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Changing World, Changing Views of Heritage:
the impact of global change on cultural heritage – Technological Change

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CHANGING WORLD, CHANGING VIEWS OF HERITAGE: THE IMPACT OF GLOBAL CLIMATE CHANGE ON CULTURAL HERITAGE

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While multidisciplinary research into the multivalent consequences of GCC is on-going, one anticipated result of GCC will include supply reductions of potable and non-potable water for drinking, irrigation, industrial, energy production, ornamental display and other uses. Since over 1.1 billion people currently do not have access to reliable, sufficient and safe supplies of potable water, the challenge of stretching an ever dwindling supply to meet an ever greater demand will become increasingly difficult. Global Climate Change will bear on both water delivery infrastructures as well as natural water resources. As water managers, policy makers and preservationists seek to fashion a comprehensive, multi-disciplinary solution to this potential crisis, re-examining the past may provide a key to establishing a constructive path forward. Since a remarkable and recurring fact of historic water delivery systems is that age doesn't necessarily negate serviceability or utility, there is merit in re-examining ancient water delivery systems for lessons in improving the sustainability of modern water delivery networks. The service life of historic water infrastructure can be extended and strategically integrated to assist modern communities in meeting their drinking water needs.

PROBLEM STATEMENT: Historic waterworks infrastructure should be preserved, whether operable or decommissioned, whether in whole or in part, whether above ground or below, whether in their purpose-built or adaptively used roles, because they inform modern water managers, policy makers, and preservationists of the heroic civil engineering achievements of the past realized in the face of needed social change. Wherever they were constructed – whether in ancient Rome or industrial-era New York – aqueducts were designed to deliver adequate and reliable supplies of potable water to consumers and their presence in urban communities consistently reduced outbreaks of disease and fire.

Amidst a 21st century culture of technological invention and infrastructural expansion, a commonly held mind-set amongst civil engineers that "new is better", unduly aggressive stabilization campaigns, and the political unpopularity of infrastructure spending, the survival of this aging, yet often unseen and silent utilitarian tissue has become increasingly vulnerable to unsympathetic alteration, abandonment, demolition by neglect and loss of collective public memory. In addition to these challenges, historic water infrastructures and networks (including dams, spillways, reservoirs, conduits, and pipes) will also face the potential multivalent threat of Global Climate Change. The consequences of escalating carbon emissions, increases in atmospheric surface temperatures, and green house gas accumulations could manifest in unprecedented sea level increases, reductions in potable water supplies, changing precipitation patterns, and increased frequency of extreme weather events (tornadoes, floods, droughts), among others.[1] According to the NYC Department of Environmental Protection's Climate Change Task Force, variations in the length of seasons could result in reduced snow pack, reduced water storage, reduced ground water and reduced surface water inflows to reservoirs.[2] Although there is certainty that Global Climate Change will be experienced worldwide, there is at present no conclusive evidence as to the magnitude and time horizon of these events, which will complicate efforts to forecast and quantify these effects on water infrastructures and distribution systems.[3]

Water – whether considered as a precious natural resource or in terms of capture and delivery infrastructures that contain and transport water – is receiving increasing scrutiny from policy makers, water managers, journalists and others. According to the World Health Organization, over 1.1 billion people do not have access to reliable, safe and sufficient supplies of potable water. If Global Climate Change could significantly reduce the quality and quantity of drinking water supplies worldwide, then the challenge of stretching an ever dwindling supply to meet an ever greater demand will become increasingly difficult.[4] Water-rich communities may find economic advantage in transporting water to distant end-user communities whose water resources are insufficient to meet local demand.

In the New York City area alone, over 9 million people rely on the 2,000 mile^2 (5179 km^2) watershed for their drinking water, and such reductions in supply caused by GCC would consequently impact per-capita demand unless conservation, waste reduction, recycling/reclaiming of wastewater, and modification of infrastructure become agency priorities. According to Dr. Peter Gleick of the Pacific Institute for Studies in Development, Environment and Security, despite advances in water quality, availability, and delivery systems, more than half the population of our civilized world today suffers with water services inferior to those of ancient Rome.[5]

According to American Society of Civil Engineers President Wayne Klutz, "Climate change is posing serious risks to the [critical] infrastructure systems that support our global economy, and…the ability of communities worldwide to prosper and thrive."[6] Since the majority of infrastructure in the U.S. was developed either a century ago or after the end of WWII, and since cyclical maintenance has often not been a priority, deferred maintenance has accelerated the decline of aging systems which could increase their vulnerability to the threats of GCC.[7]

Modifying historic water infrastructure which was engineered and built to meet technical requirements of a century ago or more to now meet 21st century challenges, including climate change, regulatory mandates, population distribution and zoning is referred to by DEP Commissioner Emily Lloyd as "designing infrastructure in the face of uncertainty."[8] The DEP Climate Change Task Force's 2008 *Assessment and Action Plan* admits: "Impacts [of GCC] could be significant…new climate and sea level extremes could be experiences that the systems are not designed to accommodate."[9] For instance, New York City reservoirs were never designed to provide rapid release during flooding events, so flood control measures reduce the supply and distribution of potable water. While managers of historic infrastructure contemplate strategic updates and modifications, preservationists must ask how such alterations can be made while respecting character-defining features, integrity and authenticity and how water management priorities can be balanced with preservation goals. Arguably, the preservation problem of GCC and its nexus with historic waterworks infrastructure is still being defined. Pro-active policies, guidelines, and best-practices approaches on sustainable stewardship regarding conservation and possible adaptive interventions in light of these threats must continue to be debated, not only within the international preservation community, but with the scientific communities of meteorologists, climatologists, marine scientists, policy makers, and other stakeholders as well.

If all climate extremes repeat themselves over time[10], it will be instructive for civil engineers, policy makers and preservationists to re-examine historic waterworks for lessons that can assist modern water management in meeting some of the future threats posed by Global Climate Change. This paper builds on previous research performed at the American Academy in Rome and at Columbia University and expands on-going dialogues by presenting case studies in New York, Rome, and Venice which illustrate four key points: 1) that the age of historic waterworks infrastructures doesn't necessarily negate serviceability or utility; 2) that historic waterworks infrastructures can be modified, repurposed, reactivated and re-integrated within active distribution systems to meet potable and non-potable water needs; 3) that historic waterworks infrastructures constructed prior to industrialization are inherently green, and 4) that capital investment in restoration and selective modern upgrades of historic waterworks infrastructure can extend purpose-built and public-service utility while retaining character-defining features.

AGE DOESN'T NECESSARILY NEGATE SERVICEABILITY OR UTILITY

Early in the morning of August 7th, 2009, in the Tribeca neighborhood of Manhattan, a 12-inch (30 cm) cast iron water main installed in 1870 ruptured, causing localized flooding, temporary evacuations and roadway closures, subway and bus service suspensions, and property damage. The failed main was part of a network of 6,500 miles (10,460 km) of waterworks infrastructure that delivers 1.35 billion gallons (5,110,306 m^3) of water daily. Steven W. Lawitts, Acting Commissioner for the NYC Department of Environmental Protection, attributed the water main's failure to old age: "Cast iron, particularly after many years of freeze-thaw cycles and street vibrations will [fail]…while we got almost 140 years usage out of it, its old and eventually they break."[11]

While it is uncertain what schedule of regular inspection and maintenance the failed cast iron main received, the Tribeca case highlights a widespread concern among water managers in the United States about aging infrastructure. In 2003, the Environmental Protection Agency conducted a survey of publicly owned and managed water systems in the U.S. and produced a report, *Drinking Water Infrastructure Needs Survey and Assessment Third Report to Congress.*[12] The report found that, after population growth and network expansion, the second greatest operational concern among public water system managers in the U.S. was the need to maintain and upgrade aging water system infrastructures. According to a 2001 study prepared by the EPA and the National Association of Clean Water Agencies, many of the water and wastewater systems in the US include infrastructures which were constructed a century ago or earlier.[13]

Despite the fact that the industry standard life span for infrastructure in the U.S. is 100 years, and that age can be a leading cause of failure, water managers and policy makers shouldn't necessarily assume that all aging infrastructure is on the verge of collapse or that the challenge of aging systems is best ameliorated by abandonment or replacement.[14]

Unlike many modern engineers who privilege new designs and technology, civil engineers of the past observed preservation opportunities when confronted with historic waterworks infrastructure. Specifically, these engineers envisioned rehabilitation programs that preserved as much historic fabric as possible while restoring abandoned infrastructure to its purpose-built use. For example, after surveying the ancient Roman Pont du Gard aqueduct bridge in Nîmes, France, civil engineer Fayette B. Tower (1817-1857) wrote in his *Illustrations of the Croton Aqueduct* that, "this structure, which has been out of use during fourteen hundred years, is still in such a state of preservation that it could be restored without a very great expenditure of money."[15] When Tower contemplated the ancient bridge, he didn't just see a monumental masterwork in stone which had survived centuries of decay. He recognized rehabilitation as pragmatic and economical with the goal of returning a disused, but valuable resource to public service. Tower's vision – that even ancient waterworks heritage can be an asset waiting to be realized – should inspire modern engineers to reassess the long-term utility and public service potential of hydraulic infrastructural heritage.

HISTORIC WATERWORKS CAN BE ADAPTED TO MEET MODERN NEEDS

The preservation, engineering, water management and policy making communities need to acknowledge the vast portfolio of waterworks infrastructure which already exists and the enormous investment in embodied energy which this heritage represents. Whether constructed to meet propagandistic, strategic, or civic-virtue purposes, monumental waterworks systems like the Aquedotto Vergine (dedicated June 19, 19 B.C.E) in Rome and the Croton Aqueducts (Old Croton 1837-42; New Croton 1885-91) in New York were built of durable materials according to engineering designs which anticipated their long-term serviceability. Consider that in Rome, an ancient aqueduct continues to function, while in New York, a mid-19th century aqueduct was decommissioned after only 123 years of use.

Comparing the two aqueducts' stewardship bears closer analysis. Within the same decade, spanning from 1955 to 1965, as NYC's DEP decided to de-activate a 41-mile long, gravity-fed, masonry-lined aqueduct which had been brought on-line in 1842, Rome's ACEA (Azienda Comunale Energia e Ambiente) surveyed and ultimately chose to repurpose a 2000 year old, 21-km (13 mile) long, gravity-fed, masonry-lined aqueduct which was deteriorated. During the post-war period in Rome, unregulated residential construction above the Vergine – and the associated absence of wastewater utilities – resulted in soil contamination, environmental degradation, infiltration, and structural damage which necessitated declassification of the aqueduct's water from potable to non-potable status."[16] Instead of abandoning or demolishing the aqueduct, ACEA undertook a structural reinforcement campaign and repurposed the aqueduct's water for ornamental fountain displays and the irrigation of public parks.[17]

The contrasts in management and long-term utility of these two aqueducts are startling. The Vergine's re-purposed use highlights a remarkable and recurring fact about many historic waterworks systems: namely, that age doesn't necessarily negate serviceability or utility.

HISTORIC WATERWORKS ARE INHERENTLY GREEN

Historic waterworks systems which were constructed before the advent of electrically-generated power benefit from energy efficiencies in delivery. Designed to operate 24/7/365, and relying on gravity to deliver water from source to terminus, these systems are inherently more energy efficient than employing a system that depends on mechanization. For example, aside from a 5% incidence rate of drought, New York's water supply is 95% gravity fed, necessitating a low dependence on and consumption of energy to meet demand.

Sustainable stewardship of pre-industrial infrastructure may become increasingly relevant within global conversations on emissions reduction and climate change. After decades of abandonment, a re-activated pre-Industrial masonry conduit delivers gravity-fed drinking water to a community in Westchester County. Etruscan drainage canals and subterranean tunnels, hand-carved from volcanic tufa over 2800 years ago, continue to irrigate agricultural fields north of Rome. Hand-drawn water from ancient springs in Bulla Regia provides an economically-viable alternative to modern private concessions for agrarian communities in rural Tunisia. Rainwater collected in underground cisterns supplements desalinated drinking water supplies in Malta and the Caribbean. And 19th-century masonry culverts in Westchester continue to divert streams from the extant aqueduct channel above. If GCC does reduce drinking water supplies to critically low levels, where survival of entire communities hang in the balance, policy makers and water managers may increasingly examine the construction methodology, engineered design, and environmental cost-benefit of historic waterworks infrastructure.

CAPITAL INVESTMENT IN RESTORATION/UPGRADE EXTENDS SERVICE-LIFE & UTILITY

That capital investment in restoration and selective modern upgrades of historic waterworks infrastructure can extend purpose-built and public-service utility – is illustrated by several examples in New York and Westchester County. In the decades following the DEP's decision to de-activate the Old Croton Aqueduct, the Department has engaged a Preservation Architect to consult on certain projects, and has demonstrably changed its tack in certain policy decisions affecting discrete historic water infrastructure elements under its purview. For example, in the Village of Ossining north of New York City, but south of the Croton Dam, a 3.5 mile (5.6 km) segment of conduit abandoned in the 1950s was re-activated in 1986. [18] Representing the only instance of Croton water delivery via the Old Croton conduit today, the village's 30,000 residents receive 63% of their drinking water from this source. [19] The re-opened conduit demonstrates how historic waterworks infrastructure can be successfully re-activated and re-integrated within water delivery networks.

The DEP has also demonstrated a commitment to rehabilitating and selectively upgrading the National Historic Landmark listed New Croton Dam. The monumental public work (constructed 1892-1903) features a 270'-0" foot (82 m) high dam and spillway with a storage capacity of 32 billion gallons (121133177 m3). The current project, which seeks to extend the Dam's service life by 50 to 100 years, will include preserving the historic dam and its associated structures, performing masonry repairs and cleaning, and rehabilitating water conveyance facilities. [20] In post-9/11 reality, the DEP has also recognized the security value of historic infrastructure in terms of creating redundancy within the system. The City Tunnel #3 – the largest capital construction project in New York City's history – was initially begun in 1970 and is expected to be completed in 2020 at a cost of $5.5 to 6 billion USD. [21] Although the ambitious project says more about the DEP in terms of capital expenditure priorities, planning and policy decisions made forty years ago, the tunnel will also allow for temporary closures and inspections of the two existing tunnels (dated 1917 and 1936) which haven't been closed in over 70 years. [22] While such redundancy may not have been a planning priority when construction began four decades ago, the opportunity to benefit from historic infrastructure in safeguarding the City's drinking water supplies is not lost on urban planners, engineers, and lobbyists today. These cases demonstrate that the service lives of historic infrastructure can be extended and strategically integrated to assist modern communities in meeting their drinking water needs.

CONCLUSIONS/FUTURE CURRENTS

For the foreseeable future, two of the greatest challenges confronting waterworks heritage will be the need for adequate and enforceable legislative protections for both sub-structural and super-structural components, and promulgating preservation management guidelines which sensitively balance preservation and water management priorities. Right now, in the United States, monumental, visible, publicly-accessible and above-grade waterworks heritage is privileged in terms of recognition, designation, protection and economic investment over the no-less monumental, but invisible, publicly-inaccessible, and below-grade heritage. Right now, in the United States, monumental, visible, publicly-accessible and above-grade waterworks heritage is privileged in terms of recognition, designation, protection and economic investment over the no-less monumental, but invisible, publicly-inaccessible, and below-grade heritage.

In addition to legislative challenges, there is a paucity of preservation management models for waterworks heritage which balance preservation and water management priorities – for both active and decommissioned heritage. Without such standard, uniform, and accepted guidelines, management of waterworks heritage will continue to be ad-hoc at best and destructive at worst. The challenge to promote the operability of existing infrastructure or the repurposing of decommissioned infrastructure must be met by water managers, policy makers, architects, and preservationists. Best practices charters, such as the *Nizhny Tagil Charter*, as well as preservation management guidelines for historic bridges, might be carefully assessed for their feasibility and applicability to waterworks heritage. For decommissioned heritage, procedures need to be established which assist municipalities in surveying out-of-use elements, assessing feasibility of adaptive use, and facilitating jurisdictional transfer of these buildings and sites to new owners bound by restrictive declarations to preserve character-defining features. Inter-disciplinary round table discussions that engage all stakeholders and which aim to codify such guidelines need to occur. All of these ideas underscore one of the *Nizhny Tagil Charter's* maintenance and conservation goals: that "Continuing to adapt and use industrial buildings avoids wasting energy and contributes to sustainable development."[23]

Amidst the challenge of Global Climate Change, management of historic waterworks will, of necessity, continue to demand alterations and upgrades. In some cases, ambitious projects which unite sustainable design and cultural heritage have already produced exciting results as evidenced by the City of Venice's response to Climate Change's threat. Venice is a city that has an intimate, unavoidable yet repeatedly strained relationship with water. The floods of November 1966, and the annual "acqua alta" events, have cumulatively wrecked incalculable damage – both tangible and intangible – to the city's architecture, infrastructure, and environment. Global Climate Change has contributed to increased tides, rise in sea level, drop in land level, and increased frequency and severity of "acqua alta" events. In response, the Venice Water Authority and the Italian Ministry of Infrastructure commenced work in 2003 on an innovative system of mobile barriers constructed in three strategic lagoon inlets. The MOSE system, as it is known, is one of the largest sea defense systems being undertaken in the world. When complete, MOSE will help Venice to withstand a rise in sea level of at least 60 cm (24 inches).[24] Ultimately, such a stunning model of sustainable stewardship – which boldly combines cutting edge technology and design to protect a World Heritage City and its infrastructure – should inspire water managers, engineers, policy-makers and preservationists throughout the world for years to come.

ENDNOTES

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[1] Lloyd, Emily. 2005. "Adapting New York City's Water Supply and Wastewater Treatment Systems to Climate Change." Lecture presentation. U.S. Climate Change Science Program Workshop. Water Management: Application of Climate Science. Washington, DC. November 15.

[2] Licata, Angela. 2005. "Climate Change and New York City's Water Supply." Lecture presentation. NYC Department of Environmental Protection, Bureau of Environmental Planning and Analysis. Licata reports that during the period spanning from 1900 to 2005, the average annual observed precipitation in the NYC region has increased 4.2 inches (9.9% increase). During the period spanning from 1920 to 2005, the observed annual mean sea level at the Battery in NYC increased approximately 0.85 feet or almost 1'-0" in 100 years.

[3] Licata, Angela. 2005. "Climate Change and New York City's Water Supply." Lecture presentation. Bureau of Environmental Planning and Analysis, NYC Department of Environmental Protection.

[4] According to the World Health Organization's *Global Water Supply and Sanitation Assessment 2000 Report*, 1.1 billion people were found to be without access to adequate, reliable and safe water resources and 2.3 billion people were found to live in water stressed areas.

[5] Gleick, Peter. "The Future of Water." Bone, Kevin, ed. 2006. *Water-Works: The Architecture and Engineering of the New York City Water Supply*. NY: Monacelli Press.

[6] "Civil Engineering's Role in Reducing the Risk of Climate Change." American Society of Civil Engineers, Canadian Society of Civil Engineers, and International Civil Engineers joint agreement on civil engineering and climate change. July 2009.

[7] Sullivan, John. 1998. "Study puts High Price on Fixing a Crumbling City." *The New York Times*. August 25. According to Samuel I. Schwartz, former Director of the Cooper Union's Infrastructure Institute and a former chief engineer for NYC's Department of Transportation, has posited that New York began to reduce spending on infrastructure maintenance after WWII, a condition worsened in the City's fiscal crisis of the 1970's and which in turn required increased future spending.

[8] Lloyd, Emily. 2005. "Adapting New York City's Water Supply and Wastewater Treatment Systems to Climate Change." Lecture presentation. U.S. Climate Change Science Program Workshop. Water Management: Application of Climate Science. Washington, DC. November 15.

[9] Climate Change Task Force. 2008. *Assessment and Action Plan: A Report Based on the On-Going Work of the DEP Climate Change Task Force.* Report 1. May.

[10] Wright, Kenneth R. 1998. "The Lessons of History - El Nino and the Fall of Empires: A Wright Water Engineers Report on Ancient Climate Impacts in the Andes of South America." *South American Explorer*, Number 53, Autumn.

[11] "Water Main Break Floods Section of Tribeca." *The New York Times*. August 7, 2009.

[12] http://www.epa.gov/safewater/needsurvey/index.html

[13] http: //epa.gov/safewater/needsurvey/pdfs/2001/report_needsurvey_2001.pdf

[14] Hevesi, Alan. 1998. *Dilemma in the Millennium: Capital Needs in the World's Capital City.* City of New York, Office of the Comptroller. August. Page 12. http://www.comptroller.nyc.gov/bureaus/eng

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[15] The 19th century American engineer Fayette B. Tower, who worked as an assistant engineer on the first Croton Aqueduct campaign in New York, prepared a narrative of the aqueduct's construction in 1843. In the preface to his book, *Illustrations of the Croton Aqueduct,* he surveys ancient aqueduct systems, particularly the Pont du Guard in Nimes, France. Tower, Fayette, B.1843. *Illustrations of the Croton Aqueduct*. New York and London: Wiley and Putnam.

[16] This undated, internal document was provided by ACEA staff at the Serbatoio del Gianicolo to the author. Regarding illegal settlements: in 1975 ACEA was entrusted with the task of expanding service to illegal settlements in peri-urban areas (called "borgate"). A decade later it became responsible for operating wastewater treatment. Extension of service to the "borgate" which ACEA previously served by tank, was an important contribution to Rome's sustainable development. Around 350,000 people live in 82 "borgate" accounting for 12% of the city's population and raw wastewater used to contaminate groundwater. See the 2005 Watertime: Case Study for Rome, page 6. For a discussion of the phenomenon of condo, or Rome's forgiveness of violators of municipal and state codes (incl. illegal construction, see Tung, Anthony. 2001. Preserving the World's Great Cities. Three Rivers Press, New York, page 66.

[17] Nicolazzo, Vittorio. 1998. *L'Acqua Vergine: E Suoi Acquedotti e le Fontane di Roma Attraverso I Secoli.* ACEA, Roma, page 207, and an undated internal ACEA document made available to the author.

[18] *Village of Ossining Comprehensive Plan,* 2007. Prepared by the Village of Ossining Comprehensive Plan Steering Committee with Philips, Preiss, Shapiro Associates, Inc., Planning and Real Estate Consultants. n.p.

[19] Annual Drinking Water Quality Report. 2006. Village of Ossining. http://www.villageofossining.org/documents/aqwr_2006.pdf

[20] NYC Department of Environmental Protection. 2008. "New Croton Dam Rehabilitation and Normal Pool Raise." Informational Presentation. Croton on Hudson Village Board of Trustees. June 16.

[21] http://www.nyc.gov/html/dep/pdf/factsheet.pdf

[22] http://www.nyc.gov/html/planyc2030/downloads/pdf/report_water_network.pdf

[23] For the complete text of the charter, see: http://www.international.icomos.org/18thapril/2006/nizhny-tagil-charter-e.pdf

[24] For more information about the MOSE system, see http://www.rtcc.org/2008/html/society-gov-4.html