HIDDEN COSTS:

The Environmental Impact of Aging Water Infrastructure

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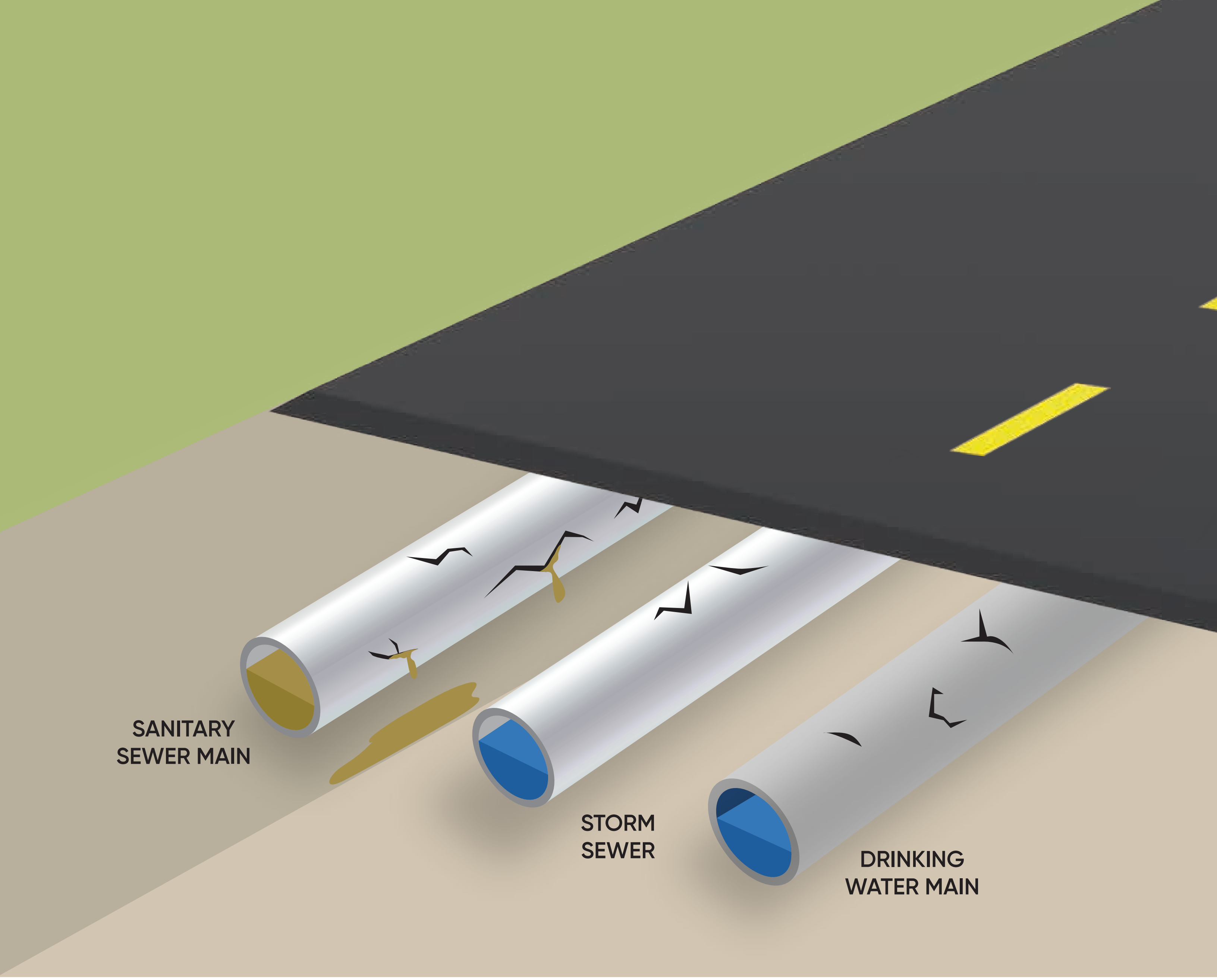
Executive Summary

Aging water and sewer systems in North America are rapidly deteriorating, causing not only service delivery interruptions and water quality concerns but also widespread environmental damage. High rates of leakage and breaks, reduced pumping efficiency, and infiltration of groundwater and stormwater contribute to wasteful overuse of natural resources and increased pollution through chemical treatments and greenhouse gas emissions. These increasing deterioration issues are all connected to the same design problem: using materials that are subject to corrosion within highly corrosive environments. This article provides an overview of the current conditions of water infrastructure in the United States and Canada and the environmental damage that results from its failures. The conclusion offers four principles that can be used to guide the development of sustainable water infrastructure: durability, water-tightness, resourcefulness, and transparency.



Invisible Failures:
Current Status of Water Infrastructure

Approximately 4 million miles of water and sewer pipes run beneath the cities and towns of the United States and Canada. Their jobs of delivering clean drinking water and safely removing waste are among the most vital services for human health, yet they take place invisibly. While hundreds of millions of people rely on these pipe systems, they cannot see how they are performing — or what hidden costs are incurred when they deteriorate.

What would change if water and sewer pipes were out in the open, where everyone could see them?

Would people in North America be satisfied watching 15% of their clean drinking water pour out through leaks, totaling more than 23 billion litres of wasted drinking water per day? Would they be comfortable with sewer lines so permeable that groundwater and rainwater floods in, frequently overwhelming systems so that untreated waste is dumped into waterways? If they could witness the rapidly increasing corrosion of decades-old metal and concrete pipes before each of more than 300,000 annual water main breaks, would they call for preventive measures?

In fact, there is already broad public support for water infrastructure upgrades. A 2020 poll of U.S. voters indicates that 84% of people support increasing public investment in water infrastructure — and support is bipartisan. Spending has consistently fallen dramatically short of needs, however, with 2019's capital spending totaling only about one third of the $129 billion needed to keep the system in good condition. The American Society of Mechanical Engineers graded the U.S. drinking water system a C- for 2021, with wastewater earning a D+ and stormwater systems receiving a D grade. In Canada, conditions vary widely with less than half of water mains in good condition; Montreal loses a third of its water to breaks and leaks and First Nations communities have historically contended with extremely poor water quality.

Raising the bar and delivering the performance the public expects requires the water industry to commit to a greater level of transparency. Residents deserve to know the condition of these vital systems and how well they are functioning. Importantly, they also need to understand the broader impacts of system failures. While financial costs and interruptions to service have been the focus of many discussions, an aspect that has been largely overlooked is the environmental damage caused by aging water infrastructure.

REPORT CARD FOR THE WATER SYSTEMS IN THE US

Wastewater

C-

Wastewater

D+

Stormwater

D

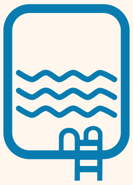
Environmental Costs of Current Conditions

The environmental impact of water system deterioration takes many forms, collectively increasing greenhouse gas emissions, destabilizing ecosystems, and adding to climate-related water management challenges including water scarcity in some areas and flooding problems in others. Water infrastructure is currently responsible for 5% of all U.S. carbon emissions; in some North American cities the proportion is much higher, with 30% of greenhouse gas emissions in Toronto attributable to water and wastewater. Major factors contributing to environmental damage — all of which are related to corrosion of metal and concrete pipes — include drinking water leakage, water main breaks, increased friction, intrusion into sewage systems, and unsustainable pipe materials.

Drinking Water Leakage

The environmental impact of leaking drinking water pipes begins with withdrawal of water that will never reach its destination. In Toronto alone, the amount of water lost to leakage would fill 41 Olympic swimming pools per day. In addition to disrupting ecosystems through excessive water removal, the treatment and pumping of water through leaky pipes results in higher energy costs and greenhouse gas emissions. The non-linear relationship of leakage to energy inefficiency means that increases in leakage cause even higher increases in pumping energy costs; increased energy demands due to leaks are typically 30-80% higher than the percentage of water leaking. This estimate indicates that the 15% of water lost to leakage is causing a 19.5% to 27% increase in pumping-related greenhouse gas emissions.

SCALE OF WATER LOSS



15,000

Olympic swimming pools can be filled by the amount of water lost to leakage each year in Toronto

Leakage also disperses water into the underground environment, accelerating erosion. In addition to ecological harm, this washing away of soil can cause major infrastructure damage such as sinkholes and collapsed culverts. Repairs to roadways and other infrastructure add to the environmental cost, particularly through air pollution from diesel equipment.

Water Main Breaks

Water main breaks, in which a major service delivery pipe shears in two, demand even more extensive and carbon-intensive repairs. Across the U.S., 45% of cities experience more than 50 breaks annually; Vancouver averaged 71 annual main breaks over the past ten years and within Montreal some boroughs have experienced more than 100 annual water main breaks. These catastrophic breaks are twice as frequent for small utilities, can require days of repair work, and often cause major flooding damage. Across North America, break rates for cast iron and asbestos cement pipes have increased 40% in a six-year period, further intensifying water waste and greenhouse gas emissions. Contamination is also a serious threat during such events due to the entry of pathogens that can cause disease outbreaks and gastrointestinal disorders.

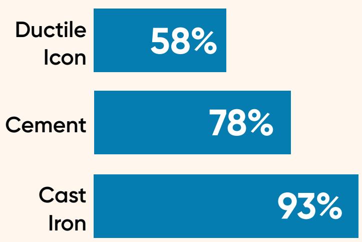
WATER MAIN BREAKS

+50 45% of the cities across the U.S.

average **71** over the past 10 years in Vancouver

+100 in Montreal

INCREASING BREAK RATES



2-9X
More energy to produce ductile iron pipe than PVC pipe

6X
The volume of dioxins produced from source material of ductile iron pipe

8X
Easily recycle PVC material than metal material

Increased Friction

While corrosion on the outside of metal and concrete pipes causes leaks and breaks, corrosion on the inside of these pipes slows water flow by increasing friction. More energy is required for pumping against this force, further increasing greenhouse gas emissions. These corrosion problems also introduce new contamination challenges because the chemical treatments used to inhibit corrosion (phosphates) interfere with treatments to control contaminants. Drinking water thus becomes less safe and a greater range of manufactured chemicals are introduced into the environment, where they contribute to ecological problems such as the proliferation of toxin-producing algae.

Intrusion into Sewage Systems

Permeability of wastewater systems is so commonplace that systems are rated with dry-weather flows (actual sewage) and wet-weather flows during which the volume of water in sewer pipes typically swells by a factor of four or five. This means that, during wet weather, the vast majority of sewage treatment — and its associated energy costs and chemicals — are being wastefully applied to rainwater. Additionally, the treated drinking water that leaks out of water delivery pipes can then intrude into sewer pipes as groundwater, running this same water through two futile cycles of treatment without ever reaching a customer.

Contamination crises arise when severe storms or snowmelt overwhelm wastewater systems, resulting in untreated sewage being dumped into waterways. This problem is particularly acute for the hundreds of older cities in which wastewater and stormwater systems are combined. The magnitude of raw sewage released into the environment during bypass events can overwhelm ecosystems, threaten drinking water supplies, and devastate recreational areas. In Canada, nearly 900 billion liters of raw sewage were released into waterways between 2013 and 2018, and this volume is increasing.

Unsustainable Pipe Materials

High rates of leakage, breaks, increased friction, and intrusion all result from use of pipe materials that are unsuitable for corrosive environments. Approximately 75% of North American water delivery systems run through corrosive soils, and in such environments break rates of cast iron pipes can increase 20-fold and ductile iron pipes require replacement in as little as 11 years. Internal corrosion of metal and concrete water pipes occurs under common conditions including low pH, high oxygen, and the presence of dissolved and undissolved solids. In wastewater systems, in addition to external corrosion from soil and groundwater, hydrogen sulfide produced by sewage oxidizes into highly corrosive sulfuric acid that destroys metal, concrete, and cement-lined pipes from the inside.

In contrast, use of pipes that do not corrode has predictable benefits. Break rates of PVC pipes are the lowest of all pipe materials — 58% lower than ductile iron, 78% lower than asbestos cement, and 93% lower than cast iron. Moreover, the break rate of PVC pipe is decreasing over time, whereas break rates are increasing for iron and concrete pipes. PVC pipe also withstands sulfuric acid in sewer systems, and pumping energy requirements for PVC water pipes are far lower than pumping energy requirements for pipes subject to internal corrosion. The City of Calgary provides an illustrative example: comparing similar lengths of distribution mains, water managers found that their capital and operating costs for the metal portions of the city's water infrastructure were more than 300 times that of the portion built with PVC.

In addition to these cost, durability, and efficiency considerations, pipe material choice has environmental consequences due to the resources involved in pipe production, transport, and installation. Depending on the size of pipe compared, the cradle-to-gate "embodied energy" in ductile iron pipe (reflecting the amount of energy used to create the product) is anywhere from two to nine times higher than that of equivalent PVC pipe. Production of source material for ductile iron pipes emits six times the volume of dioxins as that released during production of PVC resin. PVC can also be easily recycled up to eight times through re-grinding, whereas metal recycling is an energy-intensive process that releases toxic emissions such as lead and mercury. Due to PVC's lighter weight, emissions associated with transportation and installation of PVC pipe are substantially lower than those associated with concrete and ductile iron pipe.

Taking into consideration all energy requirements over a 100-year period, the carbon footprint of ductile iron pipe is between two and eight times that of PVC, depending on pipe size and application. Continued use of unsustainable materials therefore not only increases failure rates but also increases environmental stresses associated with climate change.

Sustainable Water Infrastructure

The environmental consequences of continuing to rely on materials that are unsuitable for the task will only compound going forward. While pipe failures and system inefficiencies drive up greenhouse gas emissions, contributing to climate change, deteriorating water infrastructure is also increasingly vulnerable to the consequences of climate change including more severe and frequent storms and, in arid areas, worsening problems of water scarcity.

Sustainable solutions must prioritize:

Durability

Sustainability, by definition, demands solutions that endure over time. Pipe materials that corrode cannot meet this requirement.

Resourcefulness

Solutions that are the least carbon-intensive to build, maintain, and operate are the most sustainable.

Water-Tightness

Water systems cannot be permeable. The wastefulness and contamination problems of leakage and infiltration are incompatible with sustainability.

Transparency

Water system performance data must be monitored and shared publicly to ensure accountability and continued improvement.

The technology to meet these requirements is already available and includes durable pipe materials, joints, and fittings that withstand corrosive environments; trenchless rehabilitation technologies that line existing metal and concrete pipes with impermeable materials; and recycled-core PVC pipes that further minimize the use of natural resources.

Monitoring technologies are also rapidly evolving, with "smart water" and "smart sewer" innovations enabling leak detection, real-time flow measurement, water quality reports, and energy efficiency feedback. Implementing these systems and incorporating publicly accessible readouts can bring these critical issues into open discussion and evaluation.

Water infrastructure will remain underground, but it should not remain invisible. North American residents deserve a reliable, sustainable water system whose performance and consequences are clearly evident. We have the technological capacity. We can build a water infrastructure we are proud to display — one that efficiently delivers clean drinking water, safely removes waste, and protects the long-term health of the natural environment.

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