ARCADIS

Navigating Change Through Advanced Asset Management

Adjusting to a Paradigm Shift

A research collaboration with

bluefield RESEARCH

Table of Content

Utilities must reckon with a paradigm shift

In 2020, Arcadis and Bluefield Research published *Realizing the Value of Change with Advanced Asset Management* which examined the changing asset management landscape and how a framework that incorporates a people focus with advanced technology can address affordability, workforce and regulatory challenges. This paper also identified the limitations of traditional asset management, including the growing investment gap needed for new and improved infrastructure, steadily rising utility rates, loss of institutional knowledge through workforce retirements, and a regulatory movement for requirements on asset management.

An advanced asset management framework was proposed to address these limitations on traditional programs by utilizing asset management enablers such as applying advanced analytics and focusing on people as well as physical assets.

While these enablers remain valuable, much has changed since then: utilities have faced the repercussions of a global pandemic and its aftermath, increasingly extreme weather events have forced organizations to invest in preparedness and resilience against droughts, floods and other climate-related disasters, and a shifting policy environment has required utilities to prioritize environmental and social equity in their operations. Further, the current federal government administration has sought to address social, environmental and investment issues with a series of measures including expanded loan and grant funding programs, the creation of new EPA offices, and additional regulations for water quality protection. At the same time, historic and ongoing issues concerning the aging workforce and evolving financing schemes remain a key focus.

Key Events Impacting Asset Management Programs, 2020-2023

Date	Event	Asset Management Implications
March 2020	COVID-19 pandemic acknowledged internationally	• Major shift to remote working for entire utility workforce • Accelerated digitalization for asset management
February 13–17, 2021	Winter storm Uri	• Major freeze event impacting large water systems in Texas • Power outages, main breaks spike work orders in response
November 15, 2021	Infrastructure Investment & Jobs Act signed into law	• Increased funding available to address aging U.S. water and wastewater infrastructure
June 15, 2022	EPA releases drinking water lifetime health advisory levels for four PFAS compounds	• Focus on emerging contaminant management through testing • Remediation measures requiring additional investments • Longer term biosolids management challenges
August 4, 2022	*Lead and Copper Rule Revisions Service Line Inventory Guidance* released by EPA	• Acceleration of lead service line replacement planning within municipal investment plans
August 16, 2022	*Inflation Reduction Act* signed into law	• Measures to reduce inflation alleviate pressure on utility finances • Increased focus on energy transition, lower emitting power sources impacting municipal water systems to reduce carbon emissions by roughly 40 percent by 2030
August 29, 2022	Jackson, Mississippi Water Crisis	• Largest water treatment plant in Jackson, MS failed, leaving 160,000 people, along with hospitals, fire stations and schools, without safe drinking water • Highlighted need for equity in levels of service
September 24, 2022	EPA Office of Environmental Justice and External Civil Rights created	• Issues of environmental justice, civil rights laws in overburdened communities incorporated into municipal asset planning
December 2022–March 2023	Atmospheric river – California flooding	• Ongoing inundations challenge AM to plan for increasingly frequent stormwater events

Considered collectively, water and wastewater utilities, like it or not, are facing another paradigm shift in the way they plan, finance, staff and operate their assets to remain viable.

This is a tall order for highly siloed, risk-averse public system operators, however, there are tools available and an evolving set of best practices from which to embark on the journey from conventional to more advanced asset management. The good news is advanced asset management practices can address both old and new drivers and position utilities for success—in fact, many progressive utilities are already charting the course ahead.

Traditional drivers continue to challenge utilities

Aging infrastructure calls for action

The most recent ASCE report card, published in 2021, confirms the major need for water and wastewater asset renewal in the U.S., with both categories receiving failing grades of C minus and D plus, respectively. According to this report, the state of aging water/wastewater infrastructure has not improved since 2019, when Arcadis originally highlighted the need for advanced asset management in the water sector.

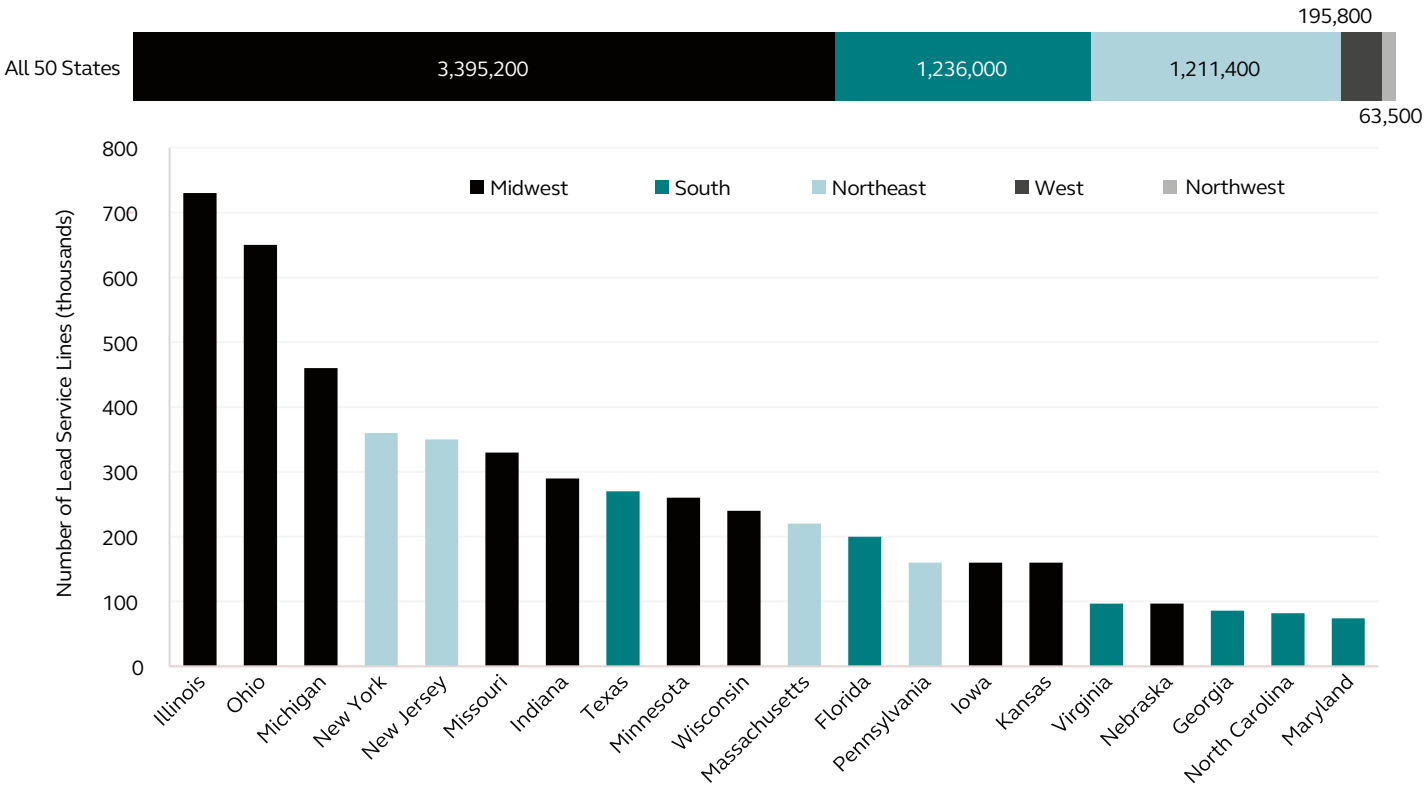
Additionally, the most recent EPA Drinking Water Infrastructure Needs Survey and Assessment, published in April 2023, found that the 20-year water investment needed was an estimated $625 billion. According to the report, 237,000 water line breaks occur each year in the U.S. At an estimated average cost of $10,000 for each repair, including pipe material, labor, traffic and business costs, these breaks cost the rate payers over $2 billion each year, meaning the need for more efficient maintenance of buried infrastructure is becoming paramount. The projected cost represents a 32% increase over the previous period, which creates a significant cost burden on utilities' operational budgets and cost to rate payers and the community.

In addition to water line breaks, this 32% increase includes new infrastructure replacement needs such as lead service lines (LSLs). Lead service lines, which are a primary source of lead in drinking water, are a strong indicator of the water sector's poor asset health, as many LSLs require partial or full replacements. A look across the top 20 states in terms of LSLs shows the

highest concentration in the Midwest, which has approximately 3.4 million lines across 12 states, with some stark geographic trends that will significantly increase the infrastructure needs in certain areas—it could cost billions of dollars to replace potentially millions of services, for example in regions such as the Midwest or East Coast:

- **Illinois faces a significant LSL replacement challenge.** While the AWWA survey estimates 730,000 LSLs in Illinois, a state survey of LSLs estimates that the number could be as low as 415,000 and as high as 1.92 million, highlighting a lack of accurate tracking. Of community water systems that serve more than 100,000 people, Chicago has the highest number of LSLs with over 120,000. In an extreme case, the town of Cicero, IL has 98% of its service lines made of lead.
- **While LSLs are highly concentrated in the Midwest, East Coast states also have high amounts.** Following behind Illinois, Ohio and Michigan have a combined 1.1 million LSLs in need of replacement. Missouri, Indiana and Wisconsin are also high on the list with 330,000, 290,000 and 240,000 LSLs, respectively. On the East Coast, New York and New Jersey have a combined 710,000 LSLs.

Estimate of Existing Lead Service Lines by Region



Source: American Water Works Association, Cornwell et al., Environmental Defense Fund, Bluefield Research

Complex regulatory drivers add pressure

As water and wastewater assets continue to deteriorate and age, the burden on utilities has become ever more complex as customers and stakeholders also demand higher levels of service. More traditional asset repair and replacement needs are now compounded by challenges such as lead service line replacement and PFAS mitigation, among many others, that are driving new regulations which will demand an extra layer of investment from the industry. At the same time, regulations driving the need for formal asset management frameworks are emerging slowly and remain relatively anecdotal. These dynamics mean that utilities can no longer focus solely on capital investment programs to address the level of service deficiencies but must also seek to maximize the capabilities of their existing aging infrastructure to manage the increase in operating cost as these assets age.

Institutional knowledge continues to leave the water sector

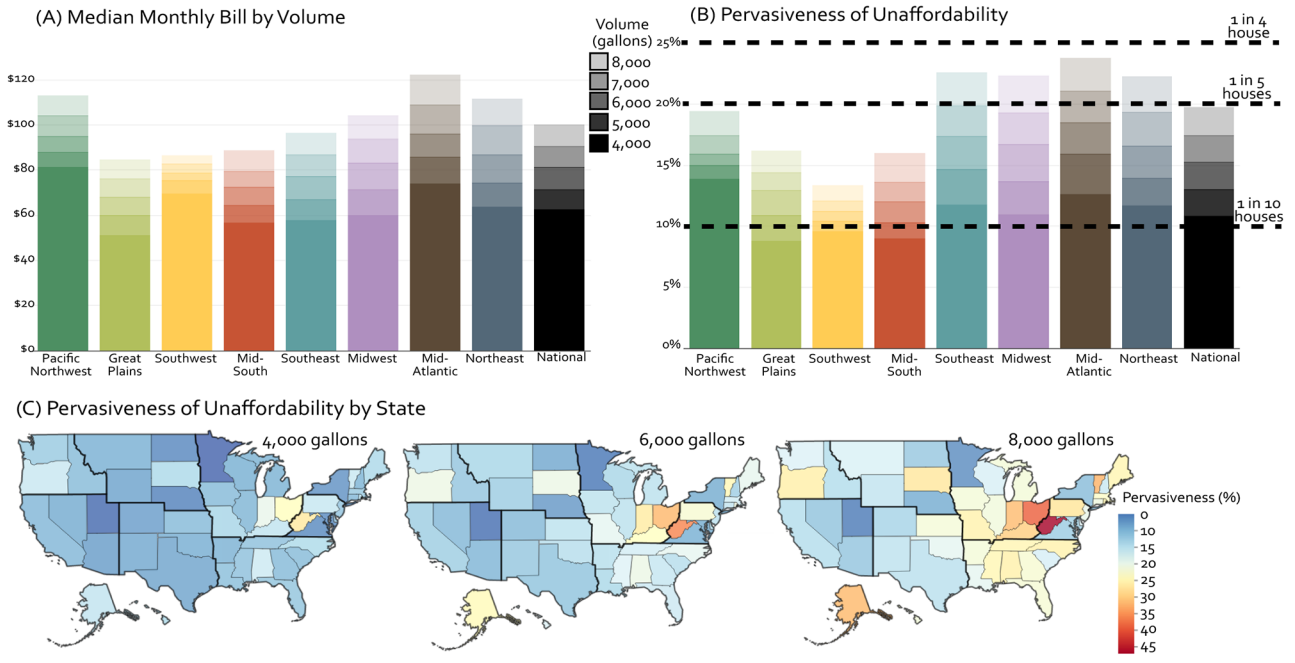
The long anticipated "silver tsunami" has arrived, creating an added challenge in the water sector. Retirement rates accelerated during the pandemic and many utilities did not have programs in place to retain the institutional knowledge of retiring experts, thus losing it in the process. Furthermore, a desire for increased wages driven by market dynamics has increased employee turnover and created chronic vacancy rates. Advanced asset management practices with a focus on standardization and automation are needed to operate systems with a smaller workforce.

Pandemic pressures further challenge affordability

While our first report highlighted affordability as a future trend for the water sector, it has grown beyond a prediction and is now a real challenge impacting significant segments of our society. Affordability challenges are further compounded by equity issues, as described later in this paper, and the need for an evolved approach to asset management is more pressing than ever as utilities struggle to maintain affordability against market forces that are driving up rates.

Affordable water service is unevenly distributed throughout the U.S., with larger systems in coastal states, for example, exhibiting higher costs to consumers. Roughly 10% of consumers' water service is not affordable in major cities, reflecting poverty rates as well as water tariff control challenges. The pandemic further complicated the tension between rates and affordability with spikes in unemployment, shifts in demand and shutoff moratoriums. Though pandemic-related restrictions have mostly ended, this has offered minimal reprieve with rising operational costs.

Affordability Overview by U.S. Region, Household Consumption



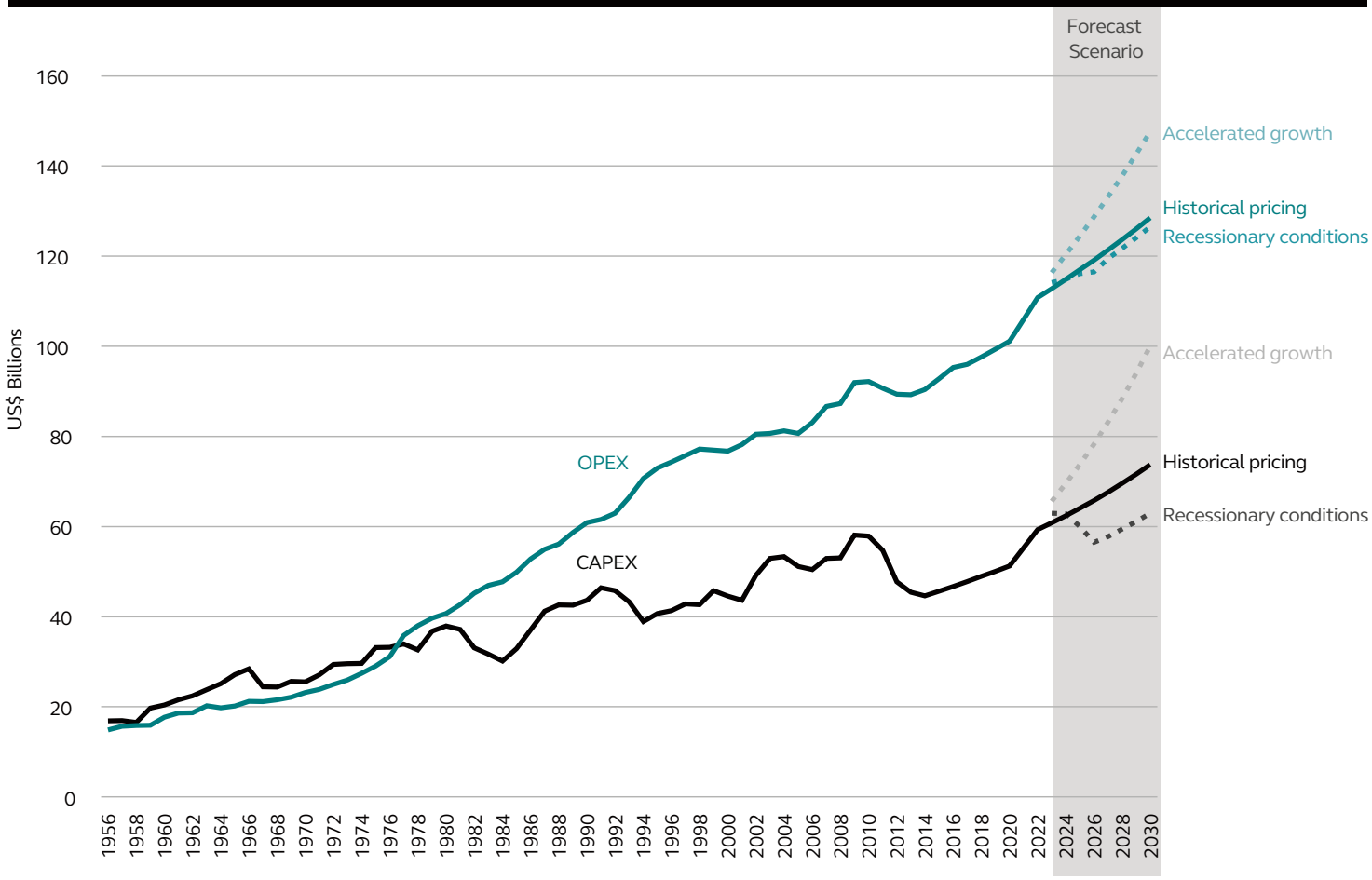
Source: Patterson LA, Bryson SA, Doyle MW (2023) Affordability of household water services across the United States. PLOS Water 2(5): e000012. https://journals.plos.org/water/article?id=10.1371/journal.pwat.0000123

OPEX continues to climb as CAPEX funding is limited for asset renewal

The OPEX and CAPEX gap is expected to continue expanding as asset renewal falls behind the pace needed to replace assets which are deficient or coming to the end of their useful life. This represents a significant cost burden on utilities' operational budgets and cost to rate payers and the community. Utilities' concerns about whether they can finance infrastructure upgrades are further compounded by the impact of recent events including supply chain issues and inflation. In a recent AWWA survey, when asked whether they were able to cover costs of service in the future, less than 15% of utilities stated they were fully able.

Utilities need to have a TOTEX perspective, which is a combination of CAPEX and OPEX used to assess the complete economic impact of an asset decision, regardless of expenditure classification.

Water & Wastewater CAPEX & OPEX Trends 1956-2030 U.S. Public Utilities



Source: Congressional Budget Office. Bluefield Research

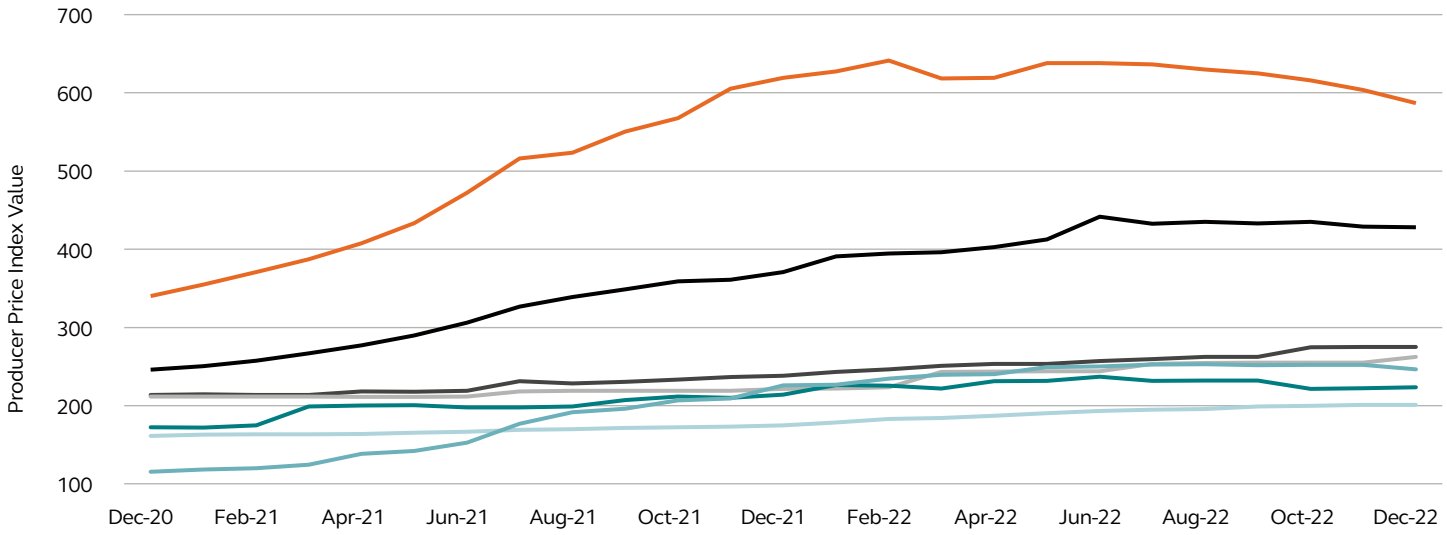
New drivers are changing the conversation around advanced asset management

Material prices are soaring

Supply chain constraints resulting from pandemic-related pressures have driven record inflation in material prices across the water sector, impacting CAPEX costs. For example, plastic and iron/steel pipe pricing increased by 134.3% and 93.6%, respectively, from September 2020 to September 2022. An analysis of historical price trends for key inputs shows prices returning to only 60-70% of the peak, rather than back to baseline, meaning material costs will continue to impact the sector for the foreseeable future.

Build America, Buy America legislation has also elevated concerns about U.S. supply chain capacity and pricing impacts, as America lacks the capability to produce the amount of material needed to support the sector's projects. As utilities are forced to buy American-made materials, prices continue to rise, and projects are delayed.

Material Price Index 2020-2022



Source: Federal Reserve of St. Louis, Bluefield Research

These shifts in costs trigger utilities to scrutinize contracts more rigorously as escalation clauses drive price increases. In response, Louisville's Metropolitan Sanitary District (MSD), for example, formed a cost estimating group that provides guidance on market conditions, material pricing and labor cost differences to guide its RFP design and bid evaluation. The District has implemented four key measures to navigate challenging markets with shifting prices:

- **Substitutions:** Allow for product substitutions including opting for alternative, similar products.
- **Partnering:** Team together by creating working groups that consider all stakeholders (owner, design professional, contractor, manufacturer, suppliers, subcontractors).
- **Schedule-Related:** A clear procurement period is vital to keeping projects within budget.
- **Value Engineering:** Upfront planning, particularly in the design phase, can optimize costs beforehand by considering functionality, costs, schedule and risk exposure.

To realize savings, utilities must leverage digital solutions that fit their needs

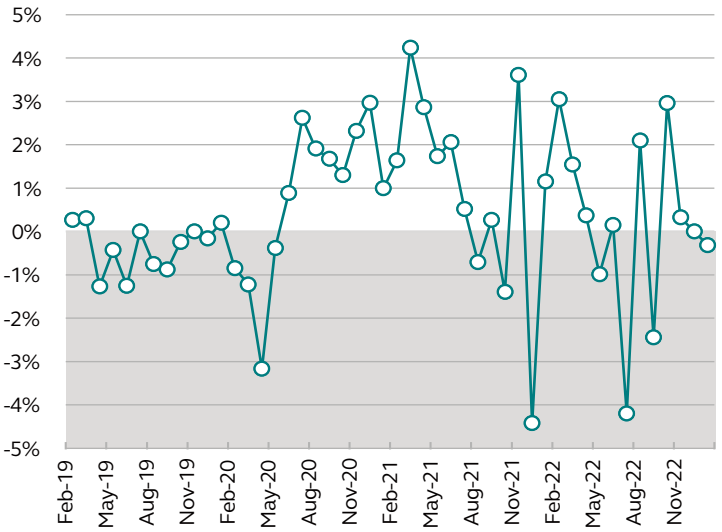
The rollout of advanced asset management software solutions continues to be driven by the significant TOTEX savings that these technologies can generate, as evidenced by the successes of early adopter utilities in the U.S. However, the number of solutions available for strategic and tactical asset management, as well as core asset management data collection and storage platforms, has grown significantly since 2020, making it a challenge for utilities to identify and adopt the right system to deliver savings in multiple areas, both in terms of OPEX and CAPEX. When selected and applied correctly, digital asset investment planning and risk analysis tools have allowed utilities to reduce annual CAPEX by between 2.5% and 20%, by enabling utility leaders to optimize their capital investments and avoid unnecessary asset replacements.

Louisville MSD

Procurement Strategies to Navigate Current Market

- Include escalation clauses
- Consider less aggressive project durations
- Offer milestone bonuses
- Obtain early permits
- Push timely contract closeout
- Review insurance requirements
- Use unit costs for high-risk items
- Lower retainage

Producer Price Index – Wire and Cable

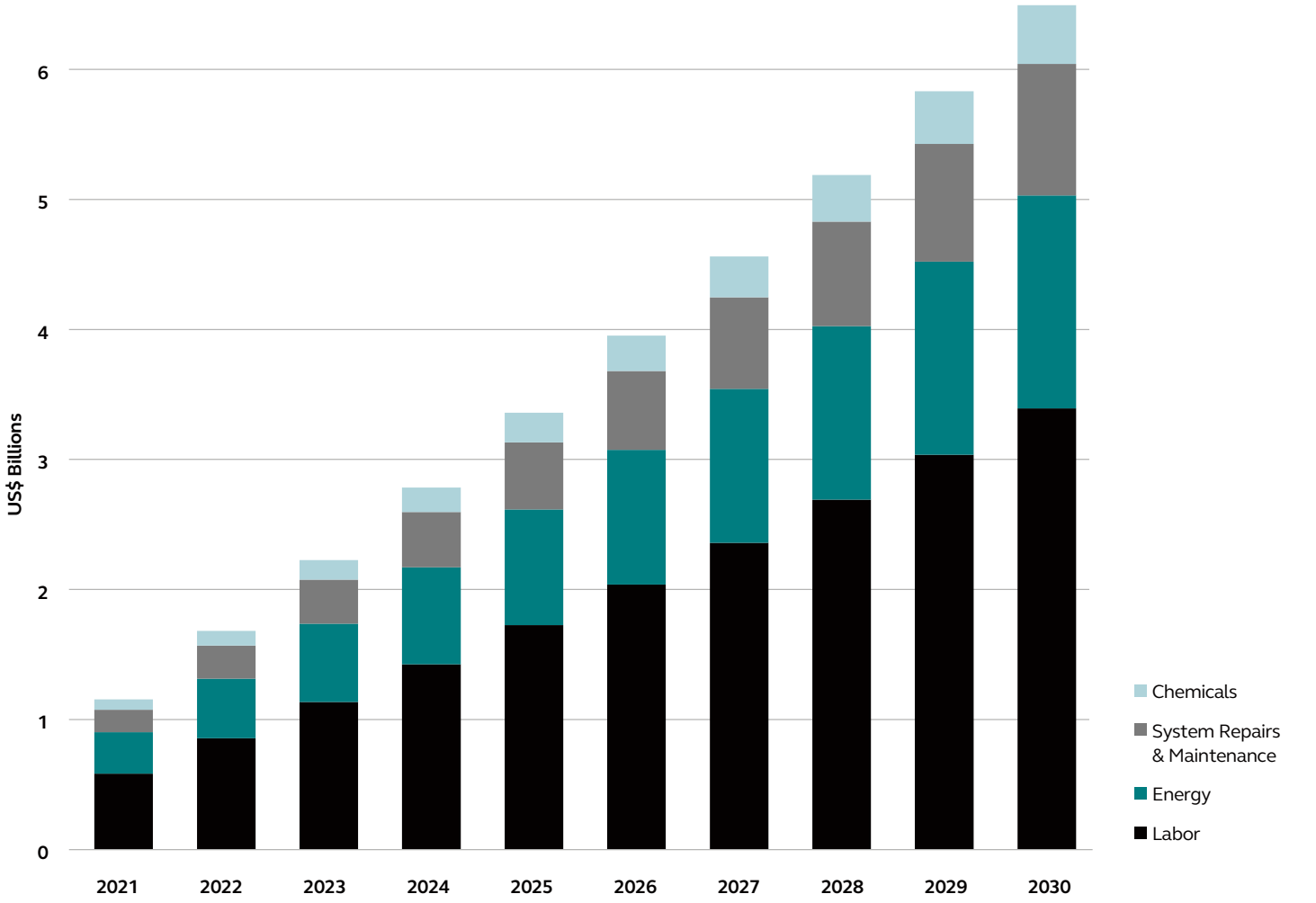


2022 Asset Management Products Landscape

	Networks: Distribution and Collections Systems	Facilities: Water, Wastewater Treatment, Desalination Plants
Strategic Asset Management Optimized decision making	**Asset Investment Planning (AIP) & Management (AIPM)** Innovyze, ICS, assetic, ARCADIS gen, POWERPLAN, DECISION LENS, suez, MINERVA	OVARRO, CGI, baseform, UMS group, technology one, copperleaf
	Risk, Design Optimization Tools esri, powel, SEDARU, VODA.ai, Optimatics, FRACTA, echologics, PIPELOGIX, pure, visenti, Innovyze	**Business Intelligence Platforms** GE, suez, Atonix, OVARRO, Innovyze, IQSight, plutoshift, Bentley, KISTERS, VEOLIA, IBM, esri
Tactical Asset Management Work order, maintenance, fleet/staff, event management	**Network Management Platforms** H2O, RIVENTA, WaterOffice, RPS, Trimble.water, TaKaDu, Innovyze, SEDARU, VEOLIA, Syrinix, baseform, OVARRO, suez, visenti, Schneider Electric, IBM, Bentley, inflowmatix	
	Enterprise Asset Management (EAM) SAP, IBM, Cityworks, lucity, infor, technology one, ORACLE, VUEWorks, Cartegraph, sisteplant, AssetWORKS, utilitycloud, anaqua, ARCADIS gen, SEDARU, GE KNX, Trimble.water **Mobile Work-Force (WFM)** ABB, assetic, esri, KloudGin, SUS, CLEVEST, Accela, PubWorks, elements	**Asset Reliability and Performance (APM)** c3.ai, GE, Bentley, Schneider Electric, plutoshift, ABB, UPTAKE, spacetime, SIEMENS, KISTERS, suez
Core Asset Management Asset data collection/ storage	**Geo-Spatial Platforms (GIS)** WaterOffice, esri, HEXAGON GEOSPATIAL, Bentley, OpenSpatial, GE, powel	**Data Repository** SAP, Schneider Electric, ORACLE, esri, OVARRO, IBM, SIEMENS, ABB, HACH, osisoft
	Data Collection and Monitoring, RTUzs, Asset Condition Inspection pure, Syrinix, H2O, AYYEKA, LACROIX, OVARRO, Rezatec, UTILIS, echologics, HYDROMAX USA, metasphere, AQUAM, inflowmatix	**SCADA** Schneider Electric, Rockwell Automation, inductive automation, VTScada, ABB, SIEMENS, GE, OVARRO

Using a median estimate of 11.3% in CAPEX avoidance, it is projected that advanced asset management platforms could help U.S. water and wastewater utilities to save a total of $27.5 billion in CAPEX between 2019 and 2030, including $17.0 billion in vertical asset CAPEX (61.7% of total savings) and $10.5 billion in linear asset CAPEX (38.3% of total).

Advanced Asset Management CAPEX Savings Forecast, 2019-2030



Beyond CAPEX, and more importantly in the short term, advanced asset management software solutions offer several savings opportunities in terms of OPEX by considering the overall lifecycle.

- **Labor** – savings for the most expensive and hardest to source category of OPEX for system operators is facilitated using digital tools that optimize labor inputs for asset operation and maintenance. For example, with advanced analytics, extending the lifetime of a given pipe requires fewer field staff and supports more efficient work order management. While it cannot solve the staffing challenges utilities face, asset management approaches to personnel can reduce their impact.
- **Energy** – advanced asset management considers uses of energy across the water cycle and pinpoints areas of inefficiency in the process of making repair or replace decisions. Most notably with pumps, predictive analytics can optimize pump usage in terms of timing and duration.
- **Plant and system maintenance** – operational and investment decisions related to plant and system O&M also benefit from asset management's consideration of the asset lifecycle, including its hours of use, age and maintenance record.

Several utilities implementing asset management programs are first focused on improving their operational information to facilitate longer-term, better-informed capital investment planning.

Following the upgrade, field staff are now equipped with mobile devices, making consultation of asset condition much more immediate.

Advanced asset management works hand in hand with operations

Northeast Ohio Regional Sewer District

Advanced asset management starts with quality data, and the proper tools to manage it, to inform decision-making. The Northeast Ohio Regional Sewer District (NEORSD) understands this very clearly as they are in the process of implementing a new software platform to optimize work order management and provide more detailed, integrated condition assessment data, with the goal of achieving more proactive maintenance processes using predictive analytics.

“We have three wastewater treatment plants and it’s taken some time to standardize maintenance”, says Meg Shively, the Manager of Systems Integration at NEORSD. But NEORSD has taken advantage of a $1.9 million computerized maintenance management system (CMMS) upgrade initiated in January of 2020, from Oracle Work and Asset Management to NexGen Asset Management, to make deeper workflow improvements.

Following the upgrade, field staff are now equipped with mobile devices, making consultation of asset condition much more immediate. The new system provides more robust condition assessment with a deeper dive that improves equipment condition visibility and provides pump curve analysis. It also triggers work orders more efficiently to speed maintenance actions.

While the shift from reactive to predictive maintenance is a process they are still building out, data captured from the system enables asset ranking with a criticality index and condition assessment to determine maintenance plans. As an example, NEORSD treatment plants use blowers that are 50 years old with motor replacement needs. To make the replacement decision, the department carefully evaluates historical maintenance data, with at least five years of history, to score the asset. Based on this data they can optimize usage, including consumption and the need for peak time generators.

The impact of this deep focus on OPEX improvement through maintenance excellence is reflected in capital improvement plans. This also has wider implications for the District’s consent decree compliance, which is underway. As part of Project Blue Lake , for example, NEORSD is building storage tunnels with a target to minimize sewer overflows to just four per year. NEORSD is optimistic that upgrades to CMMS, combined with a focus on more proactive asset condition monitoring, will deliver on these targets, and it’s already looking promising; throughout 2022, NEORSD had a permit compliance rate of 99.98% and just four dry weather overflows.

Trending drivers will heavily influence asset management programs moving forward

Water equity and environmental justice emerge as key considerations in asset management

Since the 2020 report, another set of considerations have emerged as key factors when asset planning: the impact of utilities and their assets through the lens of equity and environmental justice.

While these terms have been part of the broader climate change conversation for decades, they have been elevated in the last few years by utilities using asset management. These discussions are fueled by several factors, but the foundation is the growing recognition that utilities are "anchor institutions" with the power to transform their communities. Anchor institutions are organizations that are permanently tied to their location that provide benefits centered around public health, environmental health, social support and economic development.

Defining and driving water equity and environmental justice

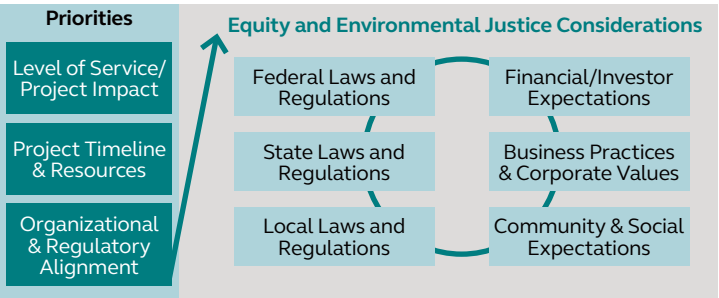
According to an internal survey of water and wastewater utility executives, environmental justice, water equity and inclusive stakeholder engagement are a key part of strategic planning. Water equity is "when all communities have access to safe, clean, affordable drinking water and wastewater services; are resilient in the face of floods, drought, and other climate risks; have a role in decision-making processes related to water management in their communities; and share in the economic, social, and environmental benefits of water systems". These benefits are vital to sustaining thriving, vibrant communities.

There is acknowledgment that historically, not all members of a community have been able to participate in the benefits associated with water and wastewater infrastructure—instead, they generally bear the burden of its negative impacts. These "vulnerable communities" are disproportionately impacted based primarily on income, class, social, and racial and ethnic factors and have fewer resources to cope with, or mitigate, heightened risks and negative impacts. The U.S. Environmental Protection Agency (EPA) defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies". Environmental justice encompasses water equity.

Asset management plays a major role in achieving water equity goals, and therefore environmental justice, as it informs the investment decisions for infrastructure. Traditionally, poorer levels of service are consistently found in vulnerable and underserved communities, resulting in community mistrust, along with failing infrastructure that often results in more extreme consequences, such as the Mississippi Water Crisis that left thousands of people, including hospitals and fire stations, without safe drinking water. As a result, capital planning requires a new approach to achieve equitable outcomes that incorporate equity and environmental justice considerations. These considerations require a holistic view of legal frameworks from the federal to the local level, business/corporate values, and community and social expectations. This can include considering demographic and affordability indicators in addition to the traditional asset condition and risk factors as part of capital project prioritization.

The primary drivers fueling these expectations are social justice, economic development and regulatory and legislative mandates, specifically those attached to funding. At the heart of this conversation is water affordability, which has manifested in a variety of ways, from rates based on class to the proliferation of customer assistance programs, driven by investment from the utilities themselves and bolstered by first-ever federal funding for water assistance programs, including the Low-Income Water Assistance Program, which in FY 2021 provided $1.138 billion to states, tribal organizations and territories.

Approach to Capital Planning for Equitable Outcomes



The economic benefits associated with water and wastewater investment are spurring requests for more inclusivity in planning. According to a joint white paper by The Value of Water Campaign and the American Society for Civil Engineers, nationwide investment in water and wastewater systems would create 800,000 jobs and $2,000 in annual disposable income per household. Another study found that for each additional dollar of revenue in the water and sewer industry, there is a $2.62 return on investment, and that adding one job in the water and sewer industry creates 3.68 jobs in the national economy to support that job.

Regulatory and legislative mandates are a result of significant attention from local, state and federal governments on the inclusion of equity and justice factors in receiving access to funding for critical infrastructure projects. Several governments have created justice and equity working groups, taking a holistic look across all departments with a focus on water and wastewater utilities because of their role as anchor institutions. For example, the Minnesota Department of Health's (MDH) Drinking Water Protection Program (DWP) recently identified clean and affordable water as a human right and "a social determinant of health that, when unrealized, compounds environmental and economic disadvantages to weaken immunity and exacerbate health conditions." As part of their commitment to water equity, MDH recently launched the DWP Health Equity workgroup to identify challenges and barriers within the drinking water sector and working towards sustainable solutions.

Moreover, the current federal strategy has emphasized environmental justice and equity in infrastructure investment and planning. The current administration has made environmental justice a focal point, creating the White House Environmental Justice Advisory Council to bring greater visibility to environmental justice issues across the federal government and coordinate with the EPA's National Environmental Justice Advisory Council. In addition, the federal government has implemented the Justice 40 initiative, a goal that "40 percent of the overall benefits of certain federal investments flow to disadvantaged communities that are marginalized, underserved, and overburdened by pollution". The EPA has created the Office of Environmental Justice and External Civil Rights, which has a purpose of ensuring that the historic funding under the Infrastructure and Investment Jobs Act (2021) and the Inflation Reduction Act (2022) are following the Justice 40 mandates and reaching underserved communities.

Using data to drive equity and justice in asset management planning

Utilities have often lacked guidelines to tackle issues of water equity and environmental justice and are at different points of maturity in their efforts to include these considerations in asset management planning. However, there are now several tools that harness the information found in widely used data sets and planning models that provide direction on using this information to evaluate project investments through an equity and justice framework. Data points are based on the service area's demographics (social, economic, education, etc.), asset locations, customer service and operational information (affordability, points of failure, etc.) and other information. Two publicly available tools, the Climate and Economic Justice Screening Tool (CEJST) and the EPA's Environmental Justice Screening and Mapping Tool (EJScreen), provide demographic information based on the U.S. Census data overlayed with other environmental data from various government sources and provide equity and justice scores. Other information comes from diverse sources, including local and state governments and even the utility themselves.

Equity and Environmental Justice Considerations – Data Points

Statistics/Data	Source	Example(s)
Socio-Economic (Affordability)	Census Tract Data	Median Household Income; Density; Education; Age
Economic Growth Focus Areas	Federal; State; and Local designated communities	Opportunity Zones; Empowerment Zones
Environmental Justice Analysis	Climate and Economic Justice Screening Tool (CEJST)	Historically underserved and overburdened communities
Customer and/or Operational Data	Utility	CSOs; SSOs; Consent Decrees; Customer assistance; delinquent accounts
Additional environmental concerns/citations; utility projects; etc.	Varies	Floods; tree canopies/ energy burden; etc.

Asset management is a tool that enables solutions for justice and equity issues by taking a methodical approach that contextualizes and prioritizes investments throughout the water sector. Applying specific equity and justice metrics to asset planning is relatively new, and most jurisdictions are just beginning to conduct reviews of issues and potential solutions, however some water and sewer utilities are taking the lead with concrete action plans.

Leading the way with equity-centric project assessment

Washington Suburban Sanitary Commission

Washington Suburban Sanitary Commission (WSSC) Water covers one of the largest service areas in the Eastern U.S., serving 1.9 million people through 5,816 miles of water mains and 5,500 miles of sewer pipe. This area includes several low-income neighborhoods which require a greater focus on equity, facilitated by asset management. Starting with a pilot effort in 2021, WSSC's asset management division developed a tool to operationalize its equity focus.

The tool scored WSSC's capital improvement projects based on a variety of factors, giving projects located in low-income areas higher rankings. To inform the system, the utility created "heat maps" with granular level of service visualizations that reflected sewer overflows, backups, and demographic data, including income levels, county-designated economic growth focus areas, and past due accounts. Building on this framework, the division also developed bespoke scripts to evaluate consequence of failure using algorithm software from Optimatics, a leading provider of infrastructure planning software.

This approach quantified social impact scores for different projects and enabled the division to make equity a more objective factor based on the data collected.

This approach quantified social impact scores for different projects and enabled the division to make equity a more objective factor based on the data collected. An increase in equity score for a given project must show income levels, dispersed impacts, and the exact location within an equity focus area to obtain a score assigned to a direct outcome. This yielded three tiers of projects: 1) dispersed, 2) adjacent, and 3) direct, with the scores used as a multiplier applied to the ranking.

The 2021 pilot, with this methodology, is now embedded in WSSC Water's capital improvement program. In terms of re-prioritizing projects, WSSC Water emphasizes the processes put in place more than the immediate outcome of the initial pilot. While only a small number of projects were affected by the equity-based rankings—just 2.7%—those projects are now moved up in prioritization and no longer at risk of being cut.

A future priority for WSSC Water is to incorporate level of service KPIs, related to social equity, that could give additional prioritization points to projects. With most of the heavy lifting done to create an equity-focused capital improvement project planning process, WSSC Water can now lean into operational data to improve its projections and gain greater visibility across the asset lifecycle.

Calibrating service levels for greater equity

Portland Water Bureau

The City of Portland, Oregon prides itself on its progressive approach to social issues, and its water department is no exception. In 2011, a city ordinance created the Office of Equity and Human Rights that built environmental justice and social equity into the DNA of city management. For the Water Bureau, this approach coalesced with its 2021-2025 Plan to Advance Equity, Diversity, and Inclusion.

After a 2016 customer outreach effort, the Water Bureau realized the need to calibrate its service levels and identified major planning gaps that required setting more realistic OPEX and CAPEX goals. With the creation of the Equity and Human Rights Office, the city has worked to standardize equity language across bureaus while developing specific goals for each. In the case of the Water Bureau, this has translated into 60 actions in its plan, designed to achieve pro-equity outcomes, with a heavy reliance on asset management for their success.

Of the 27 service levels set by the Bureau, nine of them have a social equity focus that will be supported by an in-house “equity toolkit”, which is currently under development.

Asset management within the Portland Water Bureau evaluates service layers with a social equity overlay that provides key context to investment decisions. The Bureau incorporates investment prioritization into its risk framework and aims to correct bias in its project scoring. Evaluation of consequence of failure considers the location in which a problem occurs to apply an adjustment factor considering the vulnerability of a population. For example, the impact of outages and fire hydrant availability have varying impacts on a community depending on their income level. Of the 27 service levels set by the Bureau, nine of them have a social equity focus that will be supported by an in-house “equity toolkit”, which is currently under development. The Equity team within the city-level office releases status updates on meeting those service level targets.

Barely two years have passed since its new plan was implemented, but it is already impacting the budgeting process for pipe replacement. Recommendations are passed on to the planning team, which now reviews investments through an equity lens. Better coordination between departments and additional reporting requirements have ensued. Not until 2026 will Portland likely reveal how well the Bureau has delivered on its equity service targets from its initial plan, but it is already clear that from 2016 to 2023, the Portland Water Bureau has initiated its journey towards improved service levels with more equitable outcomes.

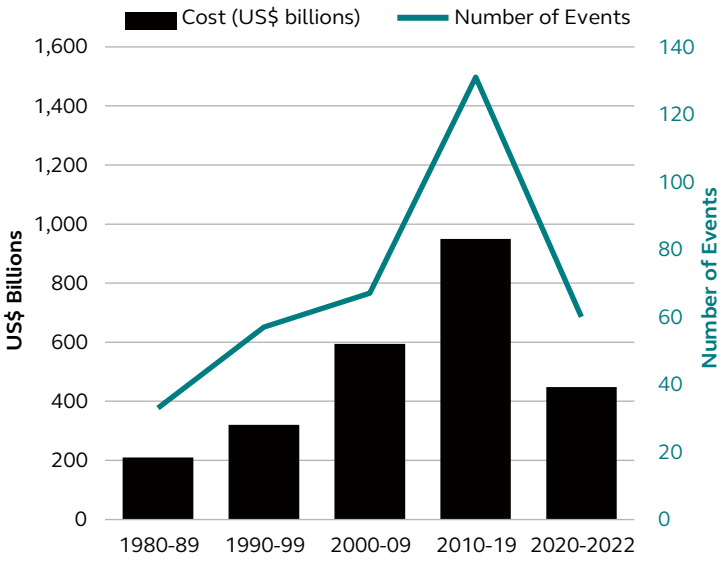
Asset planning must address climate change resiliency

In recent years, a series of major weather events have alerted municipal water authorities of their assets' major vulnerabilities. Weather events have become more drastic and more frequent, and this has upended how utilities deal with outages and damage to critical assets.

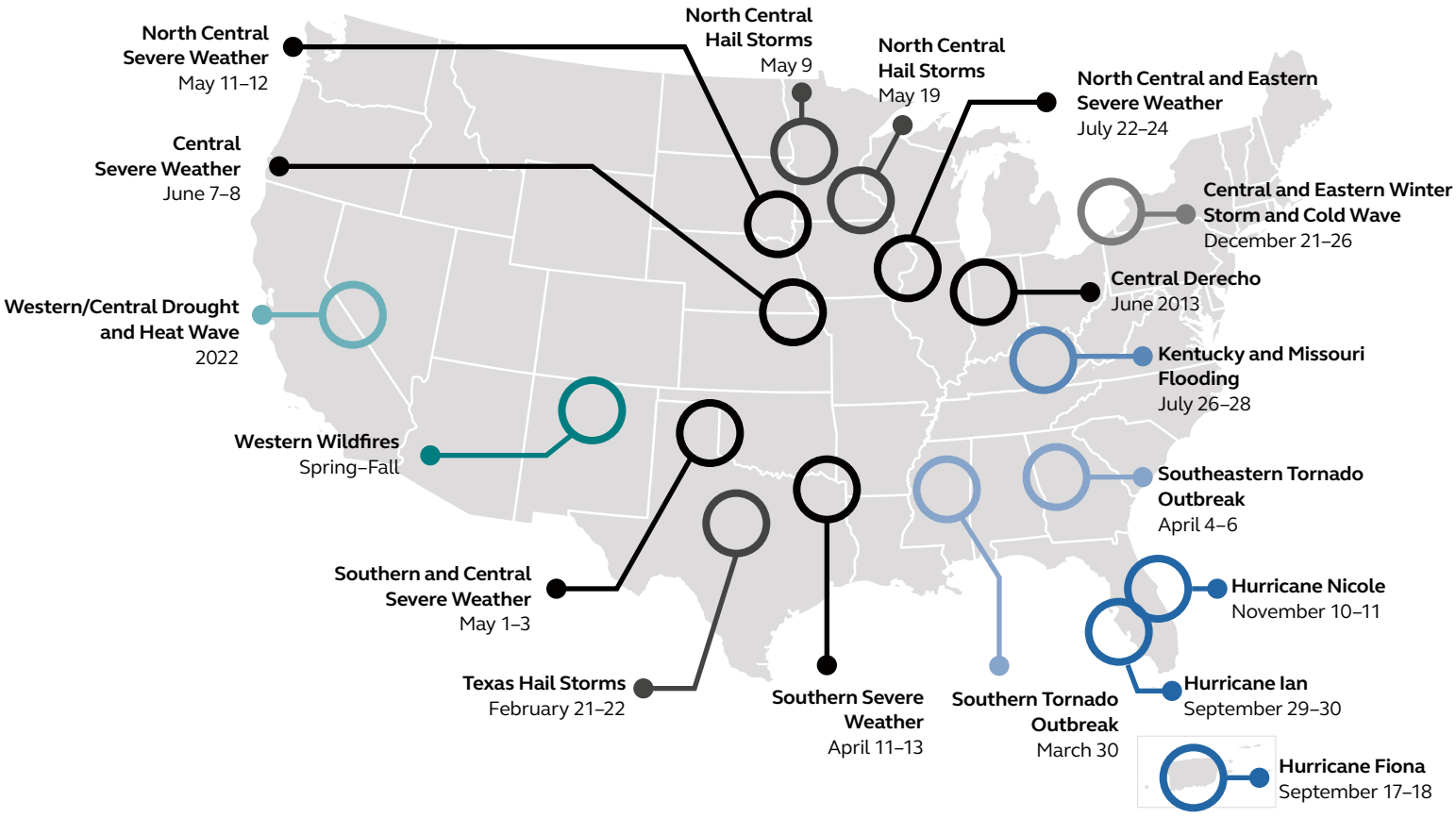
Resilience to climate change has emerged as another key dimension of asset management, factoring in higher levels of stress placed on systems amid such climate events. Conventional planning for climate events has generally centered around master plans with static modeling baselines of weather extremes that are updated every five to 10 years, but this is no longer sufficient. Improved weather data and the use of predictive analytics enables managers to model potential events' impact on assets for improved designs of more resilient infrastructure.

Water-related disasters—storms, floods, droughts—account for more than 90% of the total $3.6 trillion in economic losses in the U.S. over the last 50 years. From the 1970s until the 2010s, water-related disasters have increased 4.5x with an 8x increase in economic losses, thus changing the risk outlook for governments and companies alike. The increasingly extreme swings in weather patterns, combined with their increasing frequency, has put all system operators on notice for re-dimensioning their assets' ability to withstand these events.

U.S. Billion Dollar Disasters, 1980-2022



U.S. 2022 Billion-Dollar Weather and Climate Disasters



Weathering storms toward greater resiliency

Houston Water

The City of Houston is no stranger to extreme weather events, as Texas is routinely subjected to storms that force urban planners to think ahead. Houston's urban sprawl includes 22 watersheds and corresponding bayous that pose a persistent threat as stormwaters exceed their banks and chronically flood areas of the city. But Houston Water's assets were pushed to their limit between 2017 and 2021 as one major event after another pounded the city's infrastructure.

Hurricane Harvey flooded downtown Houston for four days in August 2017, which required emergency deployment of mobile pumping stations as three feet of rain fell on the city in a 1-in-50,000-year event, causing $126 billion of damage. Barely two years later, tropical storm Imelda again flooded residential areas of the city, and in February 2021, winter storm Uri wreaked havoc on Houston's water pipes and power grid.

Houston Water's lead engineer Satish Tripathi is on the front lines of planning initiatives to adapt clean water supply to the new norms of extreme weather.

Borne out of these catastrophes, the city published its Houston Resilient Plan 2020, drafted by a separate unit committed to hardening the city's infrastructure and services in the face of extreme weather. This initiative is reshaping the approach to stormwater management, as Houston, in coordination with the Houston Parks Board and Harris County Flood Control District, is investing in its bayous, waterways and detention basins for flood control.

Houston Water's lead engineer Satish Tripathi is on the front lines of planning initiatives to adapt clean water supply to the new norms of extreme weather. He believes that Houston is innovative and its leadership takes an early adopter approach to using new tools in the face of challenges.

"We were hit by all the extremes" he recalls, saying that the storms in recent years have permanently changed the city's mentality, which is reflected in its asset management. Houston Water's focus on drinking water supply is highly data driven and they consider a wealth of inputs including historical failure rates, supply-demand dynamics, deficiencies detected through condition assessment, and outages to prioritize projects. These inputs inform an algorithm in development to determine investment priorities. "By next year we'll have a list of projects based on AI prediction" he anticipates.

But an algorithm is only as good as its supporting data, and the division has worked hard to improve the data quality, both the detail of data capture but also how it is integrated with other datasets for decision-making. Two key objectives are applied to this assessment: near-term determinations for capital improvement plans of existing system assets, and more future-oriented planning around asset capability.

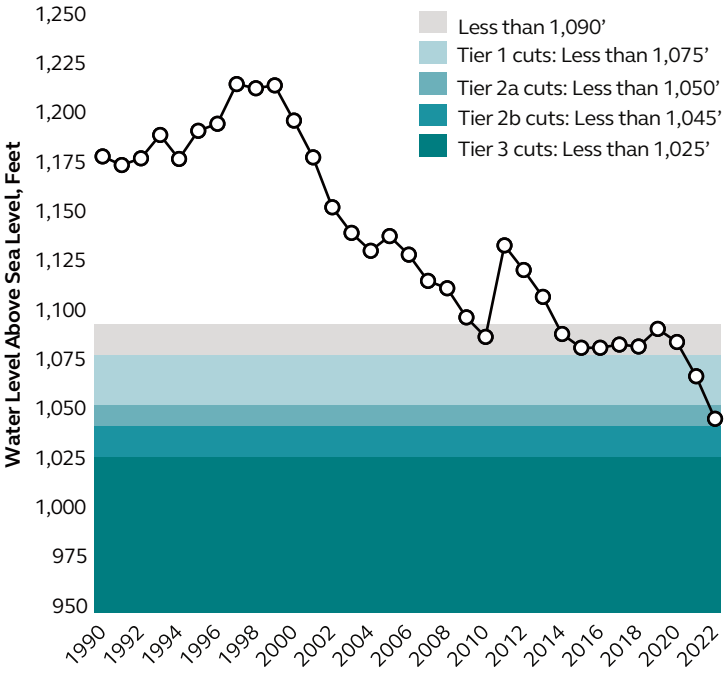
Now, Houston has no shortage of plans that address its resiliency issues. This includes Resilient Plan 2020, a follow up Climate Action Plan 2022, and development of a One Water plan. "The Action Plan needs to be acted on through asset management" says Tripathi, underscoring the central role of his planning department in providing unity around the billion dollars of investment that lay ahead.

The combination of data-centric decision-making, use of advanced analytics through AI, and an increasingly favorable environment for resilience planning point to a Houston that is better prepared for all weather challenges.

Extreme rainstorms and flooding, as seen in cities like Houston, are contrasted by the persistent climate threat of drought impacting Southwestern states. The Colorado River, for example, represents only the latest water-related emergency to drive alternatives beyond the status quo, including water reuse, desalination, smart water management in the home, and conservation for countries, states, municipalities, and industry.

In February 2022, the seven Colorado River states hurdled toward uncharted territory as water levels in Lake Mead dropped to an all-time low, highlighting the increasing risk of reaching deadpool resource levels—the level at which the water in a reservoir can no longer flow downstream from a dam—which would threaten the livelihoods of 40 million people for water and power supply. For asset managers of drought-afflicted systems, predictive models are vital tools for resource management, which in turn shapes capital investments in the form of alternative supply (i.e., desalination or water recycling plants) as well as improved efficiency through leakage reduction measures.

Lower Basin Drought Contingency Plan Allocation Reductions – Lake Mead, Arizona



Source: U.S. Bureau of Reclamation, Central Arizona Project, Bluefield Research

Whether the risk is flooding, drought, extreme temperatures or storms, climate change resiliency is undeniably reshaping asset managers' approach to investment decisions going forward. Moving from static to more dynamic information and shifting toward a baseline which factors in record-setting weather conditions is leading to a new outlook in asset management, considering its rapidly changing operational environment.

Asset management operationalizes resilient asset strategies

Anticipating greater stresses and shocks on assets is fundamental to long term investment planning and is key to utilities' resiliency. In 2015 the Cybersecurity and Infrastructure Security Agency mapped out key risks for water and wastewater systems which underscored the importance of asset management as part of utilities' resilience strategies. Further, the National Infrastructure Protection Plan lays out core principles for resilience planning that are embedded in asset management divisions of utilities. These include:

- **Inventory of assets.** Whether physical, cyber or human, asset managers are keenly aware of their asset base and leverage many data sets across multiple silos in their planning processes.
- **Road-mapping goals and objectives**. Asset management is in an optimal position between day-to-day operations and long-term investment planning that enables informed decision making driven by concrete plans. These plans can be grounded in specific operational metrics and asset performance criteria.
- **Risk management and performance measurement.** Setting levels of service targets and monitoring a utility's ability to deliver on these targets is vital to asset planners' workflows, enabling them to adjust and improve asset management plans.

Building on this basic framework, asset management provides a multi-faceted tool for resilience planning. For the assets themselves, asset management frameworks and tools provide the necessary structure and methodologies to assess asset conditions, identify vulnerabilities, prioritize investments and allocate resources effectively. Asset management also serves a diagnostic function when it comes to resiliency, as it aims to assess and mitigate a multitude of risks. Based on this diagnostic, it can then recommend performance targets and maintenance actions which lead to optimized lifecycles that can be adjusted over time.

Key Elements for Asset Management Resilience

The Asset Management Paradigm Shift

As mentioned at the beginning of this paper, water and wastewater utilities are facing another paradigm shift. Traditional drivers, like aging infrastructure and affordability, as well as new challenges and trends, like environmental justice, social equity and climate change, are requiring the industry to shift:

From climate event reactive to climate event prepared:

As utilities are faced with an onslaught of extreme weather events, they must harden their infrastructure, add new assets, and improve predictive capabilities to maintain service levels. Advanced asset management programs embed vulnerability assessments and incorporate flood evaluations into the risk assessment procedures to improve designs for more resilient infrastructure. Whether the risk is flooding, drought, extreme temperatures, or storms, resiliency is undeniably reshaping asset managers' approach to investment decisions going forward. Asset managers leveraging an advanced asset management framework are moving from static to more dynamic information to adapt to a rapidly changing environment.

From CAPEX finance planning to TOTEX planning:

Financial planning increasingly requires consideration of operational outcomes, and their associated costs, into more comprehensive budget frameworks. Advanced asset management practices take a more expansive view of asset costs, prioritizing total expenditure (TOTEX) over the lifecycle of an asset, rather than upfront CAPEX alone, leveraging new digital solutions. Optimizing operating costs requires a shift in maintenance philosophy, moving from reactive or preventive maintenance modes to predictive or prescriptive approaches.

From rate increase-based finance models to alternative finance models:

Based on infrastructure needs and inflation, rate increases are no longer a viable option to sustain cost recovery. Utilities have historically funded capital investment through revenue-backed municipal debt, and though this source of funding will likely remain important, alternative financing options are emerging. Federal programs such as the Water Infrastructure Financial and Innovation Act and the Infrastructure Investment and Jobs Act are providing new sources of funding, allowing utilities to increase revenue without raising customer rates.

From responsive to proactive and embedded environmental justice and social equity:

Asset management plays a major role in achieving equitable outcomes as it informs investment decisions and documents levels of service for the entire community served. Proactive and embedded environmental justice & social equity parameters ensure that all people are protected equally and that underinvested infrastructure in poorer communities is prioritized. Advanced asset management leverages new tools and data sources to incorporate equity and environmental justice considerations and prioritize capital projects that will serve communities who need them most.

From reliance on an aging, specialized workforce to flexible staffing that leverages digital tools:

Labor shortages for multiple positions forces utilities to optimize resources using telemetry, outsourcing and ongoing training programs. Alternatively, advanced asset management approaches require a rethinking of traditional utility hiring and staffing, including the addition of new digital skillsets to complement the financial, engineering, and operations and maintenance resources central to traditional asset management.

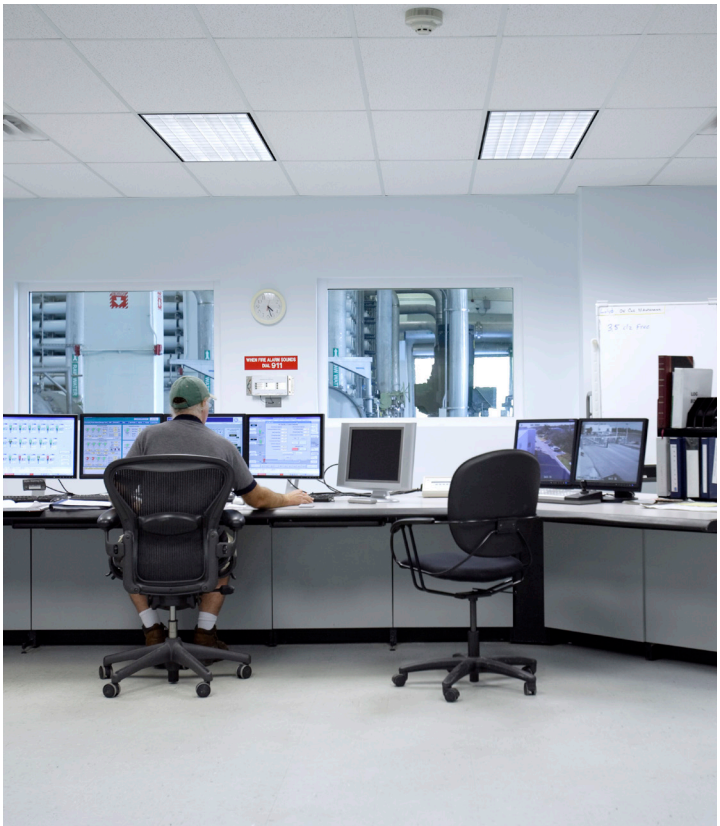
Advanced asset management continues to enable utilities to navigate challenges

As utilities navigate a complex set of challenges—both old and new—advanced asset management remains a critical tool that enables them to deliver on their mission as public service providers. To name just a few of its capabilities, advanced asset management allows utilities to optimize the lifespan and performance of their infrastructure assets by incorporating live inputs and generating dynamic solutions. It enables utilities to not only make informed decisions regarding capital investments, operations programs and budget allocations, but to ensure they are resilient and prepared for future regulatory requirements and customer satisfaction—and this is only the beginning.

In leveraging these tools, municipalities' goals to improve environmental justice and social equity are having an increasing impact on asset planning, and this will continue. Few cities have significantly integrated environmental justice and social equity into their asset management plans to date, as they have lacked the people, data, workflows, and often the political capital to drive them. But the drivers behind equity and justice initiatives are only increasing as city councils strive for more equitable and sustainable outcomes from urban development and public service delivery.

As utilities address increasingly frequent and extreme climate events, asset managers using more advanced tools will be better prepared for future challenges. With advanced asset management, new employee skillsets acquired in data science, statistics and economics will allow utilities to conduct comprehensive risk assessments of their infrastructure assets, incorporating real-time data streams, employing data-driven decision-making, and developing an internal culture of proactive planning and preparedness by fostering collaboration and information sharing.

It is clear looking forward that the best utilities of today—and those best equipped to face the challenges of tomorrow—are led by advanced asset management principles.



How can utilities successfully deploy advanced asset management practices?

To meet the next set of challenges, asset managers will need to deploy advanced asset management practices that enhance their traditional asset management programs. Utilities must continue to invest in new ways of working and advanced technologies. Together, they can empower the workforce to overcome affordability, equity and resilience challenges, seize optimization opportunities and foster thriving communities. Though utilities should not make several dramatic changes at once, they can implement incremental changes over time to create a sustainable water industry. For utilities ready to begin this journey, here are the critical first steps to take and tools that can help:

Know where you are, and where you want to go

Create or update your strategic asset management plan

A key part of a strategic asset management plan includes identifying overall organizational asset management goals and objectives as well as identifying all stakeholders and their desired levels of service. New goals and objectives should also be considered in relation to social equity and environmental justice topics and incorporated into an updated asset management policy statement. The stakeholders' desired levels of service developed for a utility's asset management program can then align the program with the utility's goals and objectives. This creates a clear line of sight for internal and external stakeholders and allows them to understand how the utility's service levels are going to impact all communities, including disadvantaged ones.

Take a comprehensive look at risk

Align and update your risk framework to consider resiliency as an additional failure mode

America's Water Infrastructure Act was signed into law on October 23, 2018, and required all community (drinking) water systems serving more than 3,300 people to conduct a risk and resilience assessment (RRA) to understand the risk of asset failures due to external factors, including weather events, and develop an emergency response plan by December 31, 2021. While all utilities complied with this requirement, many have kept these reports separate from their overall asset management programs; however, several states are now requiring the RRA as part of their asset management program requirements, making it wise for utilities to incorporate RRA into their AM programs. Best practices should include merging asset management risk assessment methodologies to include the RRA analysis so that both risk assessment methodologies are identifying the same critical and high-risk assets.

Taking this concept one step further, many coastal communities are specifically including flooding and sea level rise as criteria to grade the performance condition of both water and wastewater assets by measuring current critical asset elevations in the field and comparing them to FEMA flood maps and sea level rise future predictions to determine if assets are at risk based on their current elevations. If at risk, projects are identified to raise elevations or provide flood protection barriers.

Prioritize capital projects in an equitable way

Apply new tools and data to incorporate social equity and environmental justice into decision making

Project prioritization should be based on meeting level of service goals and include alignment with overall strategic goals and objectives. As goals and objectives change to include social equity and environmental justice, these new concepts must be incorporated into key decision-making processes. Several utilities are now including social equity and environmental justice parameters into their business case evaluation and capital improvement plan prioritization processes. Demographic indicators from new tools and data sources such as the CJEST Tool developed by the U.S. Council on Environmental Quality and the EPA EJScreen Tool can be easily leveraged as part of the prioritization process to identify equity focus areas, considering social and environmental factors such as concentrations of minorities, low income households, low English proficiency, residential density, land use, economic factors, employment rates, etc. Proactive utilities are looking to ensure that all customers receive fair and equitable service while working to right some of the wrongs of the past.

Develop a plan for selecting new digital solutions

Create an integrated asset management and digital roadmap

Digital companies are flooding the water sector. We have seen an exponential increase in digital water products since the early 2000s, with over 30% of global digital water solutions providers having been founded since 2010. The exponential growth of these companies, driven by the significant TOTEX savings these technologies can generate, has continued into the 2020s and is making it a real challenge for utilities to understand the current technology landscape. Whether utilities are looking to invest in strategic asset management products to optimize decisions or tactical asset management products to execute work orders, maintenance, and event management, there are numerous products on the market to support these activities.

Advanced asset management programs should include an evaluation of digital water technologies as part of identifying asset management continuous improvement opportunities. Utilities should review the technology they are currently leveraging and identify technology they would like to leverage in the future to meet their ultimate goals, whether cost saving or risk avoidance. Technology evaluations should identify the best fit technologies to meet their goals as well as identify appropriate timeframes in which the utility will deploy them. By including digital water products into a continuous improvement roadmap, utilities will be able to realize the TOTEX savings that many of the early adopters are realizing today.

Understand the role people play

Employ change management best practices

It is estimated that 70% of asset management change programs fail, mostly due to employee resistance. To ensure solutions are utilized long-term, people must be put at the center. Change management is not simply a task to be completed near the end of the project or program, but must be consistently addressed throughout the entire process to ensure acceptance and adoption. Many successful change management models can be applied, including the ADKAR model by Prosci, which defines five tangible outcomes that people need to achieve for lasting change: awareness, desire, knowledge, ability and reinforcement.

Key elements of change management for an asset management program include creating and communicating an overall mission and vision, defining roles and responsibilities, documenting a communications plan, providing training and measuring progress on a routine basis.

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