Boston's Groundwater Crisis:

Seeking Sound Water Policies in an Unnatural Watershed

by

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I. Introduction

A Wake up Call

One morning in 1985 a Beacon Hill homeowner awoke to discover that he could not get out his front door. His home, sitting on wooden piles, had sunk. Hidden from view several feet below his basement floor, fungi, bacteria and possibly boring insects had been for several years consuming the exposed tops of the wooden piles supporting the building's stone foundation. Overnight the rotted piles reached the critical stage at which they could not hold the weight of the building. As the stone foundation collapsed through the rotted portion of the piles, the walls cracked and the front door sank below the front stair. Other old buildings along the lower edge of Beacon Hill, including Brimmer Street, also showed signs of subsidence. Engineers hired by Brimmer Street property owners confirmed that sinking ground water levels were responsible for the subsidence. [1]

¶Supporting most buildings constructed on fill before 1920 are tall wooden pilings which are resistant to rot if they remain submerged. They begin to decay if the water table falls and exposes the wood to oxygen. The legacy of Boston's pumping, damming and diverting of water and its paving over and tunneling under its streets, buildings and green spaces has irrevocably altered the natural flow of water above and below Boston. Over the years several large scale public works projects and smaller public and private efforts have been devised to maintain groundwater levels to protect wood

pilings. Other projects and practices in the same areas have been devised, which unintentionally counter these actions by removing or diverting groundwater to prevent roads, tunnels and basements from flooding. To understand the groundwater dilemma it is essential to understand the complexity of the environmental, engineering, social, political and legal parameters of the issue and the public and private stakeholders affected by any solution.

Wooden piles have been used for centuries to support buildings constructed on filled wet lands. Builders drove tall tree trunks through the fill to the more stable soils below the surface of the fill. As long as the wood piles remain submerged in water they are resistant to decay. In several European cities submerged wooden piles continue to support buildings constructed in the 13 th-16 th Centuries. Some foundation piles in Europe are 1000 years old. Nearly every building constructed before 1920 in Boston's filled areas—Back Bay, lower Beacon Hill, the Fenway, Bay Village, Chinatown, the Waterfront, the South End and parts of South Boston—was built on wooden piles. Among these are scores of public and private buildings on the National Historic Register.

Disappearing Groundwater: Crisis events 1929, 1985, 2003

Historic buildings on lower Beacon Hill were not the first in Boston to suffer damage from foundation piles exposed to rot by a declining water table. In 1929 large cracks appeared in the walls of the landmark Boston Public Library at Copley Square. Excavations revealed that 40 percent of its granite foundation was in danger of collapsing down through its rotting foundation pilings. At a cost close to $200,000 (in 1929 dollars), workmen dug out the fill surrounding the 30 foot tall pilings, sawed off the rotted tops and replaced the top five feet with steel supports. Both the lower Beacon Hill houses and the Boston Public Library sit on former tidelands filled in the 19 th Century to create new space for a growing city. Because filled wetlands are inherently unstable, all construction in filled areas must sit on piles driven through the fill and muddy bay bottom to more stable soil or rock. Until the early 20th Century, those piles were tall tree trunks 30-40 feet in length and by specification were to be cut off below the median low tide level (5.7 feet above sea level; this elevation is referred to as "Boston City Base" (BCB). Back Bay Engineers assumed that as long as the Charles River remained above BCB in elevation, wood piles would remain continually wet and thus safe from decay. They were wrong. Even thought the Charles has been kept high, water tables have fallen in many filled areas. Boston Building Department (now Inspectional Services) records show wood piling repairs were made to over 20 percent of the houses in a 10 block area of lower Beacon Hill in each decade from the 1920s to the 1980s.

In both 1929 and 1985 engineers were called in to track the disappearing groundwater. The suspected cause was the same in 1929 and 1985—leaky sewer lines located below the water table draining off the groundwater protecting the wood piles. In Copley Square the St. James Street sewer was deemed the culprit that exposed the library's piles to decay. When sand bags were placed at the bottom of the St. James sewer to partially dam the flow of water away from the library and Copley Square, groundwater levels in the Square rose to resubmerge the remaining wooden library pile. This fix also protected the 1500 structural wood piles underlying historic Trinity Church. [2] On lower Beacon Hill leaky sewer connections were also a key factor in altering the levels of pile-preserving groundwater. Unlike the 1929 depletion of groundwater caused by the leaky sewers draining water from Copley Square, the depletion along Beacon Hill resulted when the sewers connections *stopped* leaking sufficient water to maintain normal ground water levels. For years a faulty gate at the Charles River Dam had allowed harbor water at high tide to flow back into the sewer conduit, recharging the groundwater levels in the Brimmer Street area.

The sewer system diversion was only one of several suspected sources of groundwater draw down along lower Beacon Hill and in other historic Boston neighborhoods on "made land" created upon Boston's tidal flats between the 1820s and the 1880s. Underlying the visible city is a tangled underground network of dams, railroad, highway and subway tunnels, water and sewer pipes, utility conduits, basements and parking lots. It is Boston's non-water, subterranean infrastructure that appears to be responsible for the serious draw down of groundwater in other areas of the City.

Beginning in the 1980's following the construction of the Southwest Corridor, a below-ground subway and railroad transit route, water levels below adjacent historic row houses dropped, exposing foundation piles to air and thus rot. Independent engineers hired by residents have attributed the drawdown to the Massachusetts Bay Transportation Authority (MBTA). The MBTA has been pumping thousands of gallons of water per day from leaking corridor walls and diverting that water out of the neighborhood aquifers and into Boston Harbor via the sewer system. Recent groundwater well readings by the Boston Groundwater Trust—an entity headed by volunteers and created to monitor water table levels and propose solutions—found the lowest groundwater levels in the City in this South End neighborhood along the Southwest Corridor. [3]

Predicting the Groundwater Support Crisis

As early as 1894, just four years after the final rail cars from the suburbs had dumped their loads into the remaining Back Bay wetlands at Kenmore Square and one year prior to the formation of the Metropolitan Water District, City officials learned that groundwater flows were being artificially lowered through sewer leaks. [4]

A series of state and local water-related policies over the last 150 years, conflicting missions, cycles of engineering fixes and failures and the out-of-sight out-of-mind attitudes toward subterranean infrastructure has contributed to the sinking foundations of historic Back Bay, Chinatown, the Fenway, the South End and lower Beacon Hill. The engineered complexity and instability of the Central Boston landscape, the site-specific nature of the sources and solutions to groundwater depletion and the web of agencies with conflicting or overlapping jurisdictions has stalled cost-effective, timely solutions.

Responding to the Crisis

The stimulus to action in the last two decades has been litigation followed by recent federal and state law and policy promoting watershed-based, environmentally sound approaches to water management. To date the barriers to action are most prominently institutional missions and practices at odds with new water policies promoting local solutions to groundwater protection, lack of coordination and sharing of data among and within local and state agencies and the absence of a local or state government office or official for whom groundwater is the primary mission.

II. Methodology

The topic for this paper—groundwater depletion in Central Boston—was suggested to me by Scott Horsley, president of Horsley and Witten, a consulting hydrologist and lecturer in watershed issues at Tufts University and by Karl Honkonen, Director of Water Policy in the Massachusetts Executive Office of Environmental Affairs. Scott and Karl introduced me to the issue of groundwater depletion in Central Boston. Professor Sheldon Krimsky my advisor for this project suggested the structure and analytical approach.

The Boston Groundwater Trust (The Trust) has provided me with crucial insight into the context, scope and response to the problem to date. I am especially grateful to Trust co-chair Tim Mitchell the Back Bay neighborhood representative and Jim Stetson, the Beacon Hill neighborhood representative

for giving me detailed interviews and supplying documents not available on the Trust's web site and inviting me to Trustee meetings. The Trust's web site—managed by trustee, Galen Gilbert, the Fenway Community Development representative—was a rich source of original documents, illustrations and news articles tracing the groundwater crisis particularly in the Back Bay and Fenway. Also Toni Pollak, Commissioner of the City of Boston's Environment Department and a non-voting member of the Trust, provided insight into the City's role in groundwater management in interviews and at public meetings. Interviews were not formally structured. Interviewees were asked to define their organization's mission, how that mission affected their approach to watershed issues in general and Boston groundwater depletion in particular and what level of coordination and cooperation they received from other organizations dealing with or contributing to the problem.

The Trust's web site, www.bostongroundwater.org, provided crucial scientific and historical data. Original source documents, included key engineering reports commissioned by public agencies dating from 1941 to 1990 and Boston City Council testimony prior to the passage of the ordinance creating the Trust as well as the full text of the ordinance. The Commonwealth of Massachusetts web site provided summaries and full text of state water management laws and policies. Mission statements, lists of priorities and annual reports posted on the public web sites of the stakeholder institutions supplemented or refined information from other resources.

Two recent volumes of Boston history covering Boston's land making practices and controversies from Colonial times to the present were especially helpful in understanding the sequence of events leading to the current crisis. These texts, *Mapping Boston* [5] and *Inventing the Charles* [6] were a rich source of visual material and significant details on the filling of sections of Boston. Two key engineering reports, *Back Bay Boston part II*, *Groundwater Levels* [7] by Aldrich and Lambrechts published in 1986 by the Boston Society of Civil Engineers and *Report on Groundwater Observation Wells* for the Inspectional Services Department of the City of Boston [8] by Brown and Taylor for Stone and Webster Civil and Transportation Services in 1990 were key sources of geological and hydrologic data determining the consequence of filling Boston's tidal areas and the unintended consequences of each remaking of Central Boston's topography and the infrastructure to accommodate it.

With the exception of seven in-person and telephone interviews and two public meetings, I conducted the bulk of my research on line. Of the academic research tools available to me, the Lexis Nexis Academic Service delivered the most Boston-specific groundwater hits, however most hits

were news articles, the majority of which were also available on the Trust's web site. Using more general search terms, such as "subsidence" and "water" on the FOCUS(tm) database I was able to locate legal articles on liability for groundwater depletion in other states. Searches for specific agencies such as "Boston Water and Sewer" on Focus brought up articles from engineering publications that were only peripherally related to Boston's groundwater crisis. Other science databases had many articles related to worldwide water shortages and groundwater crises in the far West but little related to "wooden pile foundations" or the chemistry of "foundation pile rot". The publicly available, Google search engine at www.google.com was consistently more productive than any others that I tested in a variety of disciplines, including law, government, politics, geology, hydrology and history, related to "groundwater depletion" and building foundations in Boston, Massachusetts, the United States and Europe.

This paper is organized into seven sections including this methodology section (Section II). Section I defines the Boston groundwater crisis in terms of three key pile damaging events that re-awakened demands for government action. Section III provides the legal framework regarding water policy that allowed the sequential filling of Boston's tidal flats and charted the state's and city's responses to the consequences of that filling. Section IV presents a chronological account of the leveling and extension of the landscape that resulted from the Commonwealth's and Boston's policies and laws detailed in Section II. Section V is organized by affected entities, individuals and organizations whose water policies and perspectives have led to at times cooperative and at times conflicting responses to the problem. The final sections survey and evaluate solutions proposed since the founding of the Trust and offer a watershed framework for developing more comprehensive, coordinated solutions to groundwater depletion and related issues of water pollution and flooding.

III. Law and Lawsuits: Framing Responses to Groundwater Depletion

Colonial water policy of wharfing-in and damming

The legacy of over 300 years of minimal groundwater management in Boston has lead to reduced groundwater levels despite more than adequate rainfall. Within a few years of the 1630 settlement of the Shawmut Peninsula (soon renamed Boston) by the Puritans, practices and policies were put in place that would constrict and pollute its waters and forever alter its hydrology.

The Massachusetts Bay Colony's General Court (the legislature) approved a series of structures that blocked the natural flow of water in Boston's rivers and bays. Slowing the flow of the Charles River was a grist mill dam erected in 1634 at the site of a 1632 fish weir at Watertown Square where the salty bay tides met the fresh water Charles. A second grist mill dam, built in 1643 in the North End of Boston, stretched from Prince Street to the West End (now Causeway Street) converting a harbor cove into a stagnant "mill" pond.

The Massachusetts Colonial Ordinances of 1641-1647 which promoted commerce by the building of private wharves along the harbor contributed to the inexorable destruction of Boston's extensive salt marshes and tidal flats. The laws allowed any coastal land owner to fill in wetlands adjacent to his land and then take title to the "made land" which could extend out to the low tide line or 1650 feet from the high tide line which ever was shorter. Boston's "wharfing-in" policy encouraged owners to fill the space between adjacent wharves and then build new wharves extending out into the harbor from the made land. [9]

By the early 1700s Boston had 40 wharves and was the largest city in the Colonies. By the last decade of the 1700's the state had authorized canal building, bridge building and the filling of lower Beacon Hill, all of which further altered water flow within the watershed. Two more mill dams in Back Bay (1820, 1828) and two rail road bridges (1830) crossed the tidal flats trapping sewage-laden run off between the man-made structures and the shoreline. In addition to blocking the natural flushing action of the tides these structures would later turn out to impair groundwater flow when the wetlands behind them were filled.

Surrounded by water and blessed with abundant rain, Boston like its English cousins demonstrated little interest in public oversight of groundwater. Massachusetts adopted the "English Rule" also known as the "Absolute Dominion Rule" or "Absolute Ownership Rule" based on an 1843 case

decided by the Court of the Exchequer in Acton v. Blundell. [10] According to this view, groundwater is the sole property of the owner of the surface land above it with no limits on removal and no liability for polluting groundwater. If pumping groundwater from one's own land depletes the water levels below a neighbor's property, even if the intent is "malicious" no damages can be assessed. Only "intentional well poisoning" is subject to prosecution. [11]

Groundwater law in the United States is for the most part state law. Federal law has been principally directed at preventing pollution and maintaining safe drinking water. The five "rules" that generally guides state judges and officials range from the least restrictive rule for property owners Absolute Dominion (8 states) to the most restrictive, "Prior Appropriation Doctrine" generally defining groundwater as a public resource to which private individuals may have permitted access (12 states). In between, from less to more restrictive, are the Reasonable Use rule (21 states), the Correlative Rights rule (6 states) and the Restatement of Torts Rule (3 states) .

Only eight of the original 28 states still follow the Absolute Ownership Rule. The adherents of this weakest of the groundwater protection traditions in addition to Massachusetts are Connecticut, Indiana, Louisiana, Maine, Mississippi, Rhode Island, and Texas. In Texas the rule is also known as the "Big Pump Theory," because the owner with the biggest pump has the legal right to pump dry his neighbors' water supply. Vermont abandoned the Absolute Ownership Rule in 1985. Based on the "Correlative Rights Rule" Vermont's groundwater law now reads, "It is hereby declared to be the policy of the state that the water resources of the state shall be protected, regulated and, where necessary, controlled under authority of the state in the public interest and to promote the general welfare." In the arid state of Idaho which follows the Prior Appropriation Doctrine groundwater is the property of the state. [12]

Because in Massachusetts the removal of groundwater that leads to structural damage of adjacent buildings is not cause for legal action, plaintiffs lawyers have relied on "the law of adjacent support" [13] to sue for damages. In a series of Massachusetts cases from 1896-1958 only those cases where negligence [14] could be proved did the courts find for those injured by lowered groundwater. [15]

In 1958, in Gamer v. Town of Milton, Massachusetts, the court stated "[I]t, is, of course, settled in this Commonwealth that a landowner has absolute ownership in the subsurface percolating water in his land. He may use it as he sees fit, even if this results in a loss of water in his neighbor's land." [16]

With the passage of the Federal Clean Water Act in 1972 surface water polluters were no longer immune from liability. Groundwater polluters lost their immunity from prosecution and liability for cleanup costs with the passage of the 1976 Federal Resource Conservation and Recovery Act and the 1979 Massachusetts Hazardous Waste Management Act in 1979.

In 1980's exceptions were made by the Massachusetts legislature to the Absolute Ownership Rule. The Interbasin Transfer Act (1984) restricts the removal of surface and groundwater from one watershed to another. A 13-member Water Resources Commission set up in the Executive Office of Environmental Affairs (EOEA) and chaired by the EOEA Secretary implements this act. The Water Management Act (1985) regulates groundwater withdrawals. Currently, users removing more than 100,000 gallons per day must register with the state. The Act also gives the Department of Environmental Protection authority, as yet unexercised, to regulate smaller volumes of water. Because these water management laws exempt existing uses from regulation, many large volume withdrawals continue, depleting surface and groundwater supplies across the state.

Litigation Spurs Action: The court-ordered Boston Harbor clean-up and groundwater depletion

In 1983 the non-profit, Conservation Law Foundation (CLF), sued the Commonwealth of Massachusetts and the United States Government to clean up Boston Harbor. CLF asserted that the Metropolitan District Commission (MDC) had been illegally dumping millions of gallons of raw sewage into Boston Harbor and the Environmental Protection Agency (EPA) had failed to enforce the federal Clean Water Act against the MDC. The town of Quincy, downstream of the MDC's raw sewerage dumping, had filed a similar suit the year before. After a state superior court judge threatened to put the MDC in receivership, the legislature passed a law creating a new entity, the Massachusetts Water Resources Authority (MWRA) which replaced the MDC as the defendant in the case. As the case moved to federal court the EPA joined the suit against the MWRA. CLF got the agency it had lobbied for—"an independent, de-politicized water and sewer authority, with its own authority to borrow and raise funds", to "allow more sound fiscal management." David Mazzone, the federal district judge overseeing the case ordered the clean-up measures that the CLF and the MWRA proposed—the building of a new treatment plant and a 9.5 mile outfall tunnel under the harbor to transfer massive amounts of sewage and stormwater from local watersheds in the 43 communities served by MWRA out to Massachusetts Bay. [17] The MWRA's centralized cross-watershed model of storm and wastewater management did not address the long term effects of such a model on groundwater levels. The plan was not one according to state water

policy manager, Karl Honkonen [18] , that his office would condone today. The plan also countered the state's policy of "keeping water local" as defined in Massachusetts state law passed just two years before the judge's order.

Brimmer Chambers Condominium Trust v. Metro Dist. Commission

Creation of the Boston Groundwater Trust

When the Charles River Dam (built in 1910) was breached by the hurricanes of 1954 and 1955 causing an estimated five millions dollars in damage along the lower Charles calls for improved flood control brought out the Army Corps of Engineers and others to draft a large-scale engineering solution. In 1962 the legislature approved the building of a new dam east of the existing dam. The new dam, its locks and pumping station were constructed from 1974-78 as a joint effort of the U.S. Army Corps of Engineers and the MDC. [19]

As the project neared completion, nearly a mile upstream from the new dam at the Church of the Advent on Brimmer Street along the flats of Beacon Hill a groundwater monitoring well showed significant new water level depressions. During 1980-81 when the new dam was officially put into service, groundwater levels at the Brimmer Street well had dropped 3-5 feet below the tops of the wooden piles supporting the church. Testing done by the geotechnical engineering firm of Haley and Aldrich in 1977 for a home buyer on Brimmer Street found his building's wood piles to be sound. But when Haley and Aldrich was called back to the house in 1984 after cracks appeared in the brick walls, a new excavation found pile tops that had been sound in 1977 were now rotted. One re-tested pile was rotted through more than half its diameter. Nineteen buildings (65 households) had wood pile damage and cracks in the exteriors or interiors of their buildings. [20]

A group of Brimmer Street property owners then hired Haley and Aldrich to investigate the extent and causes of the damage. In his paper describing "the forensic study undertaken to determine the causes" of the rotted wood piles, James Lambrechts, Vice President of Haley and Aldrich, describes his investigation as "a cooperative effort with the Metropolitan District Commission and the Boston Water and Sewer Commission." Records of the new dam constructions demonstrated that the principal cause of the drawdown at Brimmer Street was related to dam construction. The flow in the MDC's marginal (sewer) conduit, which collects stormwater flows from the combined sewer (and stormwater) overflow (CSO) conduits and delivers their contents to the harbor, had been rerouted to a new well and pumping station across the river. As result of this engineering design, the marginal conduit "was practically empty all the time." What had kept the Brimmer Street piles submerged and was now gone was the "tidal backflow" that the

old dam gates allowed in each day at high tide, submerging the Brimmer St. piles and protecting them from rot. The engineer who designed the sewer diversion to reduce flooding was aware that the new system also would prevent tidal recharge to Beacon Hill, but his employer, the MDC, did not report this information to Boston authorities or affected property owners. The MDC's failure to disclose this data was a key piece of evidence in the plantiffs' charge of negligence.

By 1987 when the Brimmer Street property owners had identified the cause of their groundwater draw down and had spent up to $200,000 per property to repair their rotted piles, the Greater Boston water system had been reorganized. The homeowners then sued not just the MDC, but also the its replacement, the Massachusetts Water Resources Authority (MWRA), as well as the Boston Water and Sewer Commission (BWSC), whose leaky CSO conduits were draining off groundwater, and the City of Boston which appoints the BWSC Board. The case was settled in 1992 and the verdict was sealed. The defendants agreed to reimburse the plaintiffs for two thirds of the costs of replacing the tops of their rotted pilings with steel and concrete piles. [21]

The Boston Groundwater Trust Ordinance

As the litigation was brewing over Brimmer Street in 1986, Boston City Councilor David Scondras representing Back Bay, Beacon Hill and the Fenway, authored an ordinance creating the Boston Groundwater Trust to monitor groundwater problems and seek solutions. Concerned that the trust's structure would increase the city's chances of being sued, Mayor Raymond Flynn, delayed, then signed the ordinance. The Trust's task as defined by the ordinance was "to promote the public health, convenience, and welfare by monitoring groundwater levels and making recommendations to raise the water table in areas where it is low to protect wood pile foundations." To limit City liability and expense the Trust's board was composed primarily of volunteers and was given the power to accept and spend donations for engaging experts to dig monitoring wells, analyze the well data and recommend solutions to the City. Three members of the 10 member board were to represent citizens organizations one each from Beacon Hill, Back Bay and the Fenway. Four members were to represent Boston business interests, one each from the Greater Boston Real Estate Board, the Coordinating Committee (a.k.a. "The Vault"), the Beacon Hill Civic Association and the Back Bay Association. Four "ex-officio" members were to represent the City, a City Councilor, the City Treasurer, a Department of Public Works civil engineer and the Commissioner of Inspectional Services. [22]

In December of 1989 Councilors David Scondras and James M. Kelly (Chinatown-South Boston-South End) introduced a bill to strengthen the City's response to groundwater draw downs threatening pile foundations. The bill would require the city to takes readings at existing city monitoring wells, employ an engineer to interpret the readings and recommend solutions when data indicated a groundwater depression affecting wooded foundation piles. (The ordinance would require the City to assign paid professionals and fund the tasks the Groundwater Trust had to manage with volunteers and indefinite funding.) The City Council voted unanimously to pass the ordinance. On the advice of the City's Corporation Counsel Joseph I. Mulligan, who warned of multi-million dollar law suits, Mayor Raymond Flynn vetoed the measure. "From the lawyers' point of view, the city should do nothing about anything ever," Scondras said. "We might get sued if we deal with the groundwater problem, but if we don't, we'll have buildings falling down." [23]

In 1989 four buildings with pile damage on Hudson Street in Chinatown were condemned and demolished. The area is vacant lot today. In 1998 an apartment building serving moderate income residents on Hemenway Street in the Fenway was torn down. The owner claimed that the expense of replacing the rotted piles to save a building with moderate rents was not economically viable. The site is a playground today.

The Push-Pull Effect of Litigation

The Brimmer Street litigation pushed the City of Boston to create a legal entity, the Boston Groundwater Trust to involve stakeholders and city officials in identifying and dealing with future threats to Boston's historic filled neighborhoods. Underfunding of the Trust halted the monitoring effort for several years. The litigation had a less positive effect on the Metropolitan District Commission and the Boston Water and Sewer Commission which had cooperated in pinpointing the causes of the Brimmer Street drawdown but became reluctant to share additional data that they feared would lead to litigation. The MDC (now split and reorganized into several executive departments as of June 30, 2003) continues to pump water out of its Storrow Drive underpass depressing water table levels on lower Beacon Hill.

Homeowners in the Ellis neighborhood in the South End, a new crisis spot with exposed piles, hired engineers who have attributed the water table drawdown to the Massachusetts Bay Transportation Authority's (MBTA) pumping of groundwater from its leaking transportation tunnels. [24] Citing fear of litigation the MBTA has refused to divulge the results of their testing to date, citing problems with the flow gauge. They promise only to address the

problem if their revised testing conducted by engineers they have hired show the MBTA [25] to be responsible.

IV. The Historic Context: Boston's Unnatural Landscape

Transforming the Ecology of Boston Basin: 1632-1890

The peninsula that would become Boston was a hilly, forested landscape edged with deep bays and small coves when the first English explorers sailed into Massachusetts Bay in the15th Century. Its aboriginal inhabitants had named the irregularly-shaped, three-lobed, peninsula "Shawmut" meaning "fountains of living waters".

Shawmut's extraordinary beauty and abundant fresh water springs, not its economic potential, drew its first English settler, William Blackstone in 1625. [26] Its five hills defined the skyline. The English called the small peninsula Trimountain after either the three linked peaks, (Beacon, Mount Vernon and Pemberton) along the inner bay or the Beacon peaks plus Copps Hill in the North End and Fort Hill at the edge of South Bay.

The security afforded by the hills and the thin, easily-defensible neck of land joining the peninsula to the mainland attracted a community of Puritans lead by John Winthrop to join Blackstone in 1630. Winthrop and his company had settled first in Charlestown but many of the group had become ill. The blamed their sickness on the poor quality of water they drank in Charleston. The forested hills of Trimountain served to absorb and filter the area's abundant rainfall into clear springs and into fresh pools at the base of the hills. Trimountain's broad tidal basins supplied the settlers with fish, shellfish and marsh hay for livestock. Just a few months after Winthrop's arrival, the Puritans renamed the peninsula, "Boston."

The settlers clustered their homes and businesses around the harbor in Boston's fist-shaped North End (a peninsula within the peninsula). The original Boston was only 783 acres. Its narrow mainland connection, "Boston Neck" (now Washington Street) was occasionally under water at high tide making Boston a temporary island. At low tide great expanses of marsh and mud were revealed. At high tide the briny bay water reached inland nearly 8 miles up the tidal Charles River to the fresh water Charles at Watertown Square. Colonial Boston was dependant on the sea and its bays for food, fodder, transportation and trade. Ferries moved people and goods around Boston and from Boston to other settlements, including nearby Charlestown and Cambridge. Ships carried goods to and from England.

Characterizing Boston's original landscape in its Open Space Plan: 2002-2006 the Boston Parks and Recreation Department says Central Boston "has changed more than any other city in the country." [27] The Eleventh Edition of the *Encyclopedia Britannica* in its entry on Boston described it as "subject to changes greater than those effected on the site of any other American City". [28]

Early settlements expanded along the eastern harbor (East Cove) framed by Fort Hill on the south, Copps Hill (as know as Cops, Corps or Snow Hill) on the north and Beacon Hill to the west. The settlers grazed their animals in the rich salt marshes from East Cove to South Cove. They cut the salt marsh hay along Boston Neck for fodder. With a grant from the General Court they placed a stone weir across the Charles River at what is now Watertown Square to capture fish returning up the river to spawn. In 1634 they erected a mill to grind wheat into flour above the weir at Watertown Square where the fresh water met the tidal estuary. The Watertown mill was the first of dozens of mill dams constructed along the River and in Boston's bays.

Taming, Fouling, and Filling

By 1656 Boston's river and harbor waters had been fouled by indiscriminate dumping. To reduce refuse into the Charles River estuary and Boston Harbor, Boston designated the North Street bridge area as the sole location for dumping garbage and animal parts.

Well into the 1700s water remained the primary means of transportation for Bostonians as the state legislature turned down proposals for bridges and canals to connect northern towns to Boston. The construction of Long Wharf in 1711 further defined Boston as a seaport city. But by the end of the century approvals were given, canals were dug and bridges built to connect Boston to the interior. In 1786 the Charles River Bridge replaced the Charlestown Ferry. In 1795 the Causeway Bridge from Cambridge St. in Boston to Pelham Island in Cambridge was completed. Bridge footings interrupted the normal flow of tide water in the Back Bay. Until the late 1790's the original contours of Boston had changed little from the 1630s. Wharfing-in of shallow coves had fattened and rounded the shoreline. Boston Neck had thickened with fill on its south side, burying many acres of salt marshes.

Leveling Trimountain

In 1799 the first of the Boston's great earth moving projects began with the lopping off, one by one, of the Trimountain peaks. Laborers carted off the top 60 feet of Mount Whordon (named by British troops and renamed Mount Vernon by real estate speculators hoping to sell house lots). The peak of

Mount Vernon was dumped at the bottom of the hill creating Charles Street and Chestnut Street. In the early 1800s, Boston's town meeting, over the objections of many citizens, approved the removal of Beacon Hill's peak to fill the stagnant Mill Pond. Cut off from the sea in 1643, the Mill Pond had become fetid from 60 years of dumping and some residents were happy to have it covered. The top 60 feet of gravel from Beacon Hill proved insufficient to fill the former cove. Twenty one years later, after the dumping of load after load of mud from nearby tidal flats, the pond was filled and developed by Charles Bullfinch [29]

By decapitating its hills to expand its flatlands Boston destroyed the natural Trimountain topography that had effectively captured, filtered and stored groundwater and removed waste. With the loss of the hills and the extension of low lands, there was no longer sufficient velocity to push wastewater off the hill out and away into bay with the high tide. With insufficient potable water, Boston began the 100-year journey moving farther and farther inland for its drinking water and farther out to sea to dispose of its wastes.

The seeds of Back Bay's destruction as an estuary were sowed when the legislature chartered the Boston and Roxbury Mill Corporation in 1821 to build two power mill dams across Back Bay, in part to replace the mill lost by filling in the City's first mill pond. The dam's proponents claimed they would generate enough power to compete with North York's City's power developments and prevent the loss of manufacturing business to New York.

Many Boston residents predicted that damming Back Bay would make a bad situation worse. A letter to the editor of a local newspaper said the land behind the dams, cut off from the tides, would be "an empty, mud-basin, reeking with filth, abhorrent to the smell and disgusting to the eye." [30] The critics were correct. When the addition in the 1830's of two railroad lines crisscrossing the flats, raw sewage from the Muddy River and Stony Brook was trapped behind the dam and trestles. The dams never produced much power but effectively closed off the Back Bay's tidal flushing action. [31] Some property owners took advantage of a dike built by the city behind the dam and extended their shoreline property by filing in behind the dike. The ruined bay was ripe for filling.

The Public Health Model: Moving Water out of Back Bay

In 1850 Lemuel Shattuck, delivered his first "comprehensive report on public health published in the United States in which he proclaimed, "Every house should be supplied by water." And "[d]rains and sewers should be made to carry off water introduced in any way into cities and villages." Shattuck lobbied with developers and the Boston Health Commission for the grand

engineering systems approach to sanitation to remove breeding grounds for disease. [32] Piping rainwater as well as wastewater out of the watersheds in which they were generated contributed to the loss of groundwater and stressed ecosystems.

Just 6 years after Shattuck's pronouncement, in the 1856 Tripartite Agreement, the City of Boston, the Commonwealth and the Boston and Roxbury Mill Corporation negotiated the ownership of the Back Bay land to be filled. The Bay was to be filled to an average depth of 20 feet with the hills of Needham. Streets were to be filled to Boston City Base (BCB) elevation of 17. Filling lots at nearly 12 feet above the mean tide was to allow basements to go below ground level and remain dry while allowing a high enough water table to keep wooden piles wet and safe from rot. By 1882 the main filling of Back Bay was finished and 450 areas of wetlands had been filled.

Water Supplies Move West as Waste Water Moves South East

First Metro Boston sewer system: diverting groundwater

Building homes on filled low lands does not afford the benefit of gravity to move waste away from properties; thus, engineering drainage systems are required. With the settling of the fill, drains can crack at their connection points causing sewerage to back up. In 1876 the Massachusetts legislature approved the construction of the First Metro Boston Sewer System (also known as the Boston Main Drainage System). From 1877 to 1884 the system was built to move sewage from 18 cities and towns, deliver it to holding tanks on Moon Island in Boston Harbor and on the outgoing tide pump the untreated sewerage out to sea. In 1889 the Metropolitan Sewerage District (MSD) was created by the state legislature. The MSD drains were designed with underdrains to remove groundwater during construction. These underdrains were underpinned with wood timbers that could settle and crack over time causing cracks in the sewers drawing groundwater into the sewers. More problematic to this day are the remaining underdrains which, after sewer cracks are repaired, continue to channel groundwater away from foundation piles.

Drawing good water from elsewhere: diverting attention from Boston's groundwater

By 1795 inadequate supplies of clean water in Central Boston (settled for its abundant fresh water) led the city to create one of the first municipal water systems in the colonies, piping fresh water from Jamaica Pond through wooden pipes a few miles to the central city. By 1840, the water had

become polluted and inadequate in capacity to supply Boston's needs, including fire fighting. In 1845 the city tapped Lake Cochituate 17 miles to the West until that supply proved inadequate. The Boston Water Board moved 25 miles from Boston damming the Sudbury River watershed. As indoor plumbing grew in popularity, still more water was needed. This time Boston opted for a regional solution and in 1895 the Metropolitan Water District was formed to supply 29 municipalities within a 10 mile radius of the State House. The Metropolitan Water Board flooded 6 miles of rivers in four towns to create the Wachussett Reservoir. Finally in 1926 the Swift River, 65 miles west of Boston, was dammed flooding 4 towns to create the Quabbin Reservoir now managed by the MWRA. [33]

Transportation Tunnels

Boston constructed its first subway in 1897 tunneling one half mile from Park Street under the Boston Common to Boylston St. As the lines and stations multiplied, tunnels crisscrossed the filled areas of Boston. Early tunnels were supported by wood piles subject to the same settling problems as water conduits. When cracks develop in a transportation tunnels (subway, intercity rail line, automobile underpass or highway tunnel), water leaks in and the pumps come out, drawing down groundwater in adjacent areas.

Infrastructure as Barrier to Positive Groundwater Flow

The developers of Back Bay did not account for the barrier effect created by the old mill dam (running below Beacon Street) which is one of several pieces of infrastructure preventing Charles River water from following its natural path to fill the top level aquifers in Back Bay. Each new underground structure below the water table and running parallel to the River has contributed to the diminished flow. These structures include but are not limited to the marginal sewer conduit, old railroad trestle foundations and Storrow Drive underpasses. (Many Beacon Hill and Back Bay residents opposed the MDC's four-lane Storrow Drive project. It passed by only one vote in the legislature in 1949.) Many water pipes, sewers and subways tunnels have been abandoned and their whereabouts unrecorded. In some areas foundation builders cut corners by cutting off wood foundation piles above the prescribed level. Boston's underground history poses a difficult challenge to the stakeholders for whom the resolution of the groundwater dilemma is essential for the preservation of the City's architectural heritage.

V. The Stakeholders: Conflicting Missions and Interests

Property Owners and Sellers' Perspectives

At a public meeting on June 25, 2003 [34] called by the Boston Groundwater Trust, State Representative Byron Rushing, an African American, told the 90 or so assembled stakeholders that he was as frustrated as they were that the groundwater problem that has persisted during his entire tenure in office was not solved: "I've been the representative from the South End for 20 years. It is amazing to see middle class white people ignored by the City."

Rushing's political exaggeration drew laughter and applause from homeowners frustrated at the lack of solutions offered at the meeting to quickly halt the decay of wood piles supporting their homes. At least some government officials were not ignoring homeowners. Boston's Environment Department Commissioner, Toni Pollak, who was chairing the meeting and state Water Policy Director, Karl Honkonen were attempting to bring together the state and local agencies and departments involved with the groundwater problem. Honkonen explained the four steps the state was supporting to address the problem: meetings, monitoring, ongoing development projects and environmental bond funding for groundwater monitoring ($1,600,000 over next the 2 years; with $500,000 in process). The Boston Groundwater Trust announced the letting of a contract to drill 31 new monitoring wells and restore three existing wells in each of the problem areas where wood pile foundations were vulnerable to groundwater drawdown.

An Ellis Neighborhood Association member whose South End home is in one of the "hot spots" wanted his piles re-submerged, not more monitoring wells. "Rome is burning," he said. "In 3 to 5 years our piles will be fully rotted….Recharge worked in 1985. Require developers to return groundwater into the ground." Several owners suggested small scale recharge projects such as capturing storm water from roofs and diverting it to backyard and neighborhood dry wells rather than sewers.

One man cited the problems of elevator pits "and sump pumps removing water into sewers. Couldn't this be part of inspections? he asked.

"We have to make it a priority to come up with solutions," said Rep. Rushing. "Maybe we should all go home and start digging."

Some South End homeowners had already started digging and they were none too happy with the results. In November of 2002, Haley and Aldrich, geotechnical engineers, reported that wood piles on Saint Charles Street

they had tested in September 2002 were "above the water table and rotting, although still structurally viable." A second engineering firm dug a test pit to view the piles running along shared walls of other row houses on Saint Charles Street and found as did Haley and Aldrich that piles were exposed and rotting.

One Back Bay resident, complained, "it's a government problem because water flows. We don't hear the mayor. We don't see it in the newspapers. If this isn't solved we have no tax base. We have no city. The mayor has to say that to the Governor. Leadership has to happen at that level.

Another Back Bay resident was "astonished at the lack of urgency.

A third complained of a "profound lack of solutions" and demanded to know, "what are the specific next steps?"

" One homeowner wondered, "What happens if we refuse to pay our taxes?"

Alan Fink, a Coldwell-Banker Real Estate agent and former builder who has sold real estate in Back Bay and South End for last 10 years, spoke of being "increasingly concerned about the structural integrity of the properties we're selling. I think we have a tremendous liability." He noted that one building he had sold in Braddock Park "showed no evidence of settling, including its common walls", but the opposite wall of that adjacent building "was settled." "All pilings need to be tested." He also reminded property owners of the complicating fact that many owners have rented basement apartments or sold them as condos: "All over the city we have ground floor [below street level] condos with pilings only two to three feet below living areas now; recharge will lead to flooding."

Matt from the South End, complained, "This is the fourth meeting. Are there specific tasks to do? Can't there be something done immediately in hot spots?"

Toni Pollak responded that was "the point of the [planned] interagency meeting" to bring together all the state and city players, most of whom had not managed to attend that evening's meeting. She had invited many of the government players to the meeting, but only the Massachusetts Bay Transportation Authority (MBTA), had sent a representative, John McSweeney, Director of Operations Support. Missing from Boston City government was the Boston Water and Sewer Commission, Inspectional Services and the Boston Redevelopment Authority. Missing from the State were the Massachusetts Water Resources Authority, the Metropolitan District

Commission (MDC) and the Massachusetts Turnpike Authority (also responsible for the Big Dig).

City of Boston Government Stakeholders

The Boston Groundwater Trust

The Boston Groundwater Trust (The Trust) is the one public entity whose only mission is to focus on groundwater levels in Boston. Its "Declaration of Trust" requires it to monitor conditions that may threaten buildings supported on wooden piles and based on that knowledge recommend solutions to the City. The volunteer members of the Trust, all appointed by the Mayor of Boston, represented the dominant neighborhood and business groups in the threatened areas: the Back Bay Civic Association, the Neighborhood Association of Back Bay, the Fenway Community Development Corporation and the Greater Boston Real Estate Board. All live or work in the affected areas. Most own properties that sit on wooden piles. The original ordinance, however, did not provide for a trust member from the South End, the neighborhood currently suffering the most acute drawdowns. The initial ex-officio members of the Trust were the Inspectional Services Commissioner, a DPW civil engineer and the City Treasurer. Inspectional Services Commissioner William Sommers worked closely with City Councilor David Scondras to plan The Trust.

Five years after the Trust's creation in 1986 by City Council ordinance the Trust had become inactive due to lack of funding for installing the monitoring wells called for in the ordinance. As Councilor Scondras, the original backer of the Trust legislation and the first Council representative to the trust, noted in 1991, "the important always gets displaced by the urgent." Revived in 1999 with donated services and private funding, the Trust initiated a groundwater monitoring program. In 2002 the City of Boston provided funding to maintain the monitoring program for six months. The current Inspectional Services chief has declared his presence to be a conflict of interest (For example, information received via the Trust about a rotted building foundation could force the inspector to condemn the building.) and he does not attend Trust meetings.

Complicating matters for all parties is that the South End with no official representation on the Trust also has the most serious flooding problem in the City. No flood control advocates were in attendance at the Trusts's June 25, 2003 public meeting.

The Environment Department

Mayor Menino has appointed his Environment Department Commissioner, Antonia (Toni) Pollak to represent the city at meetings of the Boston Groundwater Trust and to coordinate, City departments and contact state agencies to address the issue of groundwater depletion threatening historic structures. It is her mission according to Pollak to "coordinate city policy on environmental issues."

The Environment Department mission as defined on its web site is "to protect [Boston's] built and natural environments and provide information on environmental issues affecting Boston." Those "environments" include, " Boston's wealth of historic sites, buildings, landscapes, and waterways through protective designation and review." The Department is involved in all Environmental Review processes in the City. Because Pollak's Department oversees both the Historic District Commissions and the Boston Landmarks Commission it should be ideally placed to protect the many hundreds, if not thousands of pile supported historic buildings in the filled areas of Boston among its " more than 7,000 properties located within seven local Historic Districts or designated as individual Boston Landmarks." [35] Pollak's background in historic preservation—she served for 12 years as executive director of the Boston Preservation Alliance—further demonstrates the commitment of the Mayor to protecting the landmark buildings threatened by groundwater depletion. Unfortunately most of the funds and policies were designed to protect against demolishing historic structures and to preserve their historic facades. There are funds and tax credits for those purposes but none for repairing rotting foundations that may lead to building collapse.

Pollak has contacted the federal Housing and Urban Development Department (HUD) about funding wood foundation repair in low income housing in Chinatown. "HUD's mission is to create and renovate low income units, yet, they couldn't understand why its their responsibility" [to pay for wood pile repair], Pollak notes. [36]

Because the Environment Department Commissioner is not an ex-officio trustee, she is not a voting member of the Trust.

Boston Water and Sewer Commission

The Boston Water and Sewer Reorganization Act of 1977 (the Enabling Act) transferred control of Boston's water and sewer system from the City of Boston's Department of Public Works (DPW) to a new Boston Water and Sewer Commission (BWSC) overseen by a three-member Board of Commissioners (the "Board") appointed by the Mayor. The Mayor's Special

Assistant for environmental affairs and the Deputy Director for Community Planning for the Boston Redevelopment Authority sit on the BWSC Board.

BWSC's primary responsibility is the "provision of high quality reliable water, sewer and drainage services along its 1,021 miles of pipe to Boston customers" while "ensuring the sound, economical and efficient maintenance of the System."

The legal structure of BWSC enabled Boston to move the cost of repairing Boston's antiquated and leaking water supply and waste water system off the City's books. The Commission issues its own bonds to fund repairs and improvements. The Act required the Commission to prepare a three-year infrastructure repair plan.

BWSC's Executive Director Vincent Mannering states in his 2001 annual report message that BWSC has also met its mission to provide "the most efficient water and sewer service possible." Another "primary objective" of the Commission, according to Mannering is to meet the legal requirement imposed by the Court (the 1983 CLF suit) to reduce pollution in Boston Harbor by repairing leaks to it sewer system.

Just under 60% of rate revenues from sales of water and sewer services to BWSC ratepayers fund Massachusetts Water Resources Authority (MWRA) projects. MWRA delivers Quabbin Reservoir water to the Boston system and removes Boston's waste water to the MWRA's treatment plant on Deer Island.

When BWSC repairs leaking sewers below the water table in filled areas, groundwater levels rise. BWSC's 1989 Leak Detection Program saved 0.1 million gallons of water per day, reducing costs to ratepayers and improving water quality. When it repairs leaks to it water supply pipes, it removes a source of groundwater recharge to wood pilings.

Maintaining groundwater levels in the filled areas of Boston is not a defined BWSC mission. Its 1994 Downspout Disconnection Program "launched to reduce infiltration and inflow" into its sewers supports local groundwater recharge, but the BWSC's primary objectives are to reduce sewer disposal charges and combined sewer and stormwater overflows to satisfy the court order they are under to clean up Boston Harbor.

BWSC Commission has supported the Trust as it planned sites for groundwater monitoring by providing access to its GIS maps of underground structures. BWSC's web site is slated in the Fall of 2003 to have information for homeowners on regulations for installing dry wells for the purpose of

capturing rain water on site to recharge groundwater, according to Ralph Tomofrio of the Engineering Division. BWSC is not promoting dry wells as some South End residents with exposed foundation files would prefer. BWSC standards and permitting requirements apply only to dry wells that will be connected to the City's sewers to handle overflow. It is the South Ends history of flooding that appears to be of more immediate concern to BWSC. In 1999, BWSC hired Cambridge engineering firm, Camp Dresser and McKee (CDM) to "create a facilities plan that would address the flooding problem." In the Introduction to their report, CDM makes reference to groundwater only as it related to the design of conduits for pumping water out of the South End and into the harbor to relieve flooding.

Boston Redevelopment Authority

The Boston Redevelopment Authority (BRA) was established "to encourage commercial and residential development" by the Boston City Council and state statute (MGL chapter 121A) in 1957. According to its web site, the BRA's "broad development authorities include the power to buy and sell property, the power to acquire property through eminent domain, and the power to grant tax concessions (under MGL chapter 121A) to encourage commercial and residential development. [37]

In 1967, the BRA became involved in water management in the South End, (an area, with the exception of Washington Street that is filled land) as part of an urban renewal program. The primary purpose of the BRA's South End Recommended Sewer and Drainage System Improvements Program was to "reduce flooding" and "abate pollution" before the wastewater was pumped out to the Fort Point Channel and Boston Harbor. A second part of their flood control project was to begin the separation of storm drains and sewer drains, but their solutions did not work on stormwater flows during low tide.

The BRA also commissioned the 1986 Haley and Aldrich study of groundwater levels in Back Bay which recommended that all construction projects in areas with "groundwater sensitive buildings" undergo a "thorough review " of construction methods to "to minimize their effects on or replenish the groundwater table." Recently the Boston Groundwater Trust has been given the opportunity to review BRA-sponsored projects and comment on the proposed groundwater management measures. Many South End residents have reviewed a BRA-supported Columbus Center development and concluded that it does not adequately address harm to historic properties from groundwater depletion.

Boston Inspectional Services Department

The 1986 City Ordinance designated the Commissioner of Inspectional Services as an ex-officio member of the 10 member Boston Groundwater Trust. The Inspection Services Department (ISD) (formerly the Building Department) had commissioned two studies of groundwater depletion in Boston: the October 1984 "Structural Report-Lower Beacon Hill" submitted by P.M. Folks and the 1990 "Report on Groundwater Observation Wells" by Stone and Webster co-commissioned by ISD and the Trust.

The current Commissioner of ISD has concluded that his department's powers to investigate and to order repairs and if necessary condemn unsafe buildings conflicts with a trustee's responsibility to collaborate with citizens to monitor groundwater and propose solutions. As a result the Trust has 9 rather than 10 voting members and lacks the expertise and institutional history ISD could bring to the Trust.

Boston City Council

Hon. H. Michael Ross, District 8 (which includes Back Bay, Beacon Hill and the Fenway) is the designated city council representative on the Trust. He is the successor to David Scondras (the author of the Trust ordinance), a resident of Beacon Hill and a member of the Council's Environment & Historic Preservation Committee. He has worked with state and local officials to get $1.6 million for additional groundwater monitoring in the city.

Councilor James Kelly District 2, (elected in 1983) represents Chinatown, the South End and South Boston. As Council President from 1994-2000 Kelly was an influential supporter of the Trust and stronger measures to protect groundwater sensitive buildings in his district.

State Government Stakeholders

Executive Office of Environmental Affairs

"Striking the balance between using the water that we need and leaving the water to sustain our natural environment is the goal of Executive Office of Environmental Affairs' water policies" according to its web site. [38]

By statue, the Secretary of Environmental Affairs, currently Ellen Roy Herzfelder, should have a great deal of power to protect all water resources in the state. The Secretary serves as Chair of the Water Resources Commission (WRC),"a 13 member Commission within EOEA responsible for developing the water resources management framework under which the

environmental agencies operate." WRC is charged with developing ground and surface water transfer regulations. (See Section II, "Law and Lawsuits.")

The Secretary is also chair of the Board of the Massachusetts Water Resources Authority (MWRA) the quasi-independent agency responsible for water supply and wastewater treatment for most of the Greater Boston area. (See MWRA below.) In addition three of the EOEA's departments have water-protection programs. The Department of Environmental Protection "authorizes the regulations of the quantity of water withdrawn from both surface and groundwater supplies, and the Watershed Management Division that is charged with monitoring and regulatory activities that affect water quality and quantity within the state's major river basins." A new Division of Water Supply Protection replaces the MDC Watershed Division but retains the MDC director, Joe McGinn.

Karl Honkonen, Executive Director of the Water Resources Commission and state Water Policy Manager had been the liaison between the state and the City of Boston on groundwater issues. Supporting a watershed based approach, he attended Trust meetings and reported to Chief of Commonwealth Development, Douglas Foy on the need to bring state agencies (MBTA, MTA and the MWRA) to the table with Boston officials to address the groundwater depletion problems. Honkonen represented the state's water policy position at the June 2003 Boston Groundwater Trust public meeting. By July 1, with the passage of legislation to eliminate the MDC and reassign its water management functions to EOEA's Watershed Division and to the Department of Conservation and Recreation, the role of state liaison for Boston groundwater depletion issues was shifted from Honkonen to Gina McCarthy, assistant to Chief of Commonwealth Development, Douglas Foy.

Massachusetts Bay Transportation Authority (MBTA)

By creating the MBTA as with the MWRA and the Massachusetts Turnpike Authority (MTA) a distance from politics, elected officials have limited influence (nominating individuals for open seats) on their actions. The MBTA issues it own bonds and sets with its Advisory Board its agenda. General Manager Michael H. Mulhern in a letter to the public defines the MBTA's mission "as dedicated to providing safe, reliable, world class public transportation in an environmentally sound and responsible manner." MBTA's environmental efforts have focused on reducing air pollution not maintaining groundwater levels in the South End where their pumping is alleged to have damaged foundation pilings under houses along the MBTA's Southwest corridor.

Chief of Commonwealth Development

The position as Chief of Commonwealth Development was created by Governor Romney to lead three related cabinet departments, housing, transportation and environmental affairs. Romney appointed Douglas Foy, former head of the Conservation Law Foundation, to the new supercabinet position. Although a recent statute passed by the Massachusetts legislature defines his role as a coordinator rather than a supercabinet member, Foy is still refereed to by the Administration as Chief of Commonwealth Development. The City of Boston and the Trust hope that Foy's office can bring together the MBTA, MWRA and EEOA to solve the groundwater depletion problem that the MBTA and former MDC have been unwilling or unable to correct to date.

Massachusetts Water Resources Authority (MWRA)

The MWRA supplies water and sewer services to 64 communities primarily in the Boston Metropolitan Area, serving over 2.5 million people. Its existence is a function of the litigation and court orders against its predecessor, the Metropolitan District Commission (MDC). Beyond delivering safe drinking water from Central Massachusetts to Boston, MWRA's priorities have been set by the court-orders to clean up Boston Harbor. (See Section III, "Litigation Spurs Action: The court-ordered Boston Harbor clean-up and groundwater depletion"). The MWRA along with BWSC is also under court-order to clean the Muddy River and as a result clean-up the Charles River. The Muddy River project will improve the River's drainage and replant and extend the River's floodplain. In addition to absorbing stormwater to avoid flooding, the project may also recharge the groundwater in adjacent areas. The MWRA's independent funding from the bonds it issues and from mandatory water and sewer assessment fees on its member communities supports its large scale engineering model of water management.

Other Stakeholders

The Massachusetts Turnpike Authority (MTA) managing the Central Artery Depression (the "Big Dig") and the underground Mass Turnpike Extension which border the South End on two sides has pumped millions of gallons of groundwater to the harbor during construction of the Big Dig. The Mass Highway Department, successor to the MDC's parkways division is responsible for pumping thousands of gallons of groundwater out of the Storrow Drive underpass and depleting groundwater on lower Beacon Hill.

Engineering consultants have played major roles in designing and evaluating projects that effect groundwater levels. Haley and Aldrich and others who

provide pro-bono advice to the Boston Groundwater Trust also consult to state and city agencies and to individual groups of homeowners who have sued these agencies.

At the federal level, the EPA has been sued for inaction on water issues and also been active in forcing the MWRA and BWCS to move quickly to reduce water pollution. The USGS has been tracking groundwater in Boston since the 1970's and continues to be a source of objective data for policy makers to use. The Army Corps of Engineers is often involved in flood control projects and was responsible in part for the negative effects the new Charles River Dam had on groundwater levels at lower Beacon Hill.

The Charles River Watershed Association is a strong proponent of local, low-impact groundwater retention strategies, but has focused their recharge projects on suburban areas. Preservationist groups, including the Beacon Hill Architectural Commission and housing organizations such as HUD have yet to expand their missions to include environmentally damaged foundations.

VI. Solutions

A few simple facts about groundwater should be kept in mind before evaluating solutions to maintain groundwater levels necessary to preserve wood pile foundations. (1) Water flows to the lowest point via the path of least resistance; for example obstacles such as dams, sewer lines and tunnels divert or contain the flow of groundwater. (2) The rate at which water flows naturally depends upon soil or surface permeability. Water moves quickly through porous materials such as sand and very slowly through clay. (3) Boston's filled areas have at least three aquifers, water holding spaces bounded by materials such as clay or rock with very low permeability. The top level aquifer (the top of which is the water table) lies within the filled layer. The middle aquifer layer underlies the pre-fill soil surface of organic soil and peat. The lowest aquifer layer lies above bedrock in glacial till. Generally water does not move through the layers unless they are breached by excavations (such as high rise construction and deep tunneling) or seismic activity. (4) Pumping of groundwater from one aquifer can create a low pressure space that pulls water from a distant aquifer into the area being pumped.

In 1985 Galen Gilbert, President of the Fenway Community Development Corporation an advocate of affordable housing in the Fenway, testified before the Boston City Council on the problem of "aquifer depletion." He offered four solutions to the problem: (1) that a single city department (He suggested the DPW.) be responsible for water table "monitoring and detecting leaks" and "recharging the water table in all districts built on

wooden piles;" (2) that the BRA in zoning matters consider the need for more permeable open spaces and the city maintain parks and unpaved areas to recharge the groundwater; (3) that the BWSC, the MDC, the MTA and the MBTA be "investigated to determine their responsibility for aquifer depletion" and be required to repair any leaks; and (4) if inspections reveal leakage, then claims be made to a city "compensation fund established to pay for relevant building repairs." "Saving existing housing," said Gilbert "is more economical and important than new housing." [39] Eighteen years after Gilbert's testimony his recommendations read like the summary of a recent public meeting.

Expanding the network of monitoring wells as an early warning system

The digging of significant new monitoring wells and frequent data collection from existing wells is just beginning, managed by a group of volunteer trustees assisted by volunteer engineers. More extensive mapping is needed of well data, such as recent maps of the Ellis Neighborhood drawdown, applied over street and infrastructure maps to visually indicate flows and hot spots where piles are threatened. Data from monitoring wells and flow meters required by development projects and tunnel owners such as the MBTA and the MTA should be independently gathered, not as it now is by the owners. The data from those wells should be delivered in a standard format easily integrated into the Trust's monitoring system. All data should be quickly and publicly accessible.

Understanding the Subterannean Environment: hydrology and chemistry

Previous investigations have shown that pumping groundwater in one location can have an effect on groundwater levels one mile away. Commissioner Pollak of the Environment Department has engaged the volunteer efforts of civil engineering professors, specialists in groundwater flows at MIT, to take a broad investigative approach to Central Boston's groundwater problem. Currently Professor Charles Harvey, Associate Professor of Civil Engineering, is supervising student projects. One student is mapping groundwater flow to make predictions as to infiltration; he has created a GIS database mostly from Groundwater Trust data to compare these maps to rainfall records. Another student is looking at chemical and biological processes in wood pile rot and investigating solutions that might protect wood support piles. A third student is investigating ground-penetrating radar to see if its possible to ascertain the water table levels without having to dig. Preliminary reports are due in late August 2003.

Recharging Strategies to Restore Depleted Groundwater

For many years Trinity Church and the Lenox Hotel in Back Bay and the Church of the Advent on Brimmer Street, Beacon Hill have had groundwater monitoring wells and artesian wells in their basements. When water levels in the top aquifer drop dangerously close to the tops of the structures' wooden piles, they pump water from the aquifer below the fill to recharge the filled layer and keep their building piles wet. As Gary Saunders has noted, it can take thousands of gallons to recharge. The only permit required to dig such a well is one from the Board of Health unless excess water will be pumped to the sewer which requires a BWSC permit. But this is not a solution for homeowners; it is expensive and may potentially create subsidence problems or flooding of neighboring structures.

Recharge is best when it is based on a neighborhood districts with similar elevations and geological conditions so that repairing one problem does not create others.

Porous pavement and more green spaces for recharge are excellent strategies for improving recharge where subsurface conditions can retain water. Infrastructure and soil conditions, such as clay, underlying permeable surfaces severely limit water holding capacity.

Dry wells offer a potential benefit to those property owners with only a small amount of open space and less than ideal soil conditions. The dry well must be dug deep enough and broard enough to provide sufficient capacity and at an elevation relative to a building's foundation to move flow toward the building. Additional excavations and piping may be necessary to direct flow and make permitted connections to storm sewers to prevent overflows and flooding.

Neighborhood water districts: a proposed model for coordination

When one neighbor pumps his basement, his underground parking garage or his authority's tunnel and diverts water to the river or harbor he may be risking the well being of his neighbor and his neighbor's property by exposing wood foundations to decay. When one neighbor pumps water into her property or paves over a permeable space she may be flooding her neighbor's basement and exposing the neighbor's mortar to damage. With detailed groundwater monitoring data it should be possible to define city districts by their water flow contours, creating urban equivalents of sub-watersheds where shared conditions create shared interests and the opportunity for shared action.

Replacing Damaged Pilings

Because the City and the Commonwealth both have a stake in the preservation of historic Boston and their actions through transportation and water systems management have contributed to the deterioration of housing stock, it should be the government's responsibility to set aside funds to contribute to the repair of these structures and to investigate alternative methods for shoring up failing properties that recharge cannot help. If a hurricane or blizzard or earthquake (Boston suffered two large earthquakes in 1727 and 1755.) were to damage these structures, public funds and/or loans would be made available for repairs. Underground damage, especially that related to massive infrastructure projects and massive pumping on a scale beyond the power of a homeowner to mitigate, should be compensated. If public officials wait until they are sued, the litigation costs in dollars and the cost in public distrust will likely exceed the costs of proactive compensation.

VII. Conclusions

As with so many complex urban issues in Massachusetts, there is no shortage of intelligent people who have worked on Boston's groundwater problem. What several reports and officials have noted is a lack of interagency coordination and sharing of information. Commissioner Pollak has called for "transparency" from city and state agencies whose missions affect the groundwater problem. She has also suggested that residents need to resist threatening lawsuits to encourage transparency and cooperation. Transparency is a democratic necessity with or without the threat of lawsuits.

Narrowly defined agency missions are also factors, with agencies often working at cross-purposes. The MBTA's and the MTA's core missions are transportation and in recent years they have recognized that environmental issues are also their concern. When the MBTA spent millions to replace polluting buses they took ownership of their responsibility to correct air pollution they had caused. They must see water management as a community-wide issue as well and one they must own when they discover leaks in their tunnels.

The South End presents a vivid illustration of the problems narrow definitions of interests create and perpetuate. When the tidal flats and marshes to either side of the Washington Street, (then Orange Street) were filled in the mid 1800s, the main developers, the City of Boston and the Boston Water Power Company (BWPC) did not coordinate effectively. Each filled streets and building lots at different elevations. The result was that the

higher areas continually flooded the lower areas. When Back Bay was filled the new South End had to divert its sewers from the Back Bay to the harbor where tidal flows regularly backed up the sewers, flooding streets and basements. The problems persist to this day. Boston Water and Sewer hires a consultant to expand the pumping system to pump more stormwater to the harbor to prevent flooding. Home owners and the Boston Groundwater Trust employ consultants to advice them on how to retain water in the neighborhood while the MBTA pumps out water leaking into its "waterproof" tunnels. One government agency with access to all the data and a broad mission to design a balanced system to manage water whatever the source in defined water districts in Boston may offer an economical and environmentally better way to proceed than the current situation.

Requiring all agencies to put their existing missions into a broader context may reduce the tendency of some of those agencies to support grand engineering schemes when a series of smaller, lower cost, sustainable projects and practices might better meet the needs of Boston and the Commonwealth's communities.

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