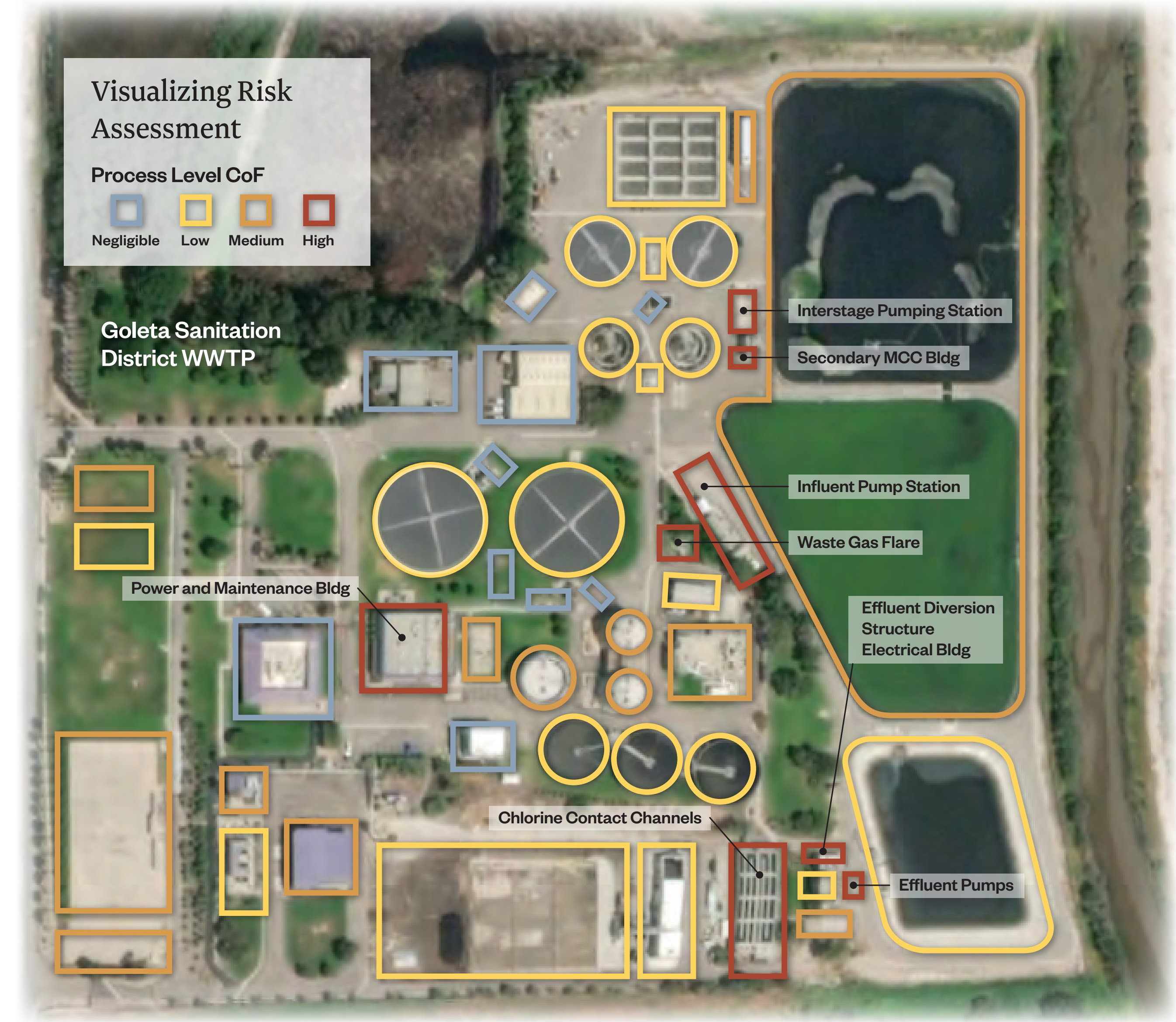
- Run to failure
- Reactive, emergencies/lost time, failed permits/fines

Data Rich

- Know what we own, the value of what we own, which assets are critical to sustained performance, what we need for future renewal
- Asset inventory provides the foundation for improved CMMS

Knowledge Rich

- Dashboards that provide information at a glance to make timely, data-driven decisions
- Communicate with stakeholders (Board, Public, Staff) using transparent, consistent, data-backed methodology



A map of all the assets within the GSD wastewater treatment plant visualized the business risk exposure scores calculated based on probability of failure and consequence of failure. Each asset—for example, the influent pump station—is color coded by its level of risk and cost of replacement. This visualization served as an easy-to-understand guide for the District to prioritize its budget and replace or rehabilitate the highest risk assets first.

Asset Management Data for Capital Improvement

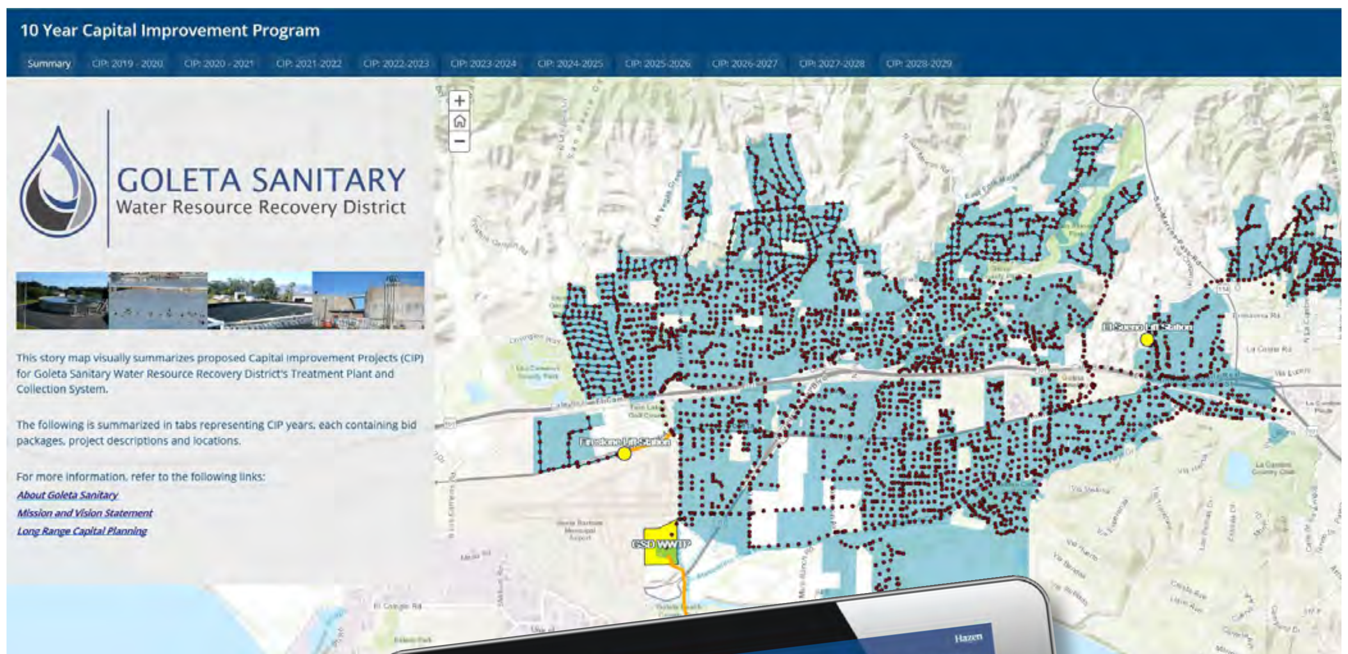
The asset management processes, practices, and tools used in the pilot project were eventually expanded to include the entire wastewater treatment plant, collection system, fleet vehicles, and ocean outfall. Hazen worked with GSD to identify projects from the asset priority list using a business case evaluation (BCE) tool and combined them into manageable capital improvement bid packages that could be designed and bid within a 10-year timeframe. All the data compiled through the AMP would be repurposed into a capital improvement program. Hazen developed data visualization dashboards, giving GSD staff intuitive navigation between the asset management and capital improvement programs. Hazen also developed a GIS-based Story Map for the District's website, providing the Board of Directors, customers and the general public a user-friendly visual tour through GSD's capital improvement program over the next decade.

Continuous Improvement

Empowered with the knowledge surfaced by the asset management program, GSD now enjoys the firmest possible footing from which to make financial decisions and project long-range funding needs, all while being transparent with the public and other stakeholders. Annual budgets can reflect an optimized asset renewal and replacement investment plan that reliably ensures a responsible level of service for decades to come.

As asset-level data inevitably changes over the coming years, the non-proprietary tools Hazen developed will enable GSD to adapt them as needed and maintain course for a sustainable future. Experience will continue to refine the facility-specific understanding of key concepts such as useful lives, failure modes, and criticality, enabling GSD to further hone estimates of risk and consequence and to continuously improve their return on infrastructure investment.

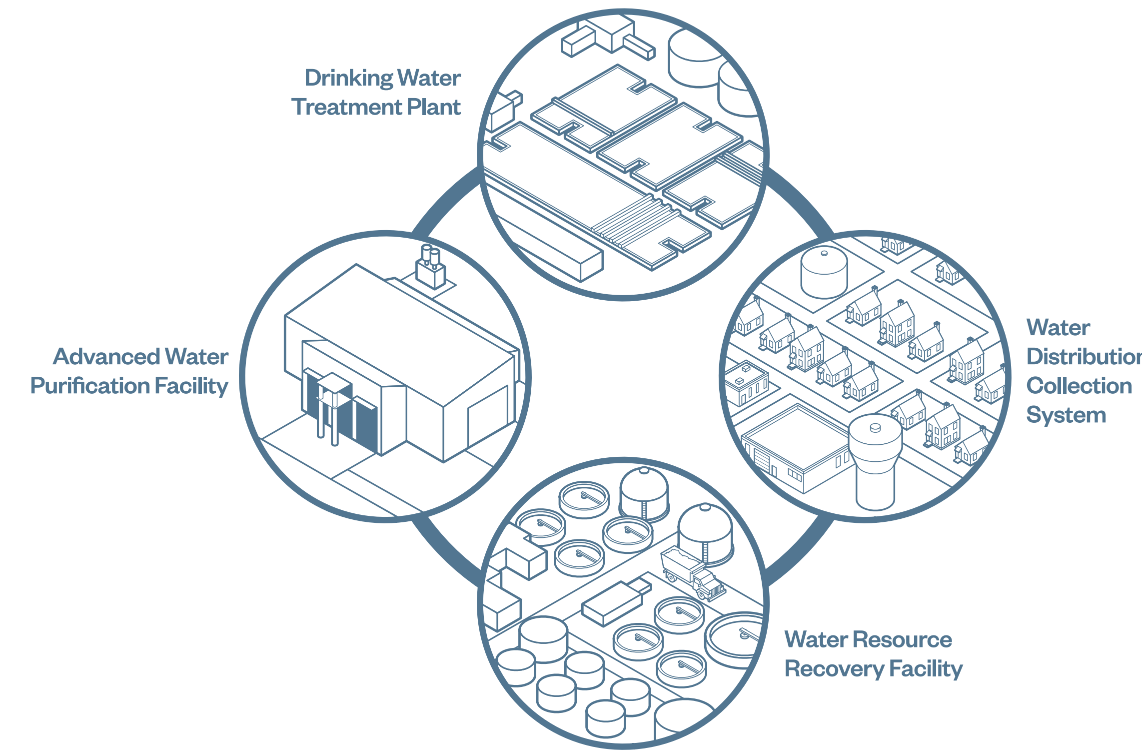
For more information, please contact Dawn Guendert at dguendert@hazenandsawyer.com



The wealth of data compiled through the asset management processes was repurposed into a capital improvement program that used projects from the asset priority list to create capital improvement bid packages that could be designed and bid within a 10-year timeframe. Hazen developed data visualization dashboards and a GIS-based Story Map, providing the Board of Directors, customers, and the general public a user-friendly visual tour through GSD's capital improvement program over the next decade.

AN INTEGRATED PERSPECTIVE OPTIMIZES ADVANCED WATER TREATMENT

Since our founding, the projects we've been most proud of have not just been our largest ones, but also some of our smallest ones. These are the projects where we've helped a client identify a small upstream adjustment that solves what initially looked like an expensive downstream problem.



Our industry continues to move in this direction more and more, integrating the planning approach to all of our water resources to capture a host of benefits. Part of this shift is from a focus on the biological treatment of wastewater prior to disposal to additional treatment that enables its reclamation for indirect and direct potable reuse.

Achieving an integrated approach to water resources management requires a comprehensive understanding of all its facets and the ways they are interrelated. The synergistic relationship between mainstream wastewater treatment—both liquids and solids—at water resource reclamation facilities (WRRF) and advanced wastewater treatment (AWT) must be understood to maintain peak performance, meet water quality requirements, and ensure safe and reliable water reuse.

Utilities are increasingly looking to invest in indirect (IPR) and direct (DPR) potable reuse to:

- *Diversify their water resources*
- *Prevent water scarcity due to drought and population growth*
- *Address increasingly stringent wastewater effluent standards and/or limited disposal opportunities*
- *Replenish groundwater resources to prevent saltwater intrusion and/or ground subsidence*

AWT OPTIONS AND BEST PRACTICES – PAGES 8-9 | AWT IMPACTS – PAGES 10-11

AWT Options and Best Practices

Generally, AWT follows mainstream treatment processes to remove additional suspended solids, organics, nutrients, pathogens, and trace organics compounds. There are two common approaches for AWT: reverse osmosis—or membrane-based—and an ozone and activated carbon approach (carbon-based).

Each approach to potable reuse comes with its own set of challenges to both the mainstream process and AWT and requires unique solutions. We've found that maintaining a holistic view of the treatment process—starting with the WRRF influent itself—yields both capital and operating efficiencies, enabling utilities to maintain reliable service more cost-effectively.

Breaking Down the Two Kinds of AWT

	Membrane-based	Carbon-based
Configuration	Microfiltration -> Reverse Osmosis -> UV-AOP -> Stabilization -> Disinfection	Floc/Sed -> Ozone -> Biofiltration (BAF) -> GAC -> UV -> Disinfection
Advantages	• Standard treatment in potable reuse • Several successful full-scale implementations • Well accepted by regulators for IPR/DPR • Good removal of TDS and majority of chemical contaminants through RO process.	• More energy efficient than membrane-based • Eliminates need to manage highly concentrated brine reject streams • Equally protective of public health through multi-barrier approach
Disadvantages	• Energy intensive • Disposal of concentrated brine challenging, especially for inland communities	• GAC requires regeneration • Ozone/BAF does not remove TDS • Higher levels of TOC

Headworks Analysis Charts a Course for Success

Source identification is a critical element of a Pretreatment Program to help eliminate, control, or manage pollutants that may impact public health or treatment performance via managerial and operational barriers. Conducting a headworks analysis to identify the load contribution and distribution of contaminants is critical in determining an optimal approach. Non-traditional approaches to developing headworks analyses are particularly useful for establishing local limits for pollutants that do not have water quality standards or inhibition thresholds available to establish a maximum allowable headworks load. For example, a headworks analysis conducted at a mid-Atlantic wastewater treatment facility quantified the non-biodegradable fraction of dissolved organic nitrogen (nbDON) from industrial inputs, combined WWTF influent, and combined WWTF effluent. The resulting data has allowed the facility to compare the relative influent nbDON loads to the WWTF to assess the viability of nbDON load management via the county's pretreatment program as a holistic approach to nutrient management.

For both membrane- and carbon-based AWT, headworks analysis can help to identify constituents that are over the AWT treatment goals and identify major contributors of challenging contaminants that interfere with AWT performance. Source identification is an initial step in developing an effective Source Control Program to reduce the impact of constituents that interfere with mainstream treatment and/or are not removed by mainstream treatment that ultimately are introduced to the AWT.

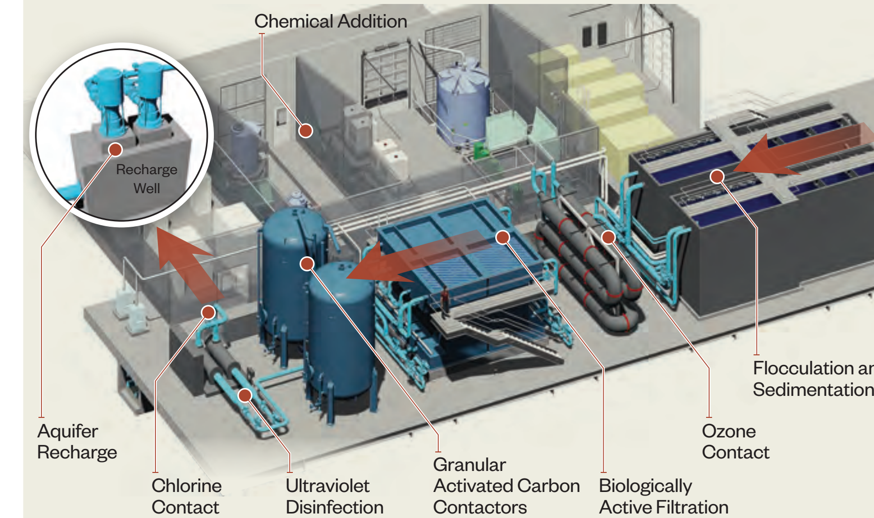
For more information, please contact Mary Sadler at msadler@hazenandsawyer.com

Hazard Analysis and Critical Control Point (HACCP) Methodology Ensures Public Safety

A carbon-based AWT program, the Hampton Roads Sanitation District (HRSD) Sustainable Water Initiative for Tomorrow (SWIFT) Program employs HACCP methodology to ensure public safety and treatment performance. In May 2018, HRSD completed construction and began operation of the SWIFT Research Center; a 1-mgd advanced water treatment and research facility designed by Hazen. Hazen and HRSD established a foundation for the operation and maintenance training with the SWIFT Research Center. This approach utilized Water Research Foundation guidelines developed by Hazen for reuse facilities, built around the HACCP framework. The HACCP methodology was used to identify, manage, and provide real-time validation of multiple treatment barriers along the treatment train installed to protect public health. Establishing critical control points in the treatment process enables response procedures to minimize the impact of poor SWIFT influent water quality due to suboptimal treatment performance at the mainstream facility.

SWIFT Advanced Water Treatment Process

Highly treated water from the Nansemond Treatment Plant is pumped to the Research Center's advanced treatment facility where it undergoes an 8-step process to prepare the water for recharge of the aquifer.



Following the success of the SWIFT Research Center, Hazen (and a partner firm) now provide program management services for the full-scale implementation of a planned 100 mgd of groundwater recharge to realize multiple environmental benefits, including reduction of nutrients discharged to the Chesapeake Bay and replenishment of the receiving aquifer. One focus of the program is developing optimal residuals management strategies for metal salt return sludge from the flocculation/sedimentation process and backwash flows from the (BAF) and (GAC) processes to minimize potential upstream hydraulic and solids impacts on the mainstream process.

For more information, please contact Dwayne Amos, or Troy Walker at damos@hazenandsawyer.com twalker@hazenandsawyer.com

Reliable Downstream Communication Protects AWT

Membrane-based AWT facilities often employ the use of chloramine to minimize biological fouling and support the lifespan and performance of RO membranes. Upstream of the facility, ammonia is dosed if it is not sufficiently present in the effluent. At one facility we are supporting, effluent is dosed with ammonia based on a ratio controller from a residual chlorine analyzer. The wastewater treatment plant doses chlorine for final plant disinfection. If the influent chlorine and ammonia concentrations are outside of the controller's capability, oxidation of the membranes may occur.

Achieving the target chlorine-to -ammonia ratio for membrane protection relies on consistent upstream wastewater treatment such that the final chlorine level from the plant is within a consistent band. In the event of a process upset, only clear communication pathways between the upstream and downstream operators and known triggers for communication protect the membrane system. As potable reuse grows, the development of robust and reliable operational interface protocols across all operational entities (e.g., wastewater, advanced wastewater treatment, drinking water) will become even more critical to assure operational success.

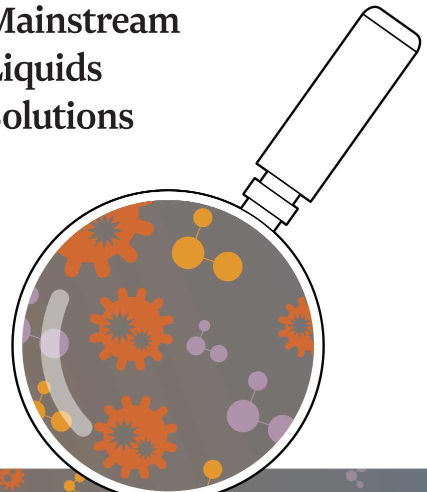
For more information, please contact Troy Walker at twalker@hazenandsawyer.com

AWT Impacts

For utilities considering implementation of AWT for potable reuse, understanding the synergistic relationship between biological wastewater treatment—both liquids and solids—and AWT at water resource reclamation facilities can help inform the design, modification, and operation of these facilities to meet the water quality requirements necessary to ensure the safe reuse of water.

Contaminants: *Microbial* *Chemical (organic)* *Chemical (inorganic)*

Mainstream Liquids Solutions

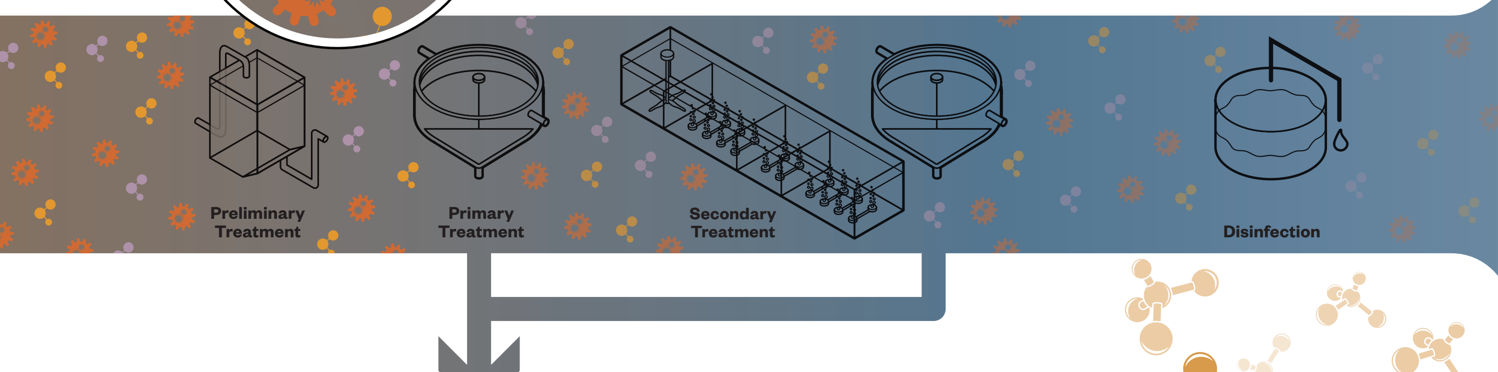


Use source control programs to monitor Contaminants of Concern (COC)

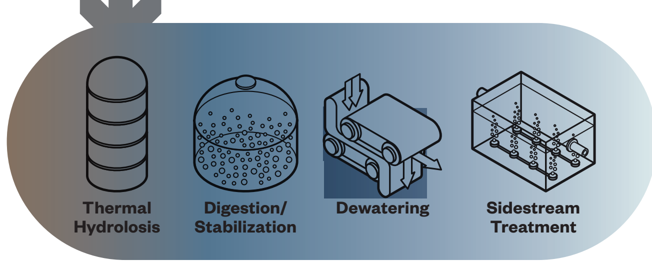
Develop source control programs to monitor and control influent contaminants of concern (1,4-dioxane, inhibitory compounds, rCOD, NDMA, TDS). If left uncontrolled, influent COC can reduce DOC removal, increase DBP formation, reduce UVT and UV effectiveness, increase GAC regeneration, and increase RO fouling.

Monitor chlorine to protect AWT membranes

Chlorine and other oxidants can damage RO membranes, reducing asset life and resulting in water quality non-compliances. Online monitoring of chlorine and ORP along with development of operating procedures and operator training is critical for membrane protection strategies. For example, ratio-controlled ammonia addition (or monitoring if ammonia is already present) to ensure chlorine is combined as more membrane favorable chloramine.



Mainstream Solids Solutions

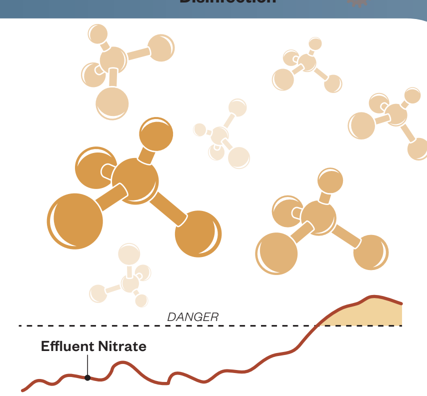


Minimize chemical carryover

Optimize chemical use and storage/neutralization capacity in solids treatment to control return flows and minimize chemical carryover into the mainstream process.

Use sidestream treatment to remove organics

Utilize advanced sidestream treatment to remove the nutrients and colored/refractory organics produced by thermal hydrolysis and mesophilic anaerobic digestion. An increase in these contaminants can adversely impact advanced water treatment performance and affect water quality compliance.



Anticipate secondary treatment issues

For example, using sensors to anticipate potential secondary process sub-optimal performance and using control logic to switch to flow-paced or dissolved oxygen control modes of biological treatment. Maintaining consistent secondary effluent quality protects the performance of advanced treatment processes. This can also result in water quality non-compliance at the AWT if the contaminant is not targeted by one of the treatment barriers.

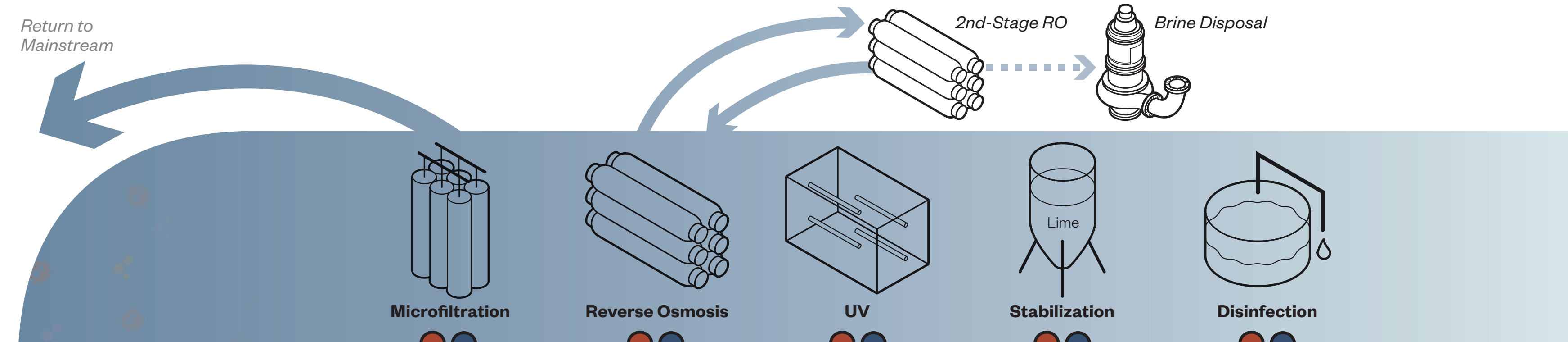
RO Solutions

Neutralize chemicals before returning to mainstream

Design clean-in-place chemical neutralization, engineered storage, and metered flow return to reduce peak return loads that could cause process upset (COD loading from citric acid, pH impacts, orthophosphate complexation).

Monitor influent water and reduce salinity

Influent water quality monitoring and targeted membrane design can manage fluctuating feed salinity (often due to seawater ingress) or manage changes over time from water conservation and drought (slowly rising TDS). Selection of appropriately targeted membrane rejection, options for altering recovery and reviewing staged RO design can provide flexibility to optimize operating pressures and operational and control complexity while maintaining water quality targets.



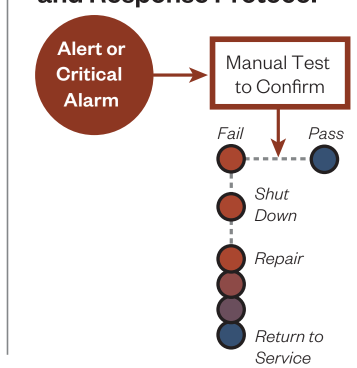
Risk Register For Contaminants

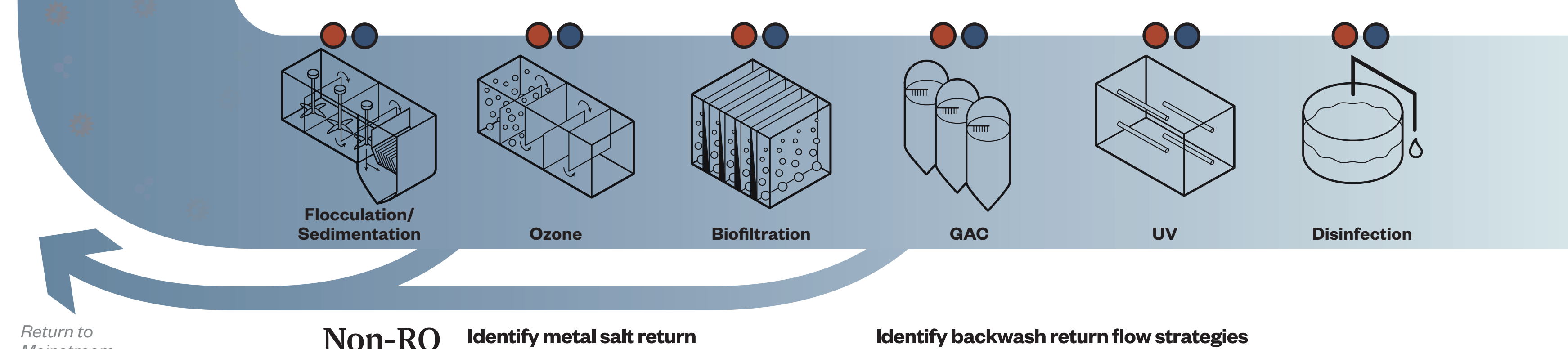
	Inherent Risk		Risk-Mitigation Treatment	Post-Treatment Risk	
	Likelihood	Risk	Treatment Barriers	Likelihood	Risk
	Almost Certain	Very High	MF, RO, UV/AOP, Cl2	Rare	Low
	Almost Certain	Very High	RO, UV/AOP, Cl2	Rare	Low
	Unlikely	Very High	N-removal, RO, Cl2	Rare	Low

Ensuring HACCP Safety Protocols

Hazen employs the **Hazard Analysis and Critical Control Point** methodology to identify water quality hazards to human health and ensure their effective removal. Hazardous events and baseline conditions are used to confirm that the proposed process can manage public health risks.

Sample Operations and Response Protocol





Non-RO Solutions

Identify metal salt return sludge strategies

Metal salt return sludge strategies, including engineered storage, separate solids management, and multiple return points can minimize solids impacts to the mainstream process. Metal salts in return sludge can consume alkalinity, complex with soluble phosphorous, increase inert mass in digesters, and increase sulfate loads to the anaerobic process.

Identify backwash return flow strategies

Biofiltration/granular activated carbon backwash return flow strategies, including engineered storage, separate solids management, and multiple return points minimize solids and hydraulic impacts to the mainstream process. Backwash flows can induce peak flows through clarifiers and biological processes—compromising performance, shifting the pathogenic load, and reducing disinfection efficacy.

A Model of Lasting Value

As part of New York City's effort to upgrade and maintain its vast water supply infrastructure, Hazen and Sawyer is leading planning, design, and construction of a new low-level outlet for Schoharie Reservoir, whose 17 billion gallons of storage provides approximately 15% of the City's supply.

The project required rigorous coordination between top experts in water resources management and water infrastructure facilities design, harnessing their modeling experience, tools, and understanding to establish design criteria, identify ideal design solutions, and deliver a project that will stand the test of time.

Project Challenges

The primary design objectives for the low-level outlet (LLO) were to provide a means to lower the Schoharie Reservoir's water level in response to a dam safety emergency, and to maintain the reservoir at a low water level during inflow conditions that occur at various times during a given year. Although these design objectives appear straightforward, many challenges had to be overcome, including establishing the appropriate design criteria as regulatory guidance was limited, the presence of deep rock stability anchors that limited the ability to go below or through the concrete dam, and the requirement for the reservoir to remain in service during construction. To address this complexity, Hazen employed modeling tools that drove and informed both the planning and detailed design phases. Innovative modeling was used to establish the outlet capacity, tunnel diameter, and other key criteria used to define the LLO's ability to release the required flows from the reservoir. As the design progressed, additional modeling was used to inform and optimize the final design.

The project's most challenging features include:

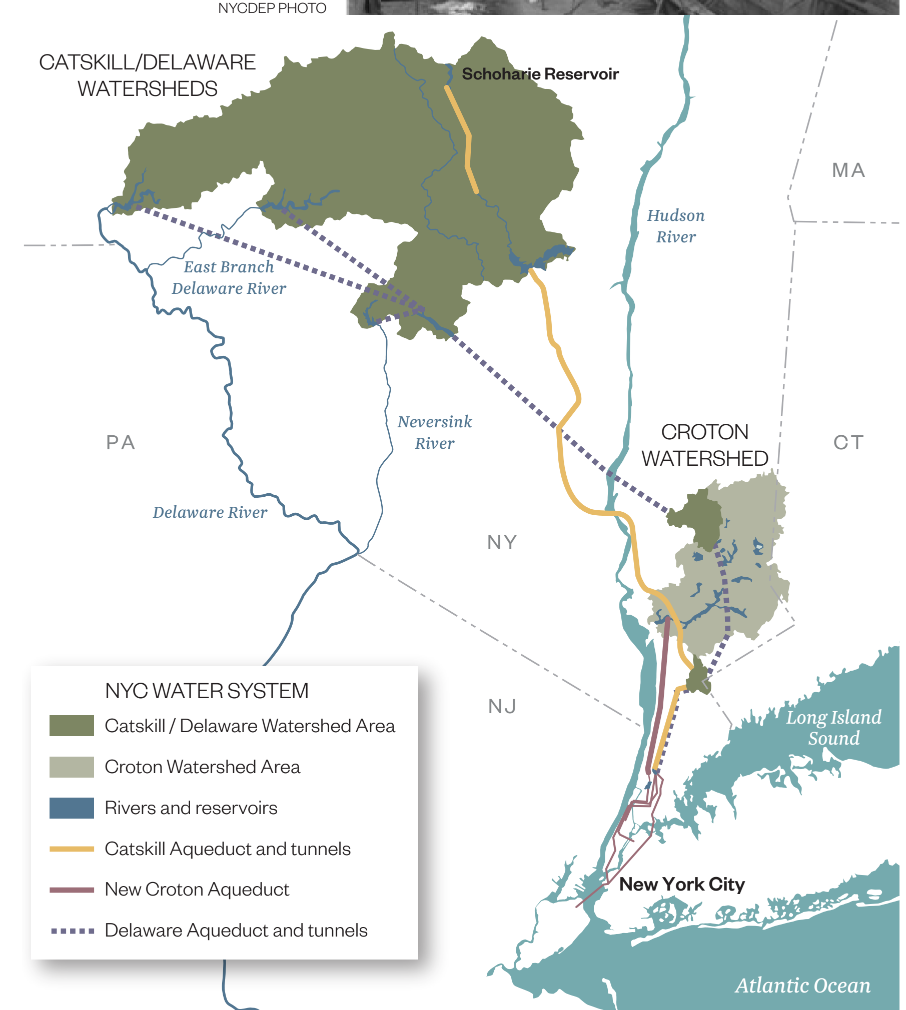
- *New intake at the bottom of 150-foot-deep reservoir.*
- *2,140 linear feet of new 9-foot tunnel constructed through hard rock and mixed face conditions.*
- *185-foot deep gate shaft, housing two 9' x 9' gates.*
- *A valve chamber housing control and isolation valves and flow transition facilities.*

Project Background

Approximately 90 percent of NYC's water supply is delivered from upstate reservoirs via gravity. Dams, LLOs, and other release methods largely control levels and flow. Like many other communities, NYC understands the need to continually reassess its reservoirs to provide a safe and reliable water supply. The Gilboa Dam impounds the Schoharie Reservoir and is undergoing a $400M improvement program to ensure reliable operation for generations to come. As part of that program, a new Low-Level Outlet (LLO) was required to release water into Schoharie Creek.

Gilboa Dam was completed in 1926, and the release works were originally constructed in dry conditions. It includes a 700-foot-long earth embankment with a concrete core wall, and a 1,324-foot-long cyclopean concrete spillway with a maximum height of 160 feet.

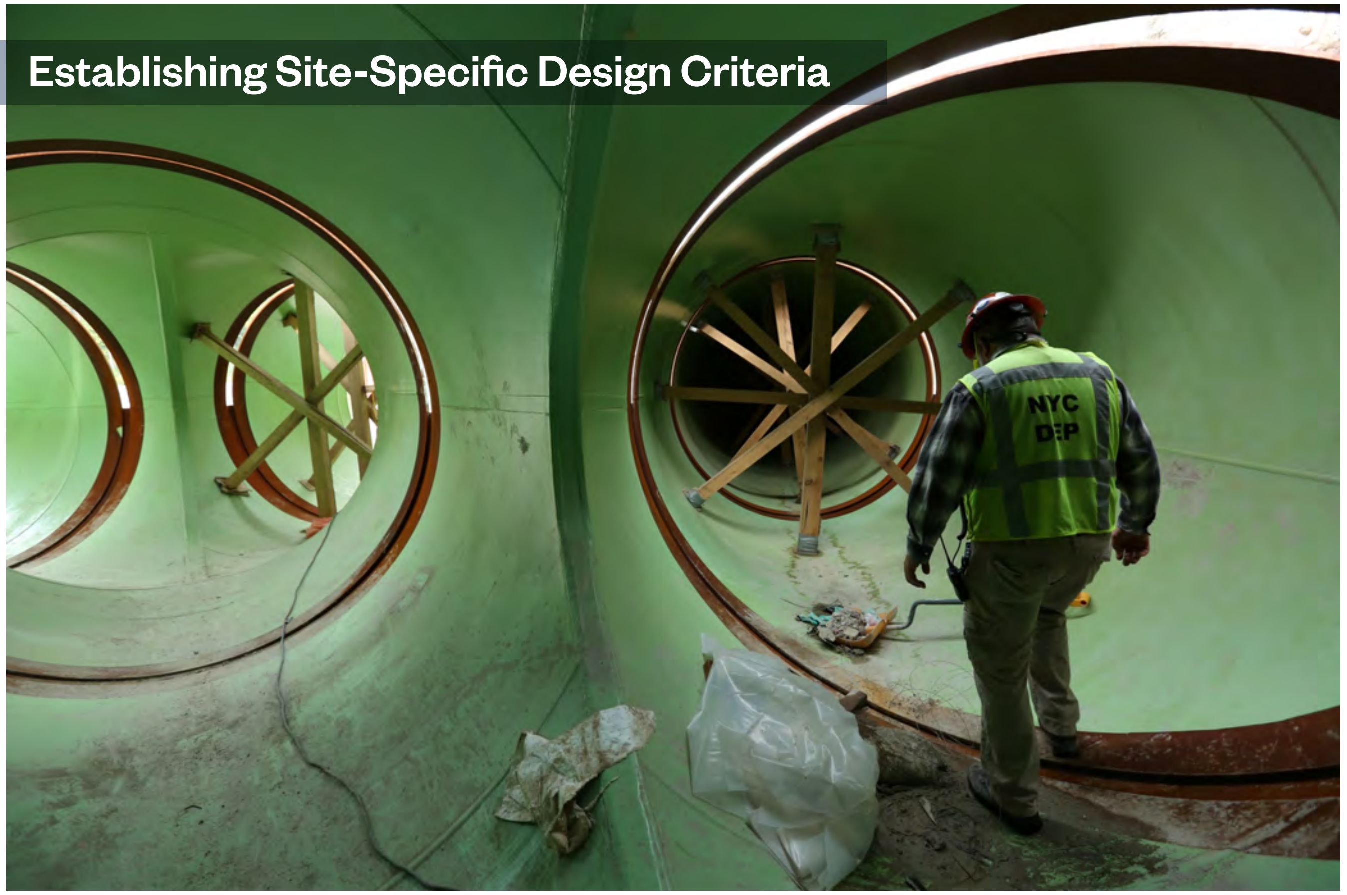
NYCDEP PHOTO



The release will give NYCDEP the ability to release water downstream of the reservoir into Schoharie Creek to facilitate dam maintenance, respond to potential emergencies, mitigate flood risk for downstream communities, and enhance downstream habitat for fish and wildlife.

Hazen and Sawyer (in a joint venture) has provided engineering services for all aspects of the improvement program including stability anchoring of the dam and subsequent rehabilitation of the spillway, site stability improvements and rehabilitation of the Shandaken Tunnel Intake Chamber. The LLO represents a $142M water resources project, scheduled to be completed in 2020, that required significant modeling expertise to inform innovative design work, producing a successful solution to an unconventional situation.

Establishing Site-Specific Design Criteria



DEP staff inspecting the tunnel bifurcation where the Land Leg enters the Valve Chamber (see diagram next page). NYCDEP PHOTO

The regulatory framework consisted of the requirements and agency guidelines that influence the drawdown procedures for the Schoharie Reservoir.New York State Department of Environmental Conservation (NYSDEC) has regulatory authority over the planned reconstruction improvements at Gilboa Dam.

Literature review revealed that reservoir drawdown criteria found in the NYSDEC guidelines would require much higher evacuation rates than those in other federal design standards and guidelines.

Hazen demonstrated that DEC's rate could create potential failure of slopes along the reservoir perimeter. As such, it was concluded that the more reasonable drawdown guideline for Gilboa Dam would be one similar to that used by the US Army Corps of Engineers (USACE), and the US Bureau of Reclamation (USBR), with appropriate adjustments for the site-specific characteristics of Gilboa Dam and the Schoharie Reservoir.

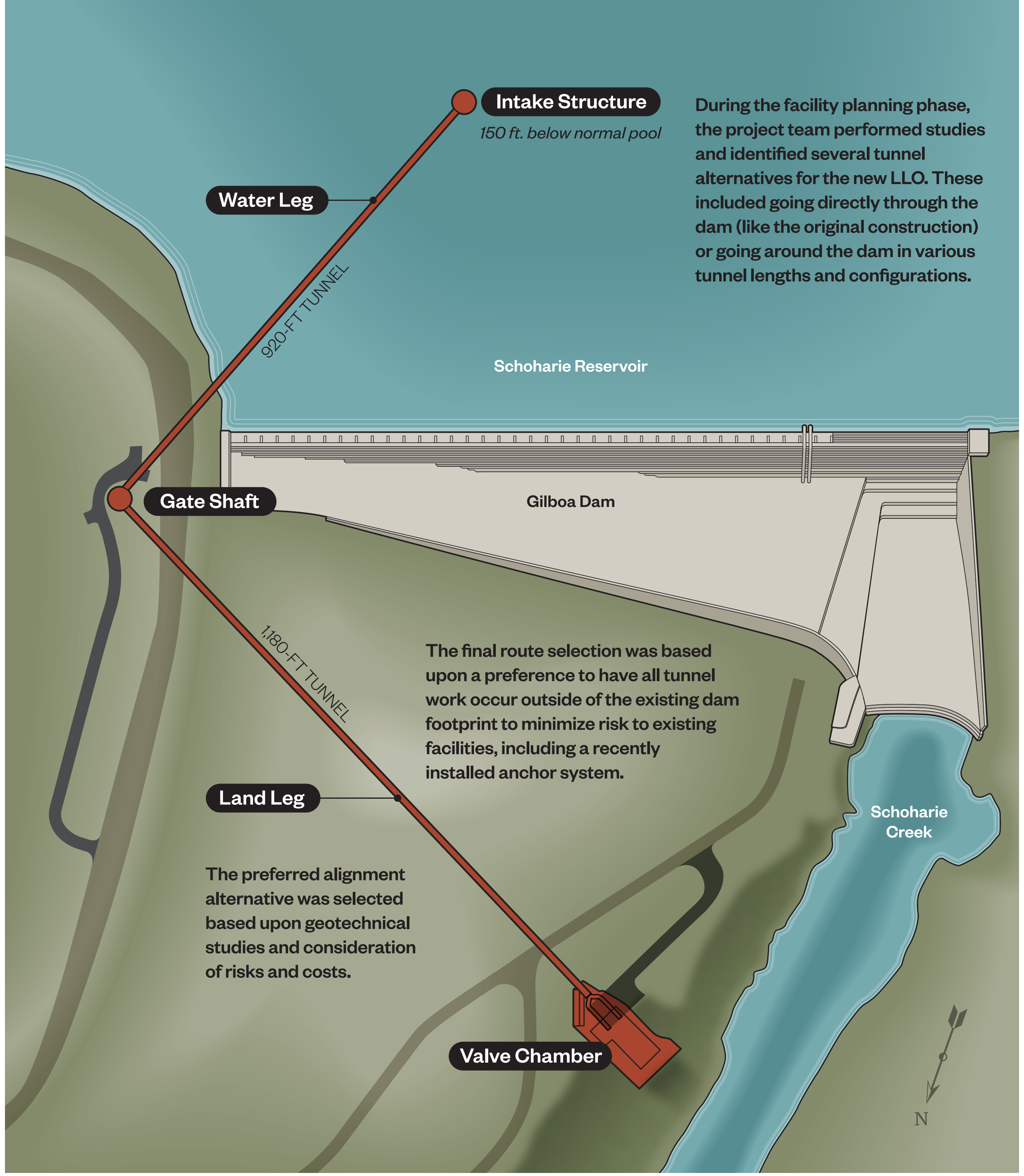
Operational and design criteria recommended and adopted:

- *Capacity to evacuate 90% of the reservoir storage volume under average inflow conditions in four months or less.*
- *Capacity to maintain the reservoir at a water level which represents 10 percent of the original storage volume.*
- *Maximum daily drawdown rates of 1 to 2 feet per day unless higher rates are deemed to be required by extreme emergencies.*

Our approach to establishing the appropriate design criteria was so successful that it has since been utilized by the City when evaluating other reservoirs in the system.

Developing Tunnel Alternatives

Hazen's water resources management expertise and innovative use of modeling tools helped identify, develop, and evaluate alternatives for the new LLO that kept the reservoir in service and did not go below nor through the dam.



During the facility planning phase, the project team performed studies and identified several tunnel alternatives for the new LLO. These included going directly through the dam (like the original construction) or going around the dam in various tunnel lengths and configurations.

The final route selection was based upon a preference to have all tunnel work occur outside of the existing dam footprint to minimize risk to existing facilities, including a recently installed anchor system.

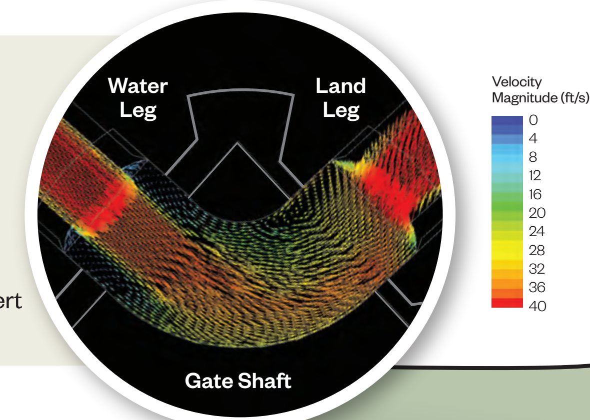
The preferred alignment alternative was selected based upon geotechnical studies and consideration of risks and costs.

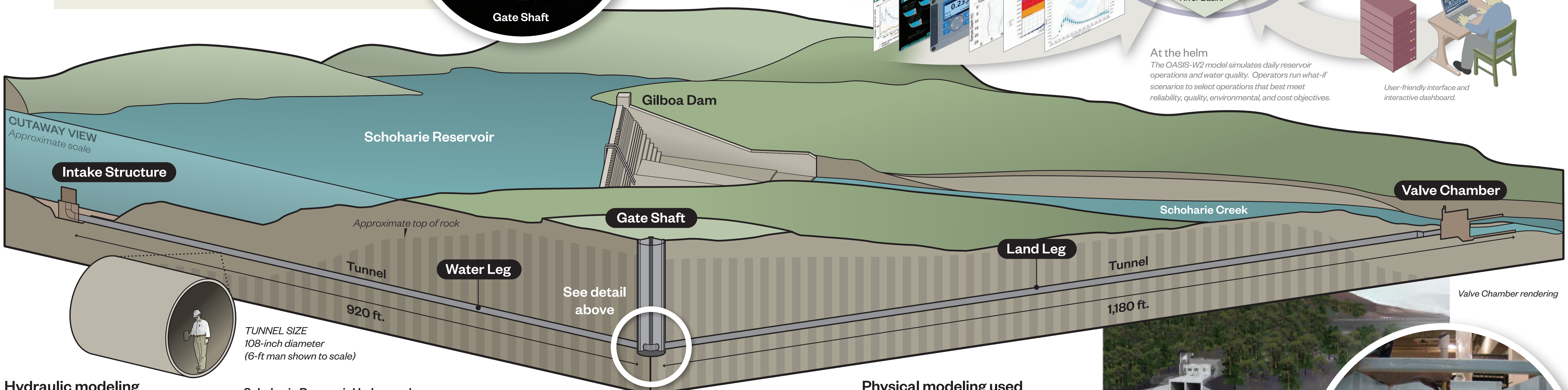
Innovative Modeling Use

Hazen used a combination of reservoir system modeling, hydraulic modeling, computational fluid dynamics modeling, and a scaled physical model of the discharge to Schoharie Creek to establish design criteria and define the basis of design.

Computerized Fluid Dynamics (CFD) and surge conditions in the new tunnel and shaft

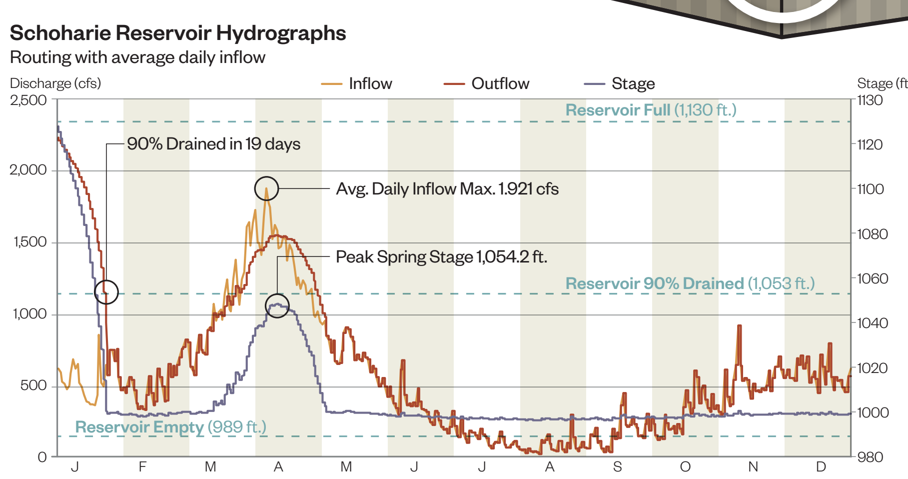
Extensive peer reviews resulted in concerns for the introduction of air into the Land Leg tunnel during operation at high flows which could result in water hammer or a shock wave. Simulations using KYPIPE's surge program were conducted to evaluate this worst-case condition. Results of the CFD modeling led to a modification of the gate shaft invert and the creation of a smooth radius within the gate shaft.





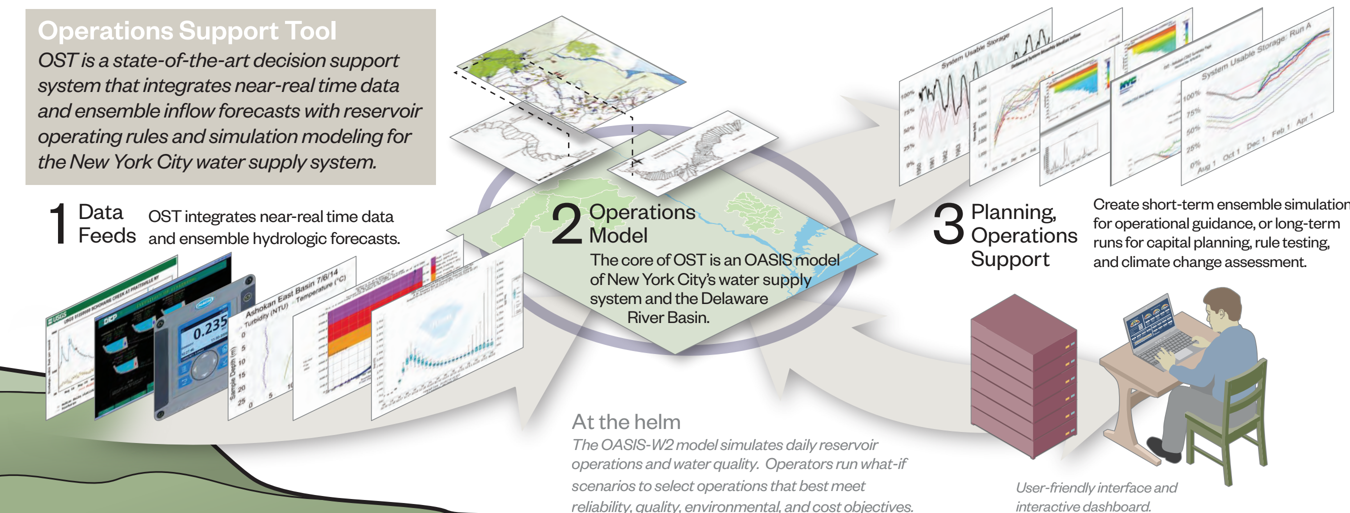
Hydraulic modeling determines tunnel size and other design criteria

To establish the capacity needs of the new LLO, a reservoir routing analysis was performed utilizing the mean of the average daily inflows, the stage-storage relationships for Schoharie Reservoir, and the applicable stage-storage relationship for the new outlet. The hydraulic profiles resulted in an optimized tunnel diameter of 108-inches.



Hydraulic modeling to evaluate varying operating conditions related to snowpack management and environmental conservation releases

The team used OST to define the operating criteria to manage reservoir levels for snowpack offset management and for environmental conservation low flow releases to support downstream habitat. Although the LLO was designed to be able to release up to 2,400 cfs to lower the reservoir in an emergency condition, the operation modeling defined the sizing and capacity of the LLO's smaller release valves needed to achieve the much more regular seasonal releases.



Physical modeling used to simulate flow velocity into Schoharie Creek

The flow transition from the LLO's release facilities to Schoharie Creek presented one of the design's most unique challenges. The potential energy at the end of the release works exceeded 25,000 HP with flow velocities under maximum release conditions in excess of 35 feet per second. Schoharie Creek is totally dry during certain periods of the year, exacerbating the challenge for transition of LLO flows to the creek without erosion.

Valve Chamber rendering

Utah State University developed a physical hydraulic model of the proposed release works for the LLO and the approach piping.

During modeling, the water flow rate, air flow rate, upstream pipe pressure, valve opening, and velocities in the downstream channel were measured and recorded. The physical model findings were used in the detailed design to ensure acceptable velocity limits under any of the creek's low flow conditions.

Utah State University physical model

Microtunnel Boring Machine with Underwater Recovery Project—One of Largest in United States

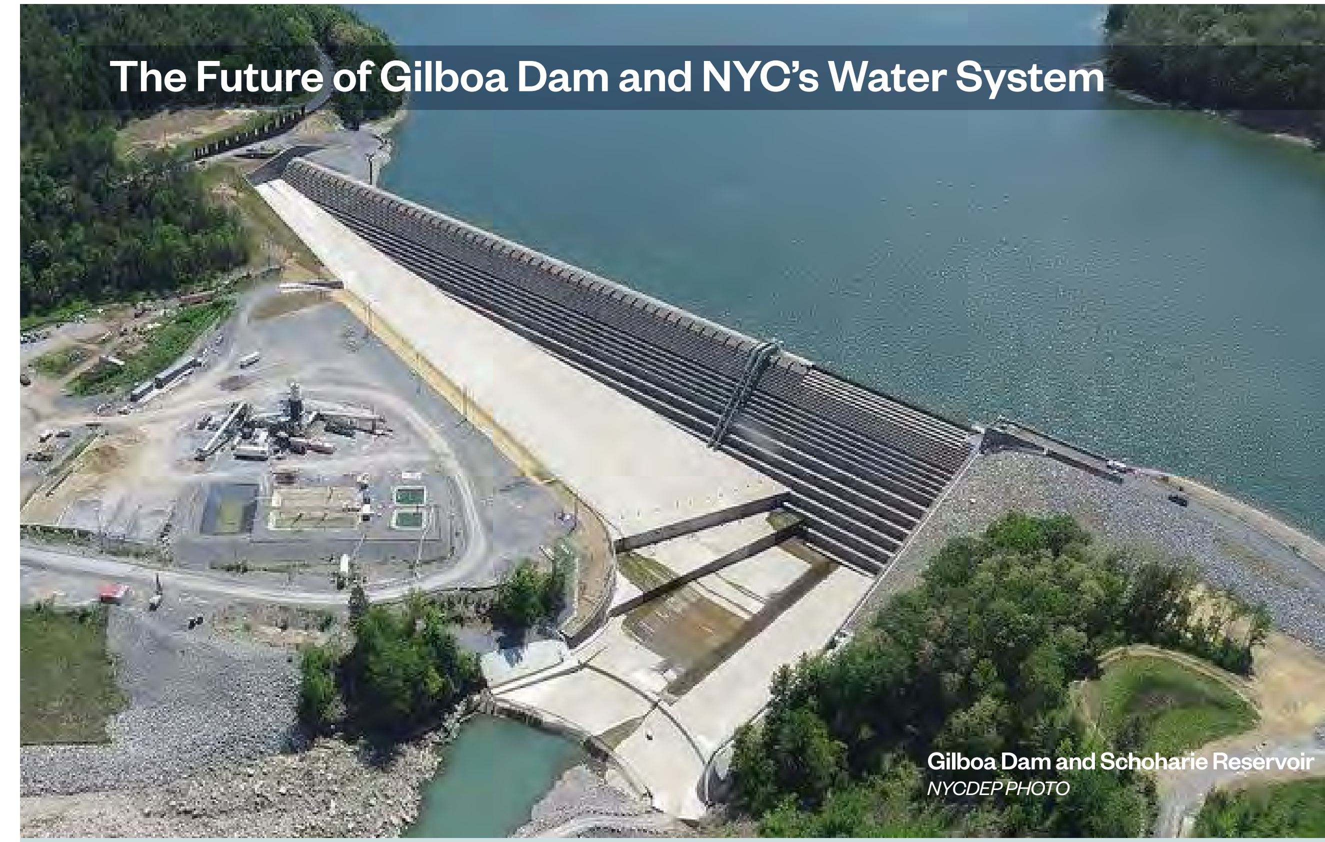
Hazen's modeling was used to determine design criteria, to determine an alternative tunnel route to create the LLO, and then to create designs that met the criteria. The final route, consisting of a "Water Leg" and a "Land Leg" almost 200 feet underground, had to be constructed all while the reservoir was still in use. An unmanned, 9.5-foot Microtunnel Boring Machine (MTBM) was sent down a 185-foot shaft to build those "legs" and connect the bottom of Schoharie Reservoir to the new LLO. Once finished, it will be pulled from its place underwater at the bottom of the reservoir and become one of the largest MTBM projects requiring "wet retrieval" ever accomplished.

MTBM breaks into future valve chamber
NYCDEP PHOTO

Tunnel segment
NYCDEP PHOTO

MTBM lowered into shaft
NYCDEP PHOTO

The Future of Gilboa Dam and NYC's Water System



Gilboa Dam and Schoharie Reservoir
NYCDEP PHOTO

Gilboa's new LLO will control flow and energy dissipation from the Dam to downstream Schoharie Creek for up to 2,400 cubic feet of water per second—one and a half times the amount of drinking water used in NYC each day.

The LLO includes a new intake at the bottom of a 150-foot deep reservoir, 2,140 linear feet of a 9-foot-diameter tunnel located under the reservoir and around the existing dam, a deep gate shaft, and a new flow control valve chamber located at its downstream end. It is comprised of 1-3/8" thick steel pipe advanced through extremely hard rock (35,000 psi) as well as mixed face and soft ground conditions, at depths that exceed 175 feet. The gate shaft facilitates the tunnel construction and houses two 9' x 9' gates for tunnel dewatering and long-term maintenance. The flow control valve chamber houses fixed cone valves that control large releases, large bonneted knife gate valves for isolation, flow meters, and valves that provide a means for conservation releases.

The $142 Million construction is scheduled to be completed in 2020. Although one part of a larger program to strengthen Gilboa Dam, the LLO will provide the ability to facilitate the ongoing maintenance of Gilboa Dam, respond to potential emergencies, mitigate flood risk for downstream communities, and enhance the downstream habitat for fish and wildlife. The Gilboa LLO is a major design of new water resource facilities—integrating extensive water resources planning and innovative modeling expertise to maximize value and create unique solutions.

For more information, please contact Everette Knight at eknight@hazenandsawyer.com

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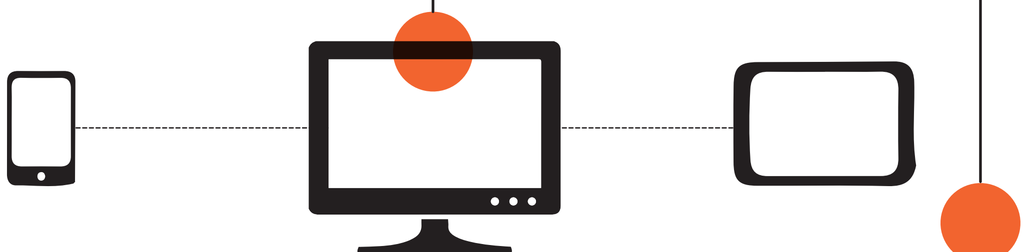

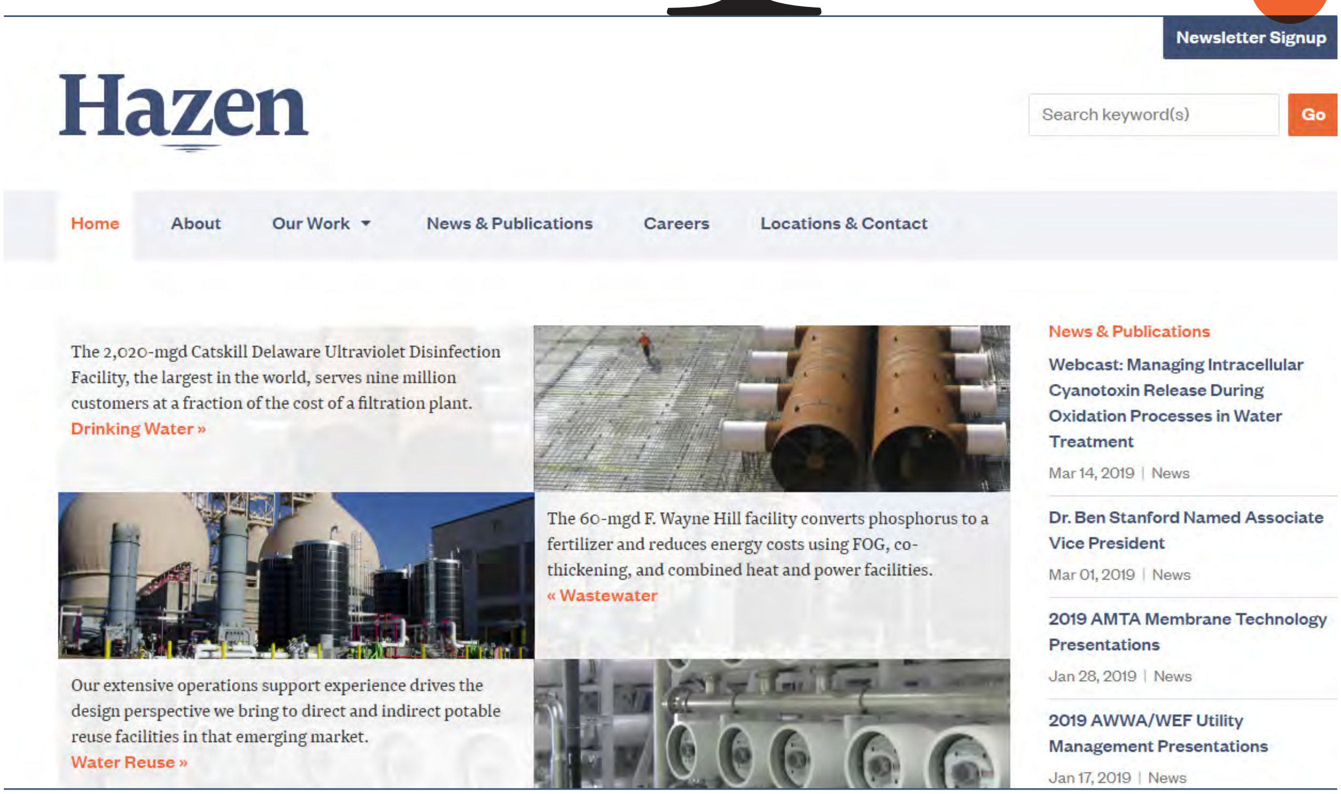

HORIZONS
water environment solutions

On the Cover:
A mountain wetland in spring.
–Photo by Sean Xu

Hazen