Reading Contamination

An Environmental Education Center at the Wells G & H Superfund Site

by
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B.S. Art and Design, Massachusetts Institute of Technology, 1995
B.S. Political Science, Massachusetts Institute of Technology, 1995

Submitted to the Department of Architecture in Partial Fulfillment
of the Requirements for the Degree of

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Massachusetts Institute of Technology

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Department of Architecture, January 15, 1999

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For my parents

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Abstract

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The thesis proposes an architectural and programmatic methodology which makes legible the processes and consequences of site contamination.

This methodology is chiefly demonstrated through a plan for the site which emerges from the examination of the intersection of site contamination with the site's (natural) characteristics and perceptual phenomena.

The site plan arises from the (abstract) institutional entities associated with the site. These entities - the wetlands demarcation zone in particular - begin to organize the site in a way which speaks not to the site's (natural) systems, but to the institutional systems which govern the site, and the means by which these systems deal with contamination.

The site is populated by wells which have been drilled to monitor pollutant levels in the groundwater. The wells (non-natural) monitor the (natural) processes of site contamination. The lines of sight between these wells (as abstraction) become the generators for site geometries, and the placement and form of the built (architectural) areas of the site.

Each built area has two sides defined by the wetlands demarcation line. Within the non-protected zone, the ground is engaged and inhabited. Within the protected zone, users never engage the ground, but instead float above it. These varied experiences of ground delineate the idea of ground as more than plane, as instead a multi-layered strata.

The tectonics of the individual built elements vary as one crosses the demarcation line. This contrast between (natural) materials in the non-protected zone and (non-natural) materials within the protected zone makes legible the invasion of contamination. The different construction methods also demonstrate the fragility of the wetlands soils. At the same time, the lifting of the structures from the ground emphasizes the danger to the ground from man, and the danger to man from the ground.

Due to the nature of the wetlands soils, contamination from a point source has a tendency to distribute itself throughout the site. The institution, an "environmental education center," disperses itself throughout the site. This dispersion forces the users to continually re-confront the site, making the link between the site's contamination and its (natural) characteristics legible through experience.

Thesis Supervisor: Mark Jarzombek
Title: Associate Professor of History and Architecture

Thesis Supervisor: Ellen Dunham-Jones
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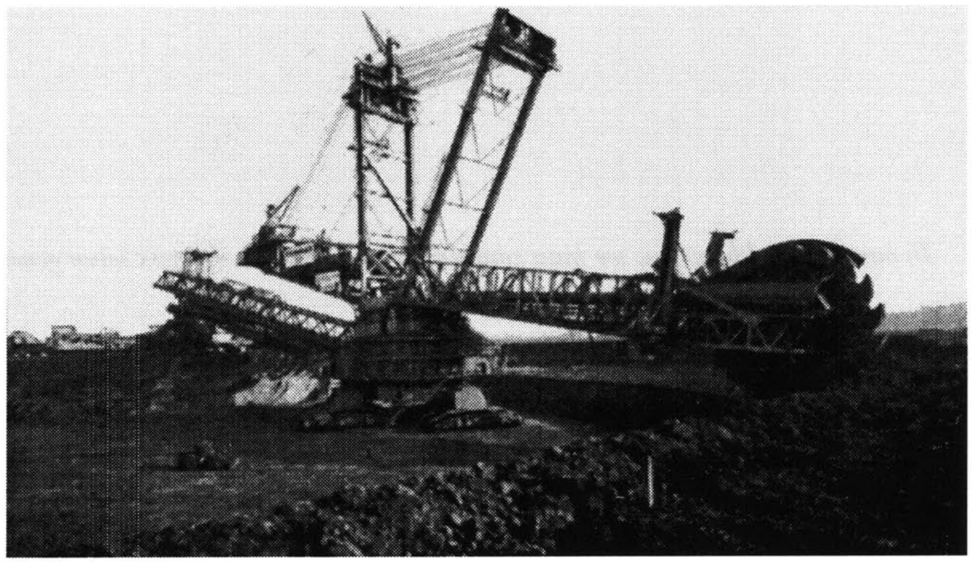
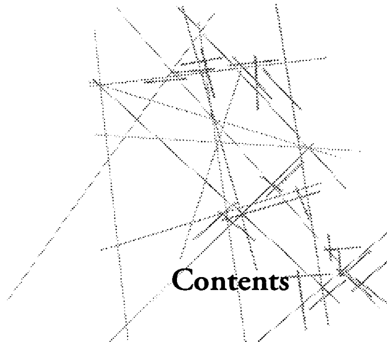
In our every deliberation, we must consider its impact upon the next seven generations.

Iriquois confederacy

6

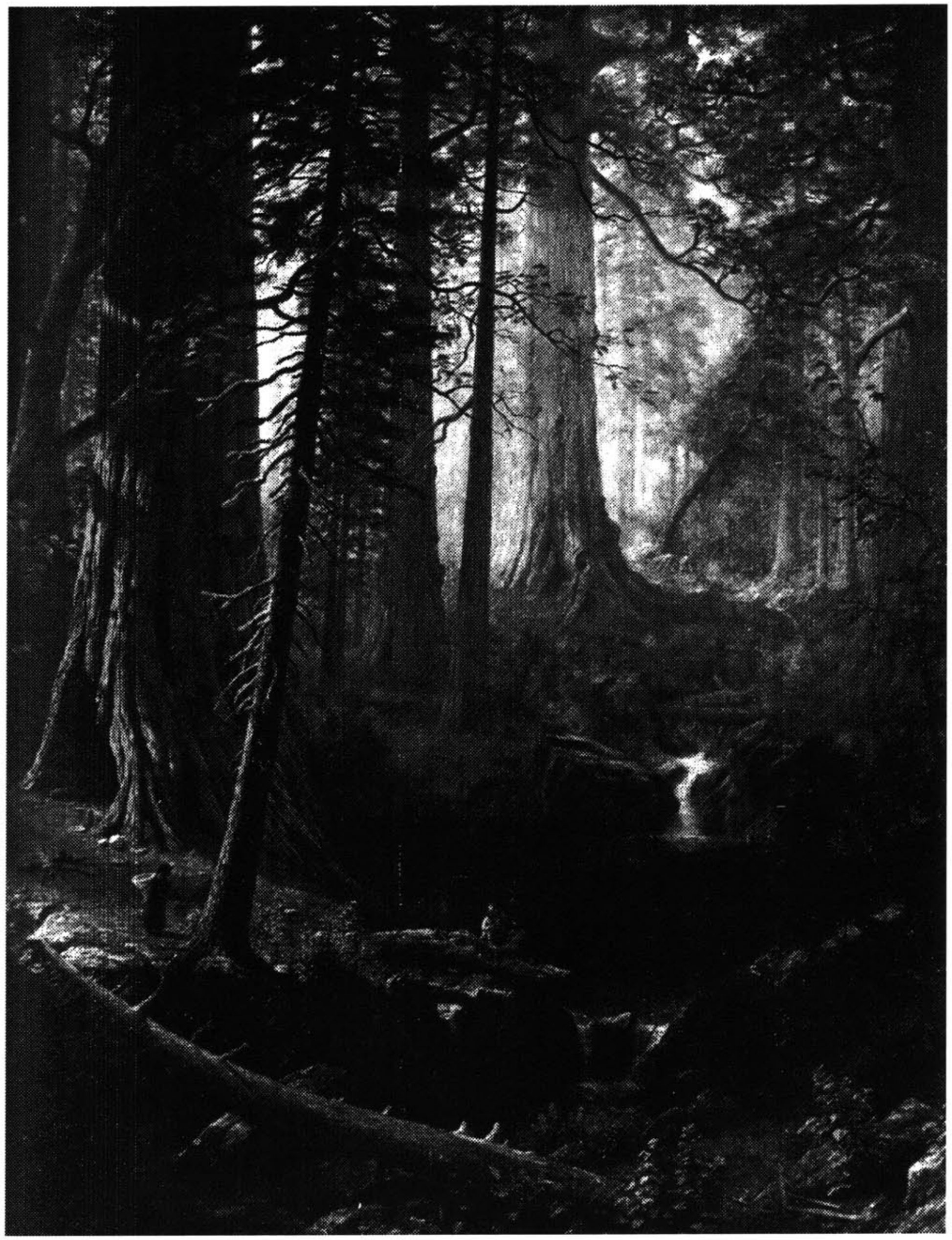


ill. 1 A mining machine at work



Contents

Landscape and Contamination 9



ill. 2 Albert Bierstadt, *Giant Redwood Trees in California*, 1874

land' scape. *n.* [17th-c. art borrowing from D. *landschap*: *land*, -land, and *schap*, -ship]
1. a picture representing a section of natural, inland scenery, as of prairie, woodland, mountains, etc.
2. the branch of painting, photography, etc., dealing with such pictures.
3. an expanse of natural scenery seen by the eye in one view.

place. *n.* [L. *platea*; Gr. *plateia*, a street, from *platys*, broad]
4. a particular area or locality; region.
5. (a) the part of space occupied by a person or thing; (b) situation
13. the customary, or natural position, time, or character.

na' ture. *n.* [L. natura]
6. the sum total of all things in time and space; the physical universe
8. the primitive state of man
9. natural scenery; including the plants and animals that are part of it.

"...by classical times it had developed to the 'innate properties or qualities of something or someone, and hence to the 'inherent course of things,' the 'way things are in the world.' The common English sense 'physical world' (as in *nature study*) first began to emerge in the 16th century."

con tam' i nate. *v.t.* [L. *contaminatus*, *pp.* of *contaminare*, to defile; *contamen*, contact, contagion, from *contingere*; *con-*, together, and *tangere*, to touch.] to make impure, unclean, or corrupt by contact; to corrupt; to pollute; to sully; to tarnish; to taint; as cowardice *contaminates* honor.

"Contaminate appears to come from the same ultimate source as *contact*, a base *tag-'touch'" [1]

1. Definitions taken from the Webster's Unabridged Dictionary, word origins from the Arcade Dictionary of Word Origins, John Ayto, © 1990, Arcade Publishing, New York, NY

How do we view the Land?

Cultural Landscape

The relationship between man and the earth is defined by his *cultural* landscape.

> "What your people call your natural resources, my people call our ancestors."[2]

'Primitive' Cultures

'Primitive' cultures observe rituals associated with the change of seasons, the flooding of rivers, or the harvest of crops. (Some of these observations have been adopted by modern society, for example, Kwanzaa, which is based on African harvest festivals.) Early cultures created earth works, some of whose purposes still baffle archeologists. Native Americans practiced rituals which celebrated the connection between humans and the natural world. The druids sacrificed humans to the spirits of the forest. Many early cultures worshipped the sun, recognizing its importance to the existence of all life. Pre-historic socieites worshipped the mother earth as a goddess, giving her thanks, and praising the spirits of animals they killed for food. The Hopi chief rises each day before sunrise and ascends to the highest point on the earth around him. He waits. The sun rises. He returns to the village. The Hopi believe that if the Chief does not wait, the sun will not rise. They are tied intrinsically to the earth and the sun, and its life-giving power.

2. The Chief of the Onondaga, as quoted by William McDonough in "The Next Modern Architecture," MIT, Cambridge, MA, November 17, 1998.

All these rituals celebrate the connection, the intrinsic link between man and his environment. Nature is power, and those who can interpret nature therefore become powerful in society. In this way, man is chiefly a part of nature, and secondarily a part of society.

> "Man is integrally attached to the natural world in the pre-Hispanic culture through the semiotic structure of culture, its spaces and cities. This structure is ordered by nature because it is through nature that power is assembled and distributed. Political power is derived from religious power, and religious power is held by those who have direct communication with the gods, who read the sky and the signs of the earth, those who are guardians of time. "(Pendleton, 151)

Within 'primitive' cultures, the lines between the land on which one lives, the culture of which one is a member, and one's own self-identitiy are fine to the point of non-existence. The beginning of 'western' culture marked the beginning of the seperation of the three, and of the definition of man as a part of society rather than a part of nature.

> "'Primitive' religions specifically associated mankind's existence with the creation of the universe through cosmogonic myth, which was the story of the beginning of creation. Through the myth, an immediate relationship was set up between the structure of man's actions on the earth and the structure of the universe as it manifests itself in the physical environment. ...Non-primitive religions that rely on divine revelation, as in intellectual epiphany, to understand the meaning of human existence, break this immediate relationship and abstract man's self-definition from an inclusive relationship with the universe and physical site.." (Pendleton169)

'Western' Cultures

Throughout the history of western culture, we have marked the land, we have claimed the earth. When the first brushstrokes were laid on the walls at Lascaux, nature and society were separated. The paintings at Lascaux, unlike the rituals of the Native Americans, are not derived from nature, but performed upon, nature. Stonehenge began the ordering of nature by man. As the first timepiece, it broke the cycle of the sun into discrete elements, able to be interpreted by a man-made device rather than measured by religious leaders.

> "So God created man in his own image;in the image of God He created him; male and female He created them. Then God said to them, 'Be fruitful and multiply; fill the earth and subdue it; have dominion over the fish of the sea, over the birds of the air, and over every living thing that moves on the earth.'"
> Genesis 1:27-28

The bible grants man dominion over the earth. Man becomes the Lord of the earth, its sole owner.

Western, 'developed' countries observe rituals around religious or nationalistic issues. Man is a part of society, not a part of nature.

Bastille Day, May Day, Independence Day

Many western religious holidays were in fact placed at times on the Julian calendar which coincided with the primitive /pagan celebrations so that the church might appropriate these times for its own purposes.

This seperation of man from nature leads to the view of land held within western culture: that land is a commodity.

It was this direct opposition of views on land which in fact led to some of the early treaties between European settlers and Native Americans. The tribes did not believe in the concept of land ownership. The land was was who you were, and who your ancestors were. It could not be owned. Thus, tribes signed away their land, not realizing until it was too late just how seriousuly the white man took the concept of ownership.

Western colonization of the "third ('primitive') world" was never so much about prestige or land, but rather, for what land was seen as: commodity. The land provided for human resources (slaves) and natural (trees, minerals, animals.) The third world was a source of goods, and the first world became the sink for the wastes from those goods. The first world thus became society, and the third world, nature.

In America, the Louisiana purchase of 1803 (the largest purchase of land until Alaska was acquired) led to a relentless march across a continent which would define the way we viewed land in this country well into the twentieth century. The Homestead Act divided the territories into neat parcels just large enough to support a family farm. As the west was more densley settled, land races were held. Claims were marked with stakes, and potential land holders would literally line up across the open prairie, running, riding, driving wagons at breakneck pace, as the gun went off signaling the beginning of the race. If you were the first to reach the claim marker, the land was yours.

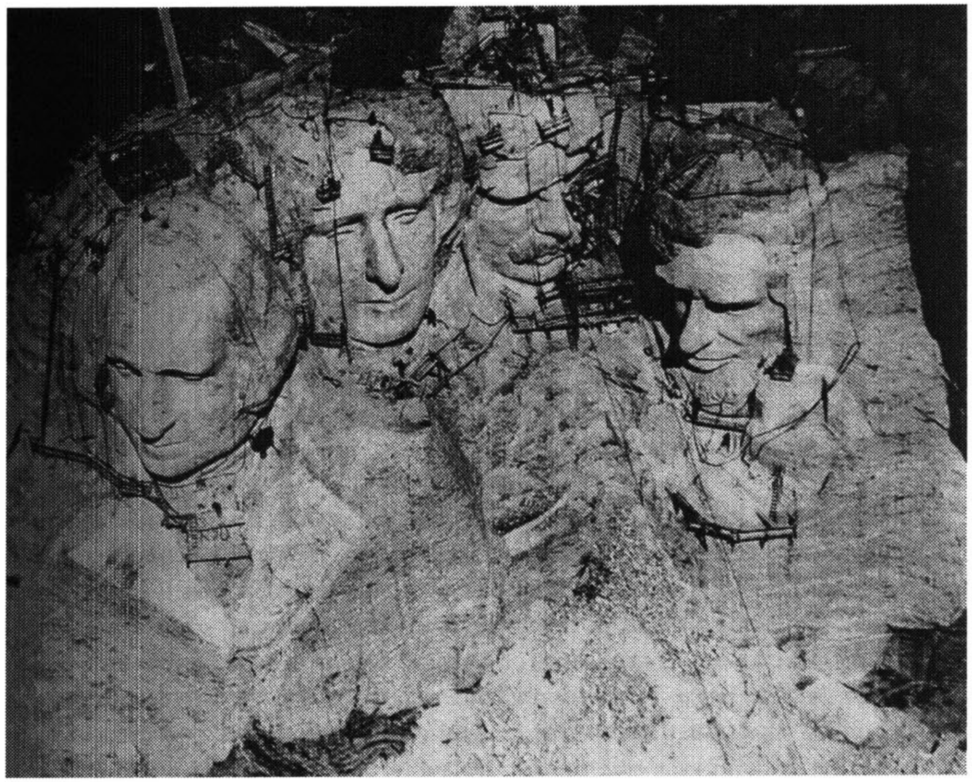
This march across the country, this neat division of the land into parcels just small enough to sell easily on the market (the ultimate commodification of land) would also propel the first ecological movements into being in the late1800's. The first concerns of those involved in wilderness preservation were expressed by city dwellers who feared for dwindling natural resources. The second push came about through the creation of landscape images which treated nature as sacred and sublime, and the western states as a utopian landscape.

The American landscape myth purports that there is an endless supply of land. When we have exhausted one area , we move on to another, and another, ad infinitum. One only needs to look at this January's Architectural Record's letter from the editor, which deals with sprawl and the need of architects to look beyond individual buildings to address the larger context of land use.

This view of the land extends to industrial uses. In the past, if we polluted the land, we simply found a new piece to live on and subsequently pollute. The combination of the view of land as commodity, and as a bottomless sink for our wastes led to an alarming rate of degradation of land in the 1950's and '60's. Billowing smokestacks and gas-guzzling muscle cars were still signs of pregress, despite early environmental efforts. It was not until we began to question whether chemical and industrial pollution might have effects on human health that a significant paradigm shift occured in how we viewed the land (and the environment generally) and our relationship to it.

Silent Spring was published in 1962. It exposed the damage which DDT's caused to humans, animals, and the earth. This seminal book served as a cornerstone for many in the modern environmental movement. In the late 1960's and early '70's, environmentalists worked to eliminate the concept of land as commodity, as an endless sink for our wastes. In the past thirty years, countless initiatives have been launched to prevent pollution and the degradation of the earth.

Among the more significant are the Clean Air and Water Acts, the formation of the UNEP (United Nations Environment Program), the founding of countless environmental organizations from Greenpeace to Worldwatch, the Montreal Protocol, which banned ozone-depleting chemicals, and the Rio Accord and Agenda 21. But despite these groundbreaking efforts and a realization by a significant portion of the



ill. 3. Mount Rushmore under construction.

On the creation of Mount Rushmore:

"Mountain Carving, of course, went one better than mountain climbing, for it proclaimed, in the most emphatic rhetoric imaginable, the supremacy of humanity, its uncontested possession of nature. But it was not given to all cultures to accomplish such feats. For Gutzon Borglum, only in the New World empire of America -the most heroic, the most masculine since the Greeks'- could such a thing be imagined, let alone executed. And that it had been left to white American man-hood to realize this ancient Columbian vision of girdling the earth was of a piece with Borglum's theory of imperial succession." (Schama 397) population that human wastes are substantially damaging to the environment, we continued (and continue) to pollute.

We have degraded many pieces of land to such a degree that the cost to remediate these sites in dollar terms is staggering, and the cost they have exacted on our natural environment is incalculable. The establishment of the Superfund points to our gross carelessness with the natural environment.

Physical Landscape

When we discuss physical landscape, we often fail to recognize its connection to our cultural landscape. We read the land around us using physical cues. Mountains, streams, rivers, a coastal edge all indicate place and perspective. But there is additional information embedded within these physical places. Open fields outside of Manassas, Virginia, look similar to other pieces of farmland. But they are different, For Manassas was the site of two bloody battles in the Civil War. The ground at Manassas has been hallowed, by the deaths of soldiers on both sides of the war. Places acquire a presence in our minds and eyes separate from their physical presence simply by what has transpired in that place.

Custer's Last Stand is memorialized with a monument set into the open prairie. Gettysburg's fields are covered with crosses. These monuments remind us of what occurred in these places, of the events which set them apart from their surroundings. It matters little whether one was actually there at the time. Historic accounts, stories passed through generations in a family, fictionalized narratives based on events. All these serve to form our understanding of a place, in addition to the physical lay of the land. Sometimes the events which occur at a place, point and time can be so powerful, that all that is required is the utterance of a name to evoke an entire epoch.

Auschwitz
the killing fields
Antietam
Woodstock [3]

3. (None of the places or events are meant to be in any way comparable to one another, they are simply meant to demonstrate the power of a sotry around a place, and how it can affect the perception of the place and the time around which the event occured.)

Understanding the Landscape

When we begin to structure a landscape, we use physical cues and phenomena.

orientation
topography
wind
soil composition
vegetation
water

The history of a place serves as an additional layer of information with which we interpret a place.

what happened here?
when did it occur?
what was the societal structure at the time?

When landscape has been contaminated, the tools we use to interpret the events of contamination can serve to structure the site.

extent and boundaries of contamination
test wells
markers, fences, other signs of boundaries
soil sample locations
property boundaries of those responsible for contamination

In addition to the physical (seen and unseen) markers of contamination, there is the story surrounding the site.

who contaminated the site?
what effects did the contamination have on both the natural environment and on the local community around the site?
what is the size and extent of the community affected by the contamination?
what is the physical/geological time scale of the contamination?

are the local residents of the same generation as those affected by the contamination? how present are the original events in the consciousness of local residents and policymakers?

Recent advances in containment technology and government incentives to rehabilitate and reinhabit sites abandoned for environmental reasons have led to the redevelopment of many brownfields. The EPA has also refocused its Superfund program to involve not simply cleanup but also redevelopment of the sites.

As we begin to redevelop these sites, we can begin by asking the questions asked above. We can use the answers to these questions to begin to understand the site, and to structure the re-use of the site. The questions relate to our attitudes about land and its use. They relate to our culture, to where we as a community are today with regards to environmental issues, as opposed to where we were at the time of the contaminating event.

All these sites have embedded within them a history, be it the legacy of the industrial revolution, as in Woburn, the legacy of the Cold War, as witnessed by the Nevada desert, or the legacy of mismanagement of our wastes. These sites have a story to tell, if we let them.

The best type of redevelopment for certain brownfields and hazardous waste sites may be shopping malls or office parks, or golf courses. But some of these sites can be used to instruct rather than to turn one form of pollution into another. They can be used to educate future generations, to demonstrate current technologies, to inspire future scientists. By understanding the complex phenomena around contaminated ground, we can shift the paradigm yet again, to one which does not trade carcinogens for sprawl, and strip mines for the fertilizer of the golf course, further exploiting the land, but instead exploits the opportunities which contaminated sites offer for inter-generational education and equity.

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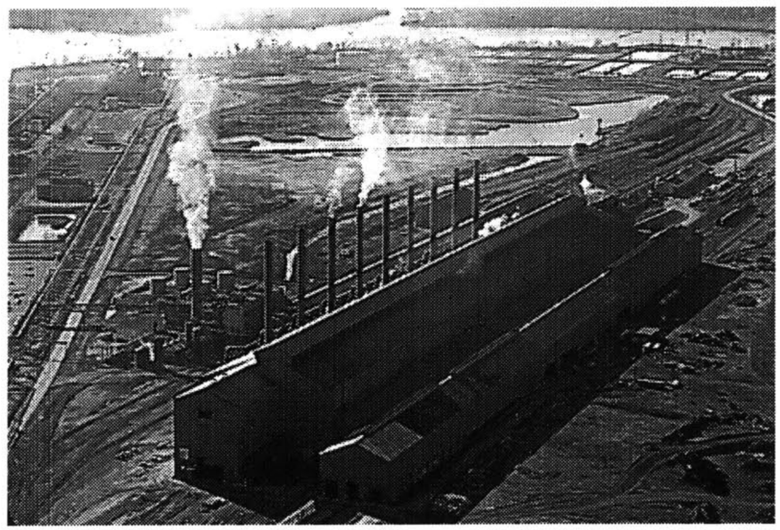
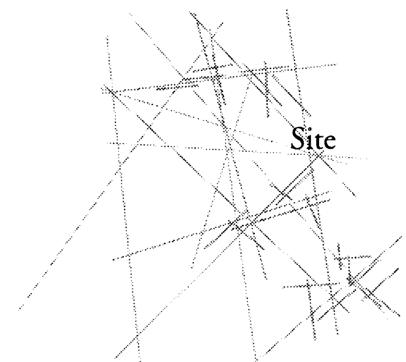
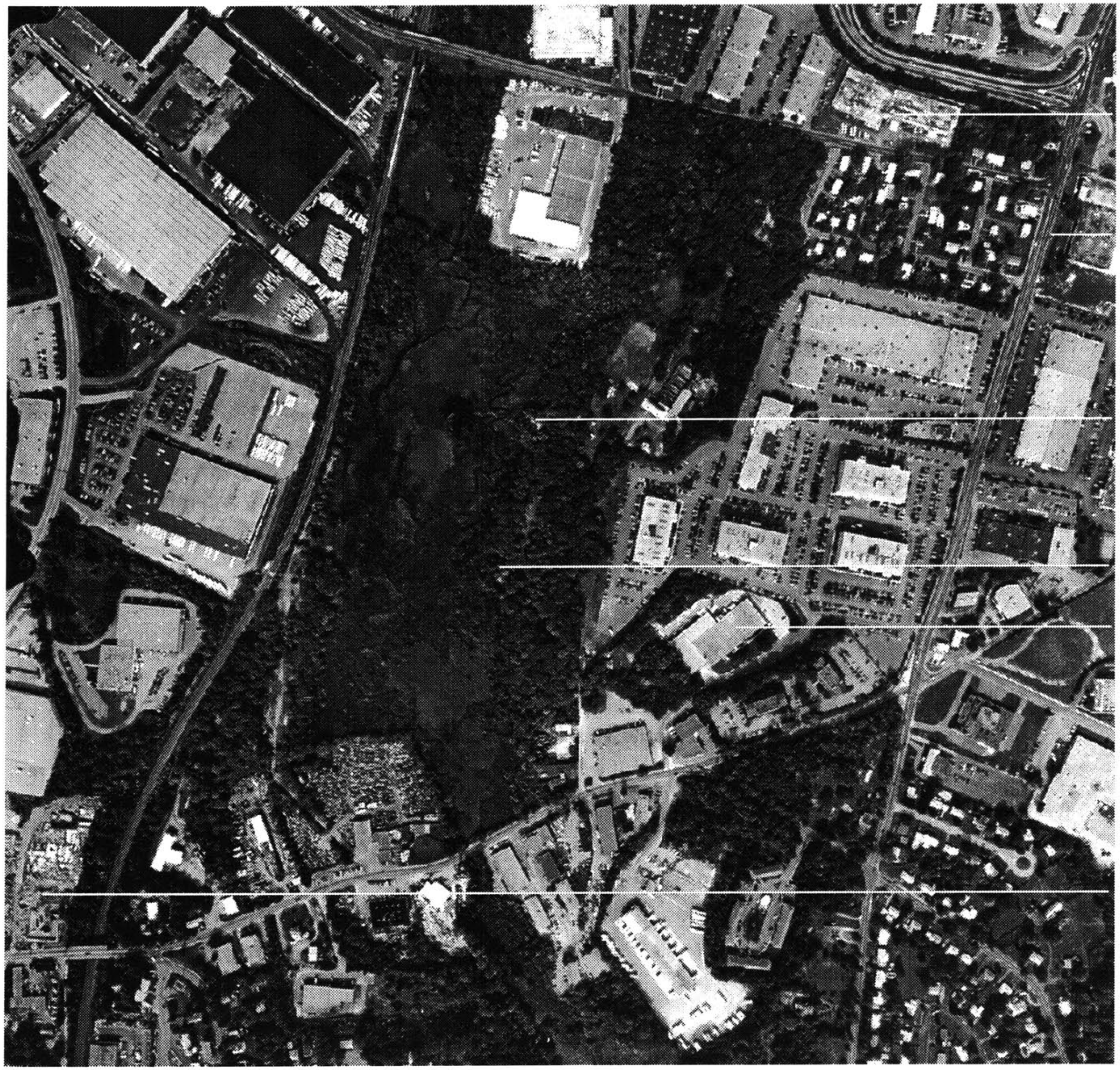


ill. 3 A factory along a river in New York State



Site



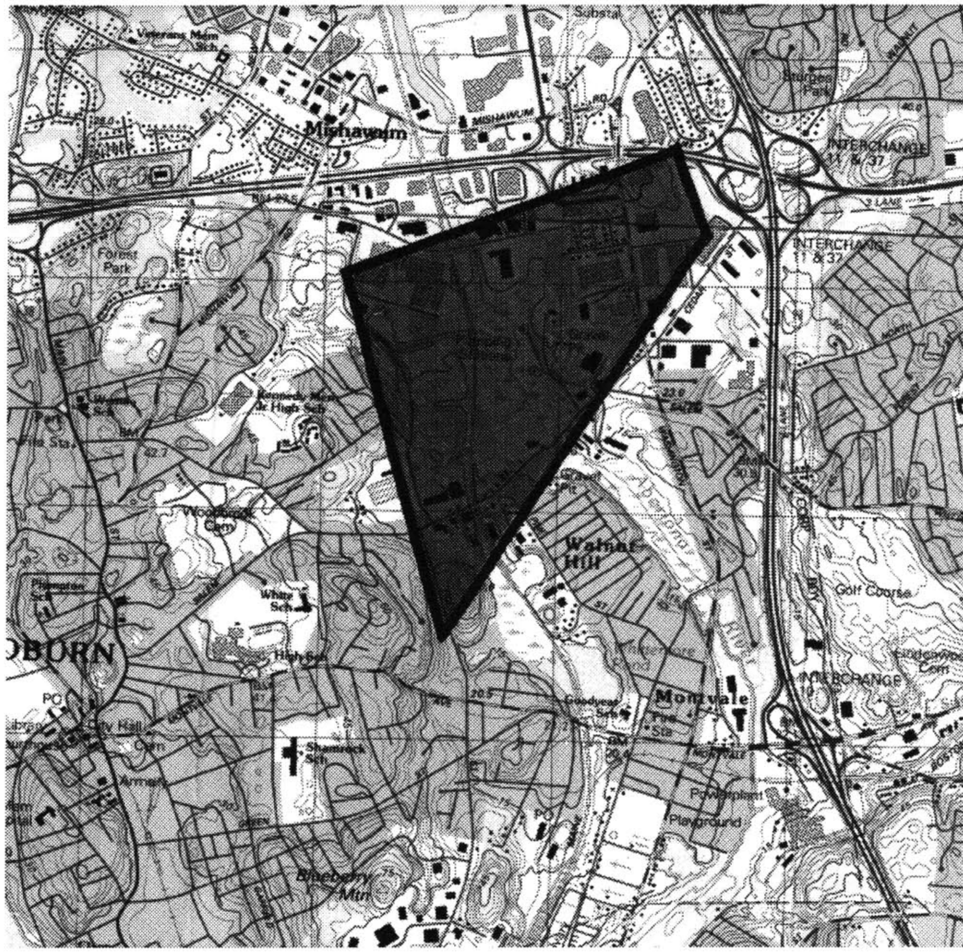
ill. 4 Aerial photo of the site, taken in 1986.

Geologial and Pollutant History

The Aberjona River Valley consists of 50 meters of glacially deposited sands and gravels. These sands and gravels are thought to have contained a number of ice block depressions which are now filled with wetland sediments. The transition of the river valley to a meadow and sedges habitat happened approximatelty 2000 ybp (years before present.) The Aberjona river stabilized to its present location about 800-1000 ybp. It was during this time period of stabilization that European colonization of watershed began.

By the mid to late nineteenth century the river valley transitioned to a fully urbanized watershed. As the river valley was urbanized in the late 19th century, sulfuric acid and arsenical pesticide manufacturing began near the headwaters of the Aberjona watershed at what is now the Industriplex Superfund Site. As early as the 1870's, concerns about possible pollution of the Aberjona due to the burgeoning industry on its banks were expressed by the State Board of Health, which carried out several watershed studies. It was also during the 1870's that the contamination of the river by chromium and other toxic metals began. The river continues to carry contaminated sediments from its headwaters into the Mystic Lakes to this day.

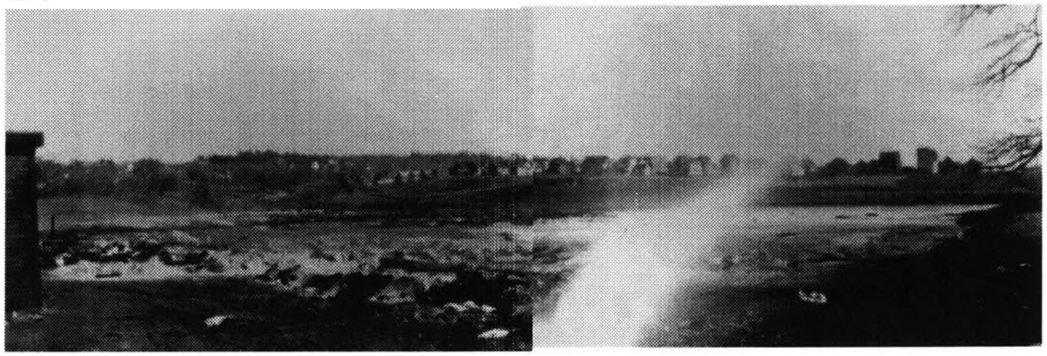
In 1921, the first formal pollution survey of the river was carried out by the Massachusetts Division of Fisheries and Wildlife. Numerous sources of pollution were discovered. The chief sources were ponds used by tanning and chemical companies to distill pollutants from wastewater. Several of the companies operated "screens" designed to remove some of the solid mass before the waste was discharged into tributaries feeding into existing streams. At points below the reception of the tributaries from the plants, streams were often observed to change significantly in character. This method of treatment, in conjunction with a settling pond, was an accepted waste treatment practice, prior to the release of water into the surrounding streams and brooks. As a result of these practices, it is conceivable that large amounts of heavy metals and other pollutants entered the soil, groundwater, and streams of the watershed.

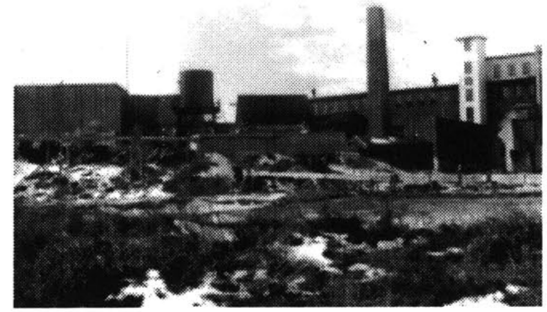


ill. 5 USGS map of Woburn and surrounding area showing Superfund Site Boundary

ill. 6 "Photogrphs No. 88 and No. 89 show the dump of the J.C.Whitten Company where the excelsior through which the gelatine is being filtered, is burned on swamp land bordering the Aberjona River. These photographs should be placed together to get a panoramic view of the dump and the sludge beds that line the southern side of the Aberjona. The photographs are taken from a corner of the Whitten Gelatine Company building."

ill. 6





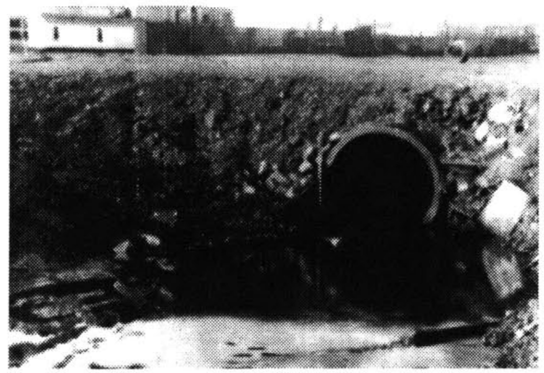
ill. 7 "The covered section of the sewer carrying off the trade wastes of the Merrimac Chemical Complany. The wooden trough soon passes underground, and discharges through a one-foot pipe into Tributary No. 6 of Willow Brook."

ill. 7

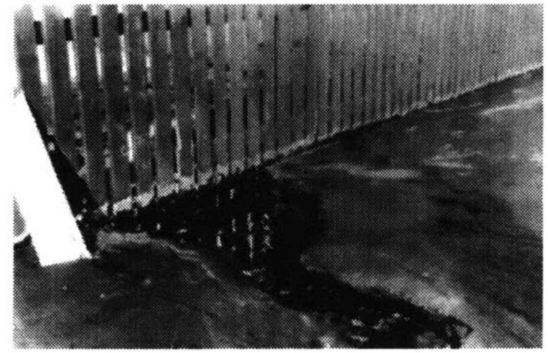
ill. 8

ill. 8 "Willow Brook, after receiving from the west side of the Merrimac Chemical Company Tributary No. 6 which contains a large amount of trade wastes, particularly from the Algonquin Leather Company, passes over the ruined dam shown in the photograph. While Willow Brook above the junction is fairly clear, and contains fish life, the polluted tributary is very turbid, and heavily laden with a brown flocculent mass, capable of settling out rapidly in spite of a strong flow. After these streams merged, fish life is no longer observed, indicating the serious character of the polluting material."

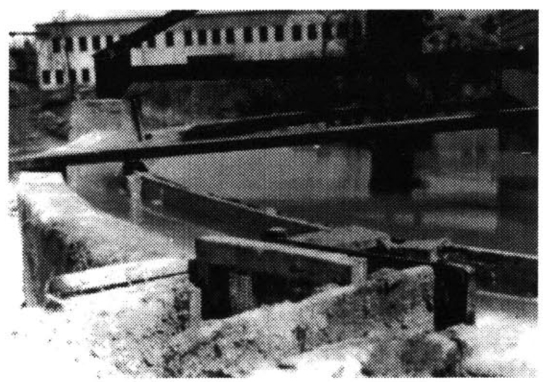
ill. 9 "The liquid wastes from the H-acid process employed by the Merrimac Chemical Company in the manufacture of dye intermediates emerging from the enclosure of the plant on the way to join Tributary No. 7 of Wilow Brook, and later the Aberjona River. Such obvious and deleterious pollution of public streams should be prohibited."

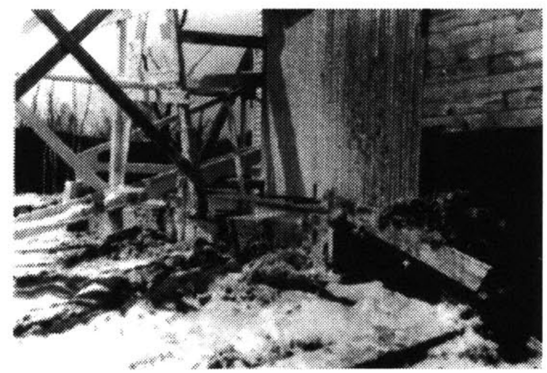


ill. 9



ill. 10 "One of the members of the Aberjona Committe endeavoring to get a closer view of the polluting material. Note the heavy, black, sticky, tarry material which is being taken from the stream."





ill. 10

ill. 11

ill. 11 "Some of the screenings removed by the drum screen employed by the Atlantic Gelatine Company, dumped near the Dorr settling basin. The foamy overflow from this basin can also be observed in the central foregound. The ground all around the basin is very soggy, and is covered by a hairy, mat-like mass or material. Some of the overflow from the settling basin, and drainage from the polluted soil flows directly into the Aberjona River."

Distilling ponds were separated from freshwater brooks and the river by small dikes, which were often observed to be broken or overspilled. Solid waste removed from the water was placed on the ground around the distilling ponds or screen houses. This was considered an acceptable waste treatment practice, except in cases where it was observed that the ground was saturated, thus allowing the waste to seep into the soil. Within the report, observations of discharge of untreated wastewater from some facilities were made, and noted as unacceptable.

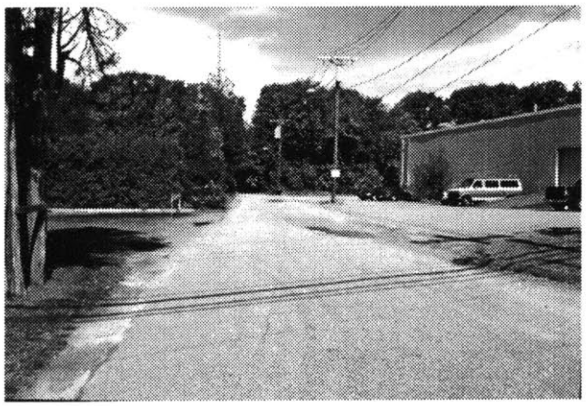
The river borne metal load of the Aberjona from these many contaminant sources is hypothesized to have carried as much as ten tons of arsenic to the Mystic Lakes in the peak periods of the 1930's and 1960's. (Zeeb 124) A 1992 survey of the wetland soils discovered high concentrations of arsenic (Zeeb 126); later surveys have discovered levels as high as 9000mg/kg. (Zeeb 141)

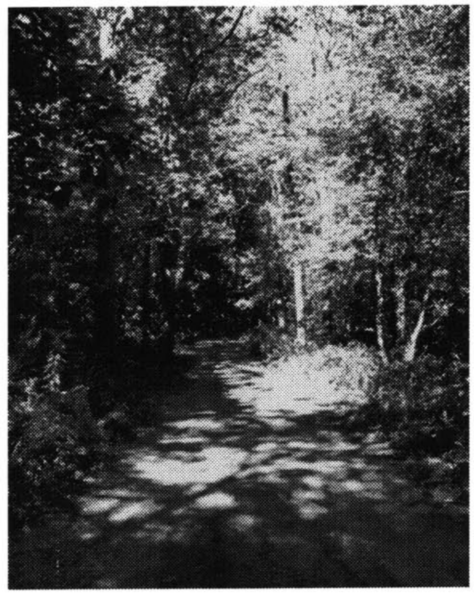
Today, the river valley is a protected wetland. It is, however, much smaller than the original wetland area. In 1830, the Boston and Maine railroad constructed an embankment through the river valley which divided the wetland into western and eastern halves. The western half has been filled, occupied currently by parking lots, and commercial and industrial buildings. (Zeeb 159) It was on the western half of the wetland that the Riley Tannery once stood.

The community of macrophytes in the wetland, including typha (cattails) phragmites and lythrum are know to be tolerant to various pollutants including metals and high conductivity waters. They can also be indicative of disturbed systems. The river valley began a gradual shift from sedge meadow to cattail marsh during industrialization, which could possibly be explained by the introduction of large amounts of heavy metals and other pollutants into the soils and waters of brooks and streams which feed the Aberjona. (Zeeb 157)

ill. 12
Aberjona looking north
from Salem Street.

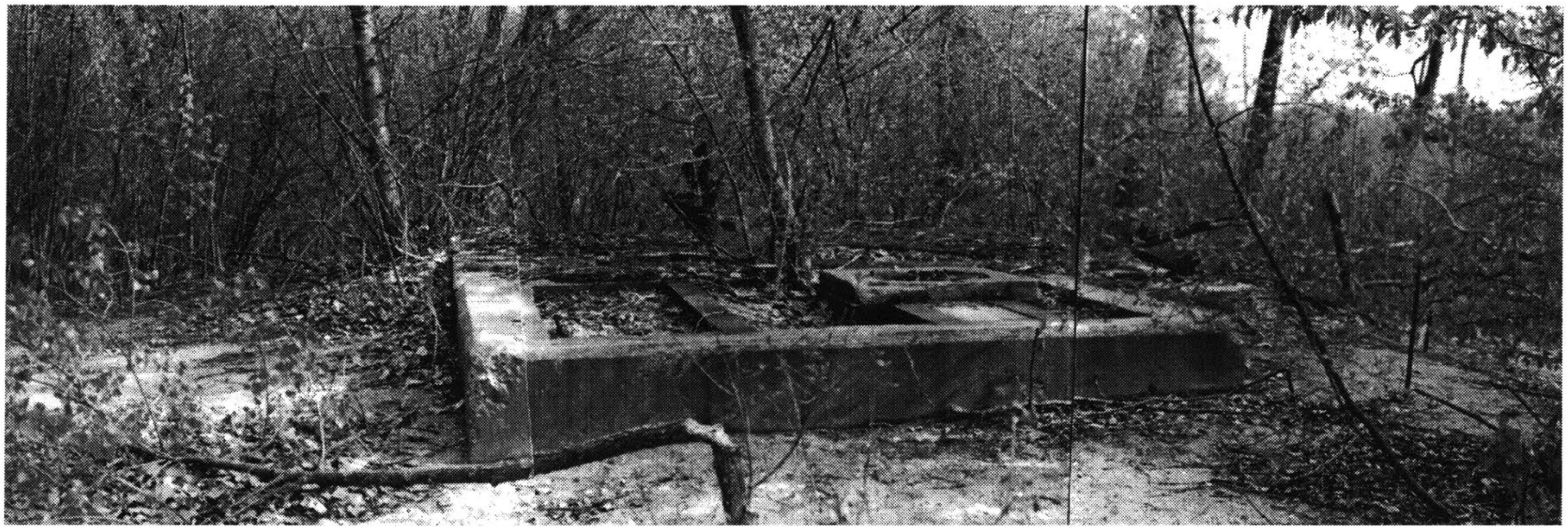
ill. 13 Looking west across wetland from Well H.





ills.14, 15, 16 Entry to site from Salem Street, Looking north on Rifle Range Road (access to site), Clearing west of Rifle Range Road

ill. 17 Destroyed wellhead at Well G



ill. 18 Destroyed wellhead at Well H

Site Contaminants:

The groundwater is contaminated with volatile organic compounds (VOC's) including trichloroethylene (TCE) and tetrachloroethylene (PCE.) Sediments in the Aberjona are contaminated with polycyclic aromatic hydrocarbons (PAHs) and heavy metals such as chromium, zinc, mercury, and arsenic. The soil at the site is contaminated with PAH's, polychlorinated biphenyls (PCBs), VOCs, and pesticides.

Contaminated groundwater will affect not only water supplies for people, i.e. wells, but also plants, whose secondary source of water (after evapotranspiration) is groundwater drawn up from roots, and surface water, as it flows toward rivers for which the site is a watershed.

It should be noted that the most commonly found groundwater contaminant at hazardous waste sites is TCE, which has been found in abundance at the Wells G&H site.

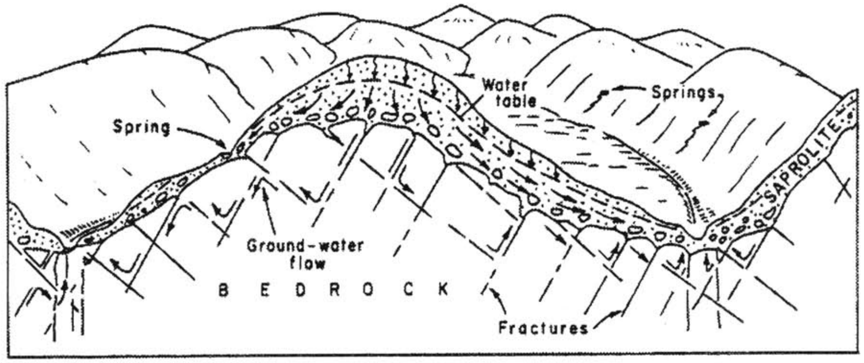
Subsurface characteristics:

There are two basic types of aquifers: consolidated and unconsolidated. The Woburn aquifer is a consolidated aquifer. The hydraulic properties of an aquifer play an important role in the ease of groundwater remediation at the site in question.

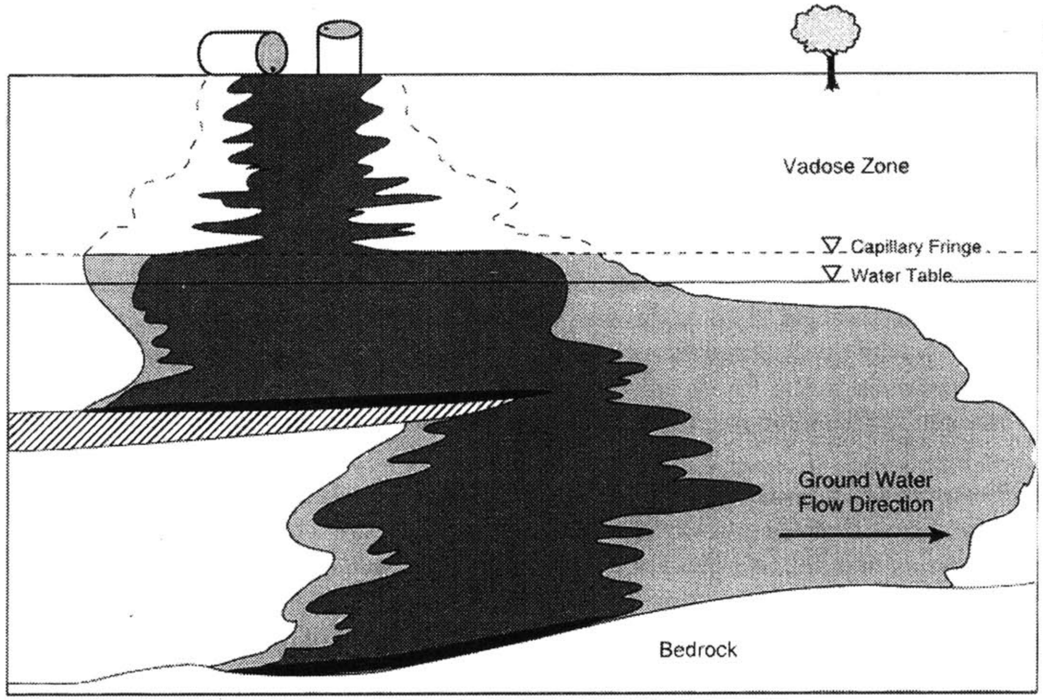
The flow of water (or other liquids) through soil is described by Darcy's law:

$$q = -K \, dh/dl$$

where q is flow, K is the hydraulic conductivity, and dh/dl is the hydraulic gradient. Hydraulic conductivity is a measure of how easily water moves through a formation. This variable influences the rate at which groundwater can be pumped from the aquifer for treatment. The hydraulic gradient measures the elevation and pressure differences in the aquifer, which is what causes the fluid to flow. This has direct influence on the movement of contaminants within the aquifer. Other physical properties of aquifers important for groundwater cleanup include the soil's effective porosity, which is the interconnected spaces between the pores in the soil. Water and contaminants flow through these interconnected pores, and the value of effective porosity can affect the



ill. 19 Simplified schematic of ground water flow in a consolidated aquifer. Direction of groundwater flow depends on fractures and is therefore tortuous and difficult to predict.



ill. 20 Simplified schematic of a DNAPL spill.

35

ability to treat contaminants. Also important is the soil's specific yield, which influences the amount of water which can be obtained by pumping the aquifer.

The physical properties of the aquifer and the soil itself will affect the spread of contaminants through the soil and water, as will the chemical properties of the contaminants themselves. For instance, TCE is a dense nonaqueous phase liquid (DNAPL), meaning that it is a liquid consisting of organic compounds which are not completely miscible with water, and that the liquid itself is denser than water. Because of the density of the liquid, it will tend to flow vertically, but be dispersed laterally at the capillary fringe, (or at the clay layer) where the saturation point for the soil is very low, due to its inherently low porosity. If a contaminant volatizes in air, it will also spread laterally in the zone above the capillary fringe. TCE will volatize, so it will behave in this manner.

Bio-Remediation vs. Pump & Treat

The EPA has chosen to address problems at the site through a traditional pump and treat system, in conjunction with the removal of some 2,100 cubic yards of soil for incineration, and soil-vapor extraction. (Currently, the soil remediation is complete.) There continue to be actions taken, however, and a groundwater remedy is still being designed for a portion of the fifth property, and the wetland itself.

One problem with traditional pump and treat systems is that these systems can cause complex perturbations in groundwater flow which may have unexpected consequences. (NRC 40) (It should be noted that the properties of aquifers as they relate the ground water cleanup are all related through their effect on pump and treat systems, which are the traditional means for remediating groundwater. As new technologies gain wider acceptance, the importance of these characteristics of aquifers may shift.)

Bio-remediation attempts to stimulate the growth of bacteria within the soil itself to cause them to literally eat away the contamination at the site. This has some potential advantages to pump and treat systems. Pump and treat can temporarily remove contaminants from the groundwater, only to have them reappear later. This is due to the tendency of contaminants to adhere to the outside structure of the soil particles. Initial pumping will remove ground water, and hence contaminants from the pores in the soil, but the latent contaminants will leach back into the water once it is replaced into the aquifer due to the difference in the pore sizes within the soil itself, and the tendency for contaminants to cling to the surface of soil particles.

Pump and treat systems can also cause the ground to sink due to removal of water. Recharge can again cause changes in ground level. If you are forced to pump and treat several in order to arrive at acceptable standards for the ground water, this can have significant implications for the cost and effectiveness of the cleanup operation. Additionally, if too much ground water is pumped for treatment, and there is a river nearby (as there is in Woburn), the water table will drop, and water from the surface water source will be pulled into the aquifer. If the river has an abundant, clean flow, this might actually help to recharge and purify the aquifer, but it can also draw bacteria (or man-made waste) from the river into the aquifer, re-polluting it. (Dune 225) (Wells G&H actually drew contaminated river water through the wetland soils when in operation.)

Bioremediation sometimes operates on a longer time-scale than successful pump and treat systems, as it takes time for microbial populations of bacteria to adapt to man-made contaminants and to build up a sufficient biomass to degrade the contaminants on-site; however, once the biomass has accrued, contamination levels often experience rapid decline. (In some circumstances, however, it is actually a faster methodology than the traditional pump and treat systems.) (NRC 65)

Pump and treat systems remove the contaminants to the surface, and because of this, they increase the hazards of exposure to the waste for humans and animals alike. Less energy is expended in in-situ remediation regimes for pumping, because "the water circulation requirements for delivering growth-stimulating materials to the subsurface are much lower than the requirements for attempting to flush out contaminants with a pump and treat system." (NRC 134) Certain microorganisms involved in in-situ bioremediation are also able to move toward regions of greater contamination, which helps to expand the zone of degradation. Bioremediation can also convert contaminants in place to harmless chemicals, such as carbon-dioxide and water.

Eight Families

3 firms must conduct Woburn pollution tests

Woburn, MA is a working class community of just under 40,000 residents, which is slowly converting to a white collar suburb. Woburn lies just ten miles north of Boston. The Wells G&H Superfund site covers approximately 330 acres, and is surrounded predominantly by light industrial and residential uses. The Aberjona River runs through the middle of the site, which consists largely of marshy wetlands. Until the early 1960's Woburn obtained its water from six municipal wells drilled into groundwater surrounding Horn Pond, in the south-central area of Woburn. In the 1950's, however, groundwater became increasingly scarce. Town officials began to look at the aquifer in East Woburn. Drilling wells in the area was a cheaper solution to the water scarcity than working out an agreement to purchase water from the Massachusetts Water Resources Authority. Despite warnings from some officials that the water would be of poor quality, the town drilled two new wells on city-owned property in 1964 (Well G) and 1967 (Well H.)

Drilling to find hazardous wastes at Woburn site

At that time, two of the site's nearest neighbors were WR Grace, who operated a small plant to the east of Washington Street, and the JJ Riley Tannery, the only tannery remaining in a city once home to twenty. (Woburn was once second only to Philadelphia in number of tanneries, and claimed as a nickname, Tan City.) Many other industrial and trucking concerns moved into Woburn during the 1960's, and the city became known for its industrial character.

It was in the summer of 1967, after Well H opened, that significant problems arose. That summer the Massachusetts Department of Health recommended shutting the Wells after testing, but settled with the City, and agreed to let them stay open, as long as they chlorinated the water. In 1968, the City began the chlorination process. In the Spring of 1969, the residents of East Woburn formed a committee to attempt to get the city to shut down the wells. In October of 1969, The Wells were shut down, but in the Spring of 1970, they were reopened by order of the City engineer. All throughout the Summer of 1970, residents complained about taste, odor, even rusted pipes, and in January of 1971, the wells were again shut down. In March of that same year, Michael Zona, a child living in the Pine Street neighborhood of East Woburn, was diagnosed with Leukemia. In May the Wells were reopened, but only for nine days, due to intense pressure brought to bear on the City Engineer by the City councilman for East Woburn.

State to study Woburn's high cancer rate

Jury: Firm fouled wells in Woburn

Throughout 1972, the Wells went unused, despite threats from the City Engineer to reopen them unless water was conserved. In January of 1972, Jimmy Anderson, a boy who lived a few blocks away from the Zona's, was diagnosed with Leukemia. In the same year the Nagles, residents of the same neighborhood, also had a child diagnosed with the disease. In 1973, a severe drought struck the state, and in August, Well G was reopened. In June of that same year, Kevin Kane, also a child living in East Woburn, was diagnosed with Leukemia. In 1975, the Lilley's, of East Woburn, lose a son to Leukemia. In 1976, the Robbins lose a son to Leukemia. By 1979, there were twelve reported cases of the disease in Woburn: Anderson, Aufiero, Aufiero, Barbas, Carlsons, Kane, Nagle, Robbins, Ryan, Toomey, Veno, and Zona (next door neighbors to the Nagles.) Of these twelve, eight were residents of East Woburn, and six were from the Pine Street neighborhood.

In the spring of 1979, police discovered and removed 184 barrels of industrial waste from vacant land one-half mile north of Wells G&H. At this point the State health inspector felt it prudent to inspect the water in the two wells, and on May 22, his report arrived on the desk of the Director of the northeast region for the State Environmental Department, prompting a same day call to the City engineer, ordering the immediate shutdown of the Wells. The levels of TCE in the Wells at the time of the test were 267 ppb for Well G and 183 ppb for Well H. Safe levels of TCE are less than 10 ppb. Later that year, in September, a lagoon of arsenic was uncovered one mile north of the Wells, at the site of the old Merrimac Chemical Company. The lagoon was heavily contaminated with arsenic, lead, chromium, and animal remains from tanning.

The fear of toxic wastes produces activist suburbs

Throughout 1980 and 1981, the EPA began extensive testing to determine the sources of contamination to the Wells. In 1980, Roland Gamache, one the few adults to acquire Leukemia, dies of the disease, and in 1981, Jimmy Anderson loses his childhood battle with leukemia. In 1982, led by Anne Anderson, who had been the first to believe that the water had something to do with the instances of Leukemia, several residents of East Woburn filed suit against WR Grace, Unifirst Corporation, and Beatrice Foods, the owner of the JJ Riley Tannery. The case was long and arduous. It was one of the first civil cases of its kind, and stretched out over five years, incorporating many experts in hydrogeology and toxicology, extensive cataloguing of the health histories of those involved in the case, and intense research into the means by which the contaminants

Love Canal, Woburn have common concern

reached the site. Unifirst was first to settle out of court. Their settlement of a little over $1 million only served to offset some of the mounting costs of the plaintiffs.

The trial ended with Beatrice found not culpable, despite a later ruling by the EPA that they were indeed a chief polluter along with WR Grace, and an eventual $8 million dollar settlement with WR Grace, small by today's standards of lawsuits. The lawyer for the plaintiffs, Jan Schlichtmann, went bankrupt and his law practice dissolved under the pressure of the case.

Law, science mix during trial

The tannery's owner, Beatrice, WR Grace, Unifirst, Olympia Nominee Trust, and New England Plastics are being addressed as responsible parties in the cleanup of the site by the EPA. The tannery shut shortly after the lawsuit, due to monetary pressures brought about by the EPA's verdict. No evidence of JJ Riley exists on site today; the tannery has been demolished. Soil from the Beatrice site was removed and incinerated as part of the EPA's cleanup plan. In 1989, the EPA released its plan for the cleanup of the groundwater at the Wells G&H site. The plan was constructed with input from WR Grace and members of FACE (For A Cleaner Environment) a citizens' group founded by Anne Anderson. The plan calls for each responsible party to pump and treat groundwater at their properties. WR Grace and Unifirst have constructed a combined system for groundwater cleanup on their properties. Agreements are still being pursued between the EPA and the other responsible parties, including Beatrice Foods, and New England Plastics.

The story of the families and the trial was told in Jonathan Harr's best-seller, *A Civil Action*, published in 1995. This Christmas, the movie version of the novel was released by Disney, with John Travolta starring as Schlichtmann.

New studies consider health questions that remain in Woburn

A Superfund Primer

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) was passed in 1980. This law was passed to respond to the growing need for large sums of money to clean up some of the worst dumping grounds for hazardous waste across the country. The law established the Superfund Trust Fund. This fund is administered by the Environmental Protection Agency. The fund, appropriate at approximately 1.5 billion annually, is used to pay for site cleanup when those responsible for cleanup of the site are unable to pay, usually due to bankruptcy. The law authorizes the EPA to conduct tests to determine the level of contamination at the site, in order to determine if it is eligible for placement on the National Priorities List (NPL) which is the list of all sites nationally which are eligible for Superfund money. Sites are evaluated and scored, based on a system which examines the contaminants present, the site's proximity to protected or residential areas, and other factors, including the expense and difficulty of cleanup methods. If a site receives a score above a certain set limit, it is designated a Superfund Site.

CERCLA further authorizes the EPA to conduct investigations to determine the parties responsible for the pollution at the site, and to propose and negotiate cleanup methodologies and costs with the responsible parties. If the responsible parties fail to reach an agreement with the EPA, the EPA can resort to a rarely used weapon: clean up the site, and sue the responsible parties for triple damages. The EPA oversees the cleanup work conducted by contractors hired by the responsible parties to insure that the cleanup standards are met, and that all contamination is removed or treated.

There are thousands of hazardous waste sites which do not qualify for the Superfund. Many states have implemented their own laws modeled after CERCLA, and have designated state sites using systems similar to the Federal government's.

Cleanups at these sites often require the input of experts in science, engineering, public health management, law, and community relations. In order to administer these sites, the EPA divides the country into nine regions and within each region, a coordinator and a group of specialists are assigned to the Superfund. The most recent NPL listing (April 30, 1998) contains 1,194 sites. (EPA Web Site)

The Ten Most Frequently Detected Groundwater Contaminants at Hazardous Waste Sites

1. Trichloroethylene
2. Lead
3. Tetrachloroethylene *
4. Benzene
5. Toluene
6. Chromium *
7. Methylene Chloride
8. Zinc
9. 1,1,1-Trichloroethylene *
10. Arsenic *

Asterisks indicate which contaminants appear at the Wells G&H Site.

Program

Educational Mission of the Center

The center exists to provide a place for students to learn about their natural environment through interaction with university students, researchers and professors, members of local environmental groups, and policymakers.

The center serves students in grades K-12, building knowledge as the student grows and matures. The standard format for programs at the center will be half-day or daylong programs. Older students should be given the opportunity to work at the center for longer time periods, depending both on educational level and personal commitment to the issues at stake. The center will serve as a link for students in grades 9-12 to longer term collaborative projects with university-level researchers.

Students will share their knowledge with their parents through projects structured around joint student/parent work. Programs will be structured which allow students to take their work to senior and community centers. Older students will be given opportunities to lead sessions at the center and at local schools for younger students.

Students will at all times be exposed to diverse views on the environment, and allowed to make their own informed decisions, particularly as they become older and more able to make value judgements.

Educational Aspects of the Center

1. Cultural: to impart to students and to community members the ways in which human begins affect and alter the natural environment; to understand the changing views of nature over time and across cultures

2. Historical: to tell the Woburn story in its broadest sense, the legacy of the industrial revolution, to tell the story of the site in tis larger context, the Mystic River Watershed, to link these stories to those of the modern environmental movement

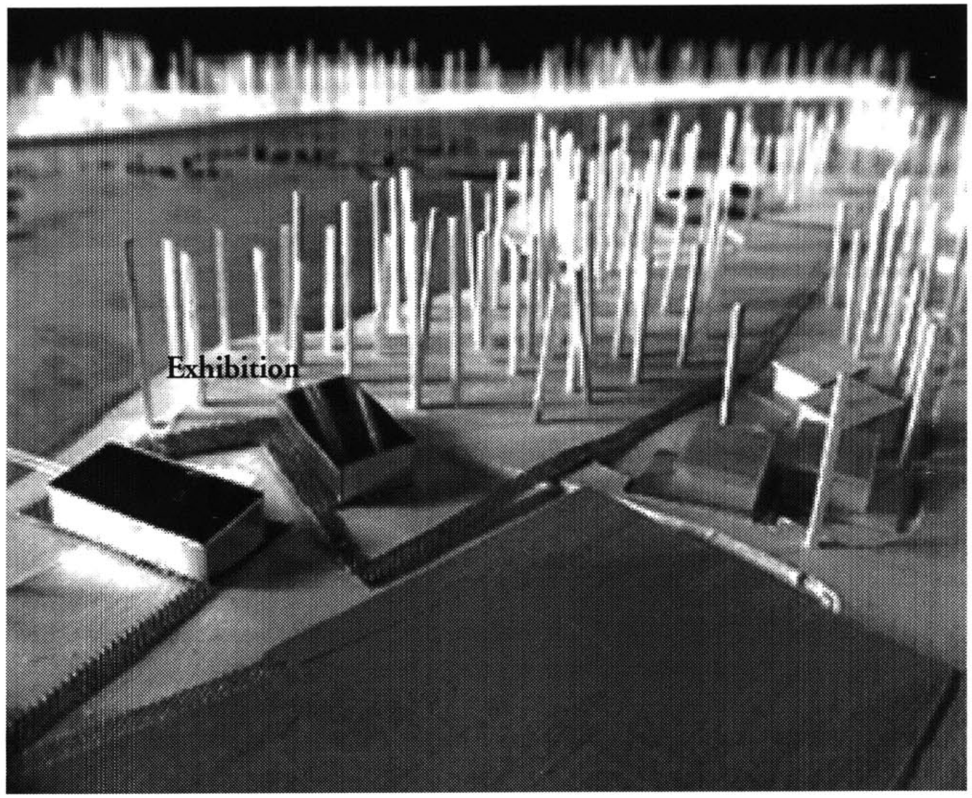
3. Scientific: to educate students and the community about principles of basic science, the history of science related to human health, about the differences between scientific and legal uncertainty, and to familiarize students with the methods which scientists use to study, evaluate and clean up polluted sites

Educational Techniques:

1. provision of information - about the local site, hazardous waste sites across the country, remediation technologies, environmental laws and policies

2. exploration by students - of the local site and surrounding natural areas, of other sites across the country through virtual links, of their own ethics and values as they relate to the environment, of the link between the man-made and the natural, of how views of economic growth versus sustainability have changed over time

3. communication - with scientists, professors and students, as well as policymakers

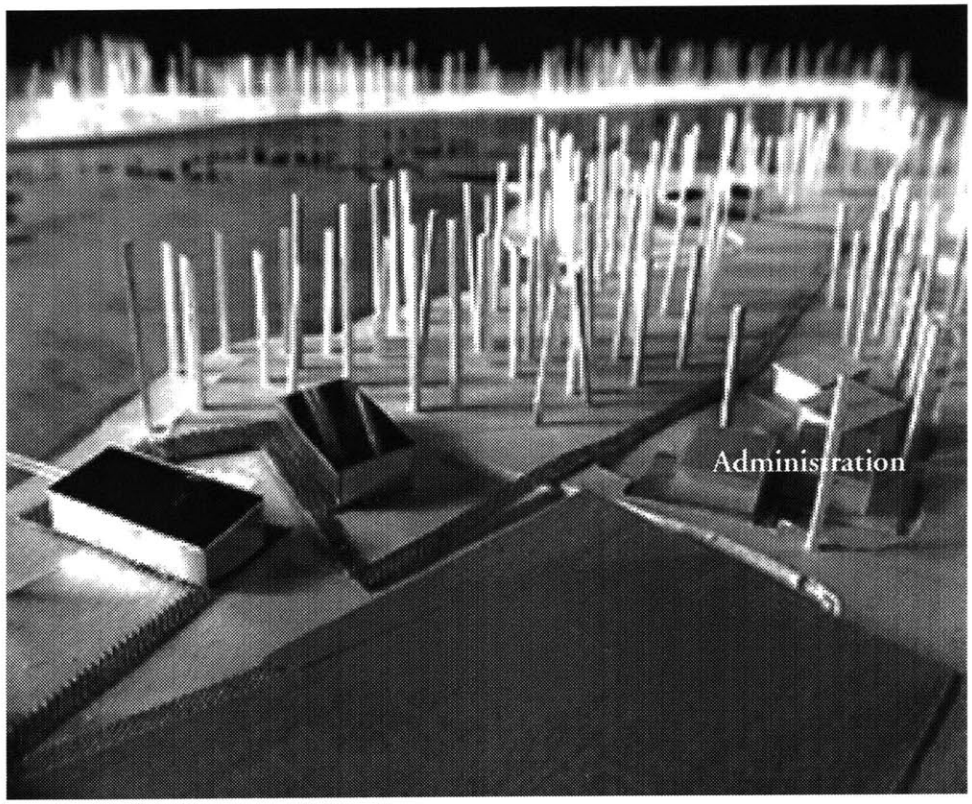


Exhibition Pavillions

2 x 1200ft^2 = 2400ft^2

Temporary Exhibit Spaces
For changing exhibits designed by students, local environmental groups, and university stakeholders.

Permanentt Exhibition Spaces
For exhibition on Woburn's history, the story told in *A Civil Action*, and current research efforts in the Mystic River Wastershed.



Administrative Pavillions

4 x 600 ft^2 = 2400ft^2

Meeting Rooms: For staff and researchers to gather to plan programs (day) for local community groups. (night)
Web Studio: Central facility for on-line videoconferencing/webcasting - each classroom/lab has camera in place and ready to broadcast, this site coordinates and runs the show.
Site Director's Office
Archive - Materials from EPA, MIT, Tufts, etc.

Classrooms/Project Rooms

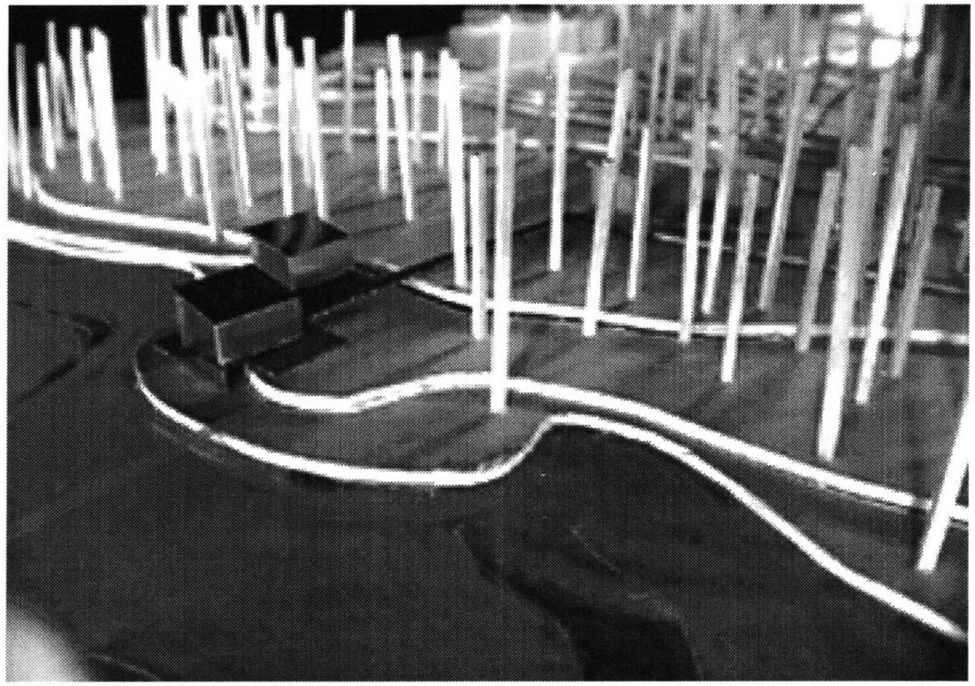
6 x 600 = 3600 ft^2

One project room equipped with minimal lab stations for students to run small experiments.

One project room equipped with computers for research and written materials, and quiet spaces for reading and research

Two classrooms for lecture and seminar-based sessions.

Two flexible spaces for use as either classrooms or project rooms.



Laboratories

2 x 600 = 1200 ft^2

One for working scientists and older students, to evaluate field samples.

One for on-site experiments/evaluations with students - this space is oriented towards demonstration labs.

Stakeholders

University

MIT - Parsons Lab, Center for Environmental Health Sciences, Earth, Atmospheric, and Planetary Sciences, Civil and Environmental Engineering, MIT K-12 Program

Tufts - Department of Civil and Environmental Engineering, Tufts K-12 Program

Boston College Watershed Institute

Local Environmental Groups

Woburn Conservation Commission

Mystic River Watershed Association

John Snow Institute

These local groups might be tapped to organize/implement the permanent exhibition of Woburn's history, and to provide volunteer docents to lead tours through both the temporary and permanent exhibits, in coordination with researchers/educators.

Municipal Government

EPA - Local project coordinators could work in design and implementation of programs related to legal aspects of site cleanup. Such a center would also provide the EPA a concrete opportunity to take a proactive role in communities affected by Superfund Sites. A prominent role in a center such as the one proposed would provide a first hand look for students at he realities of site cleanup from the legal and governmental perspective, while at the same time providing an excellent public relations front for the EPA.

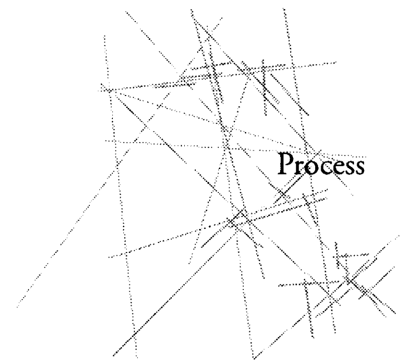
K-12 Districts - Ideally the center would serve any school district, with a liaison appointed to the center within each district.

Research Efforts in the Mystic River Watershed.

The center exists to support ongoing field research within the Mystic River Watershed; the communications of these efforts by researchers to the local community; and the sharing of knowledge between researchers and local students.

MIT's Center for Environmental Health Sciences, in conjunction with faculty, researchers and students at the Ralph M. Parsons Laboratory and of the Civil and Environmental Engineering Department are conducting a multi-year, federally funded study of the Mystic River Watershed which involves studying the "sources, fate, and transport of organic and inorganic chemicals, human health exposure and public health effects in the Aberjona River Valley in eastern Massachusetts." (MIT CEHS Web Site) This is an ongoing study, and the researchers are committed to working with local communities and community leaders, and continuing educational outreach.

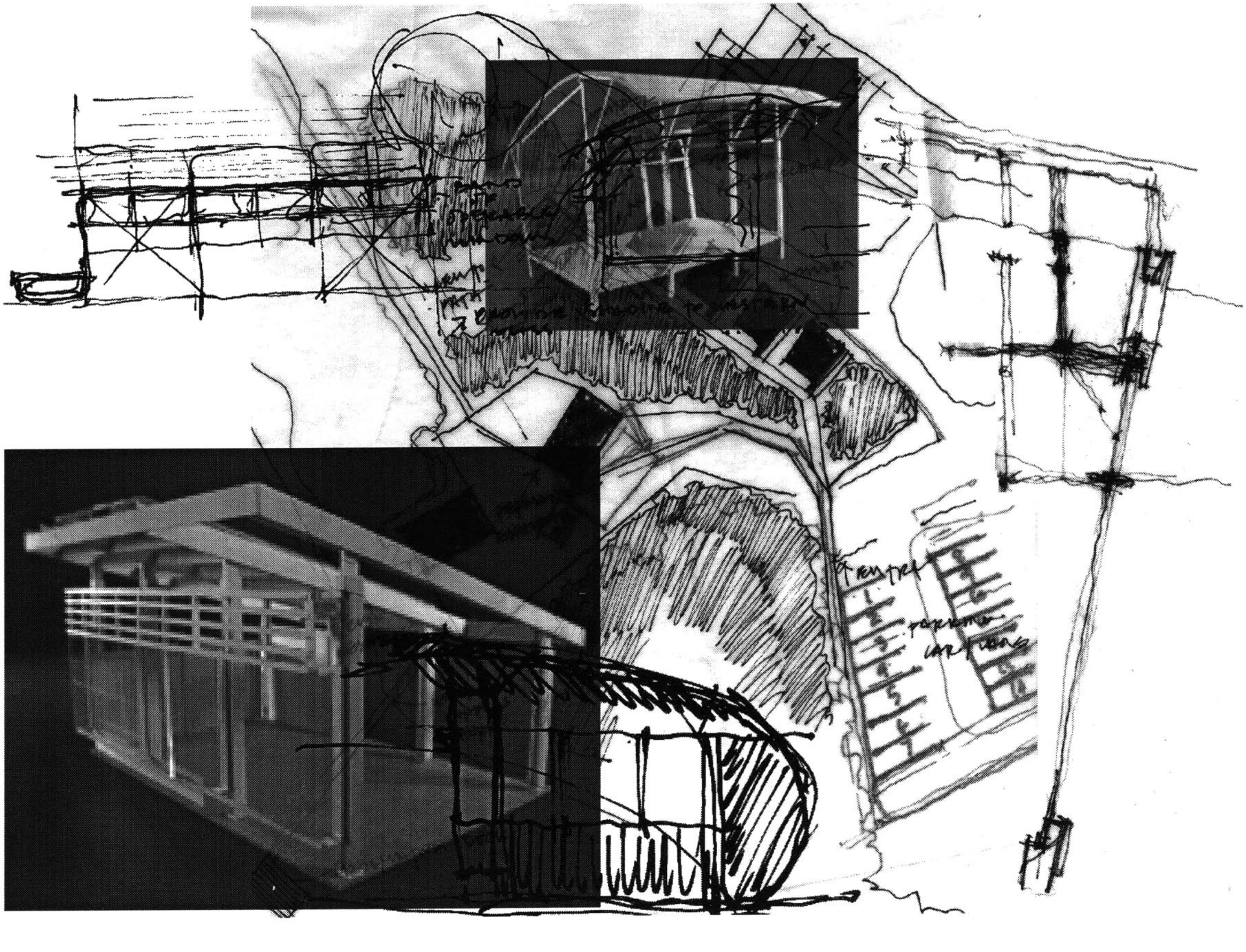
Tufts Civil and Environmental Engineering faculty member and MIT PhD graduate John Durant also works on Mystic River Watershed Issues with researchers from MIT. Students at Tufts work on independent research projects in the watershed, and also maintain a website for the Mystic River Watershed Association.



Process

55

layers of **time** like an onion skin
revealed through microscopes and wanderings
through marshy pools strangely **quiet**
and **apparently** refreshing
despite highspeed **rushing** of commuters
and crimes below the **surface**
where centuries old **processes**
disturbed by human hand see whole lives
altered at such pace that entire
generations know nothing but the **moment**
in which a child draws a last **breath**
before joining in a cycle so **timeless**
only the rocks below can tell of its **life**


ENTRY

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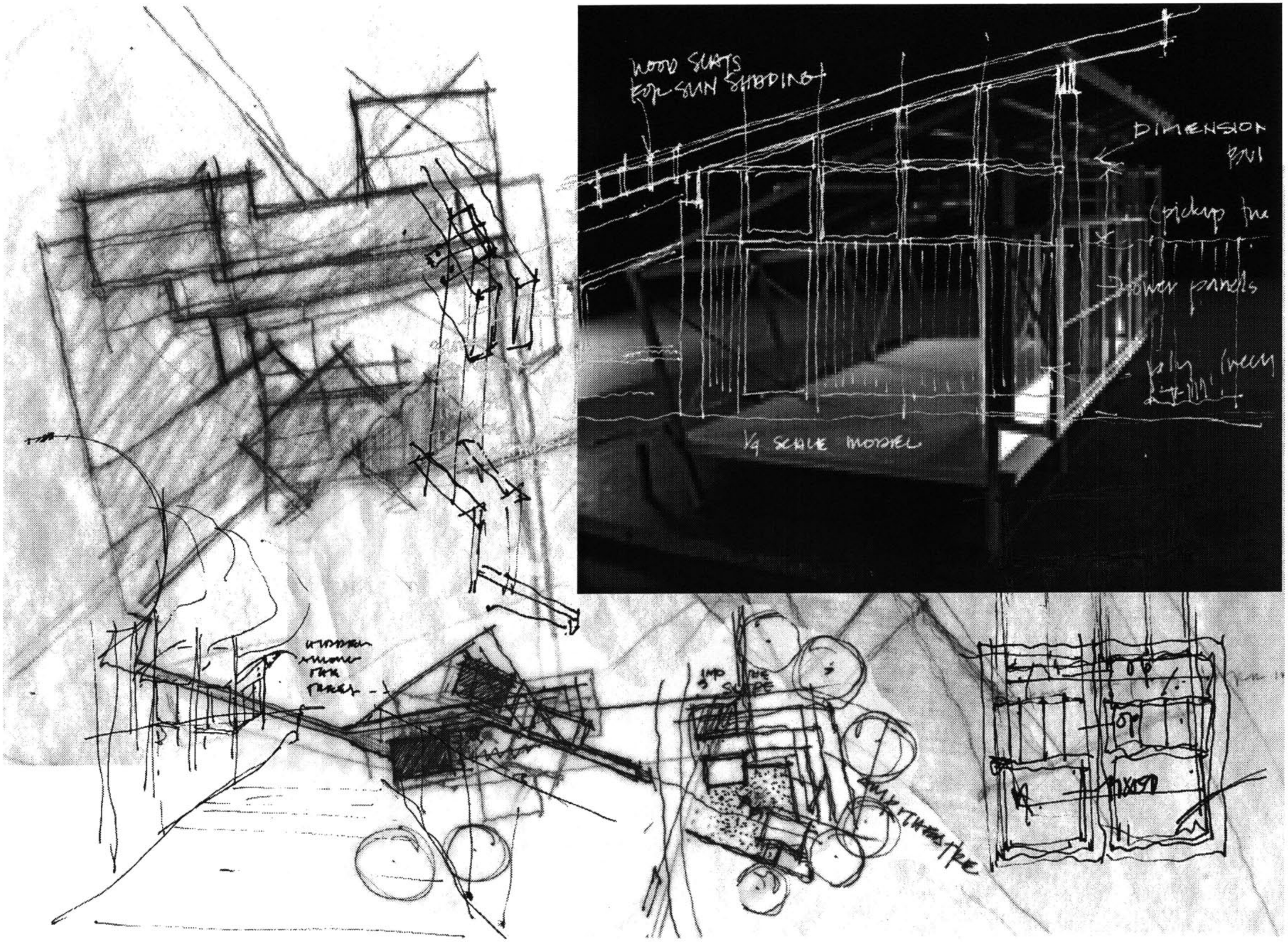
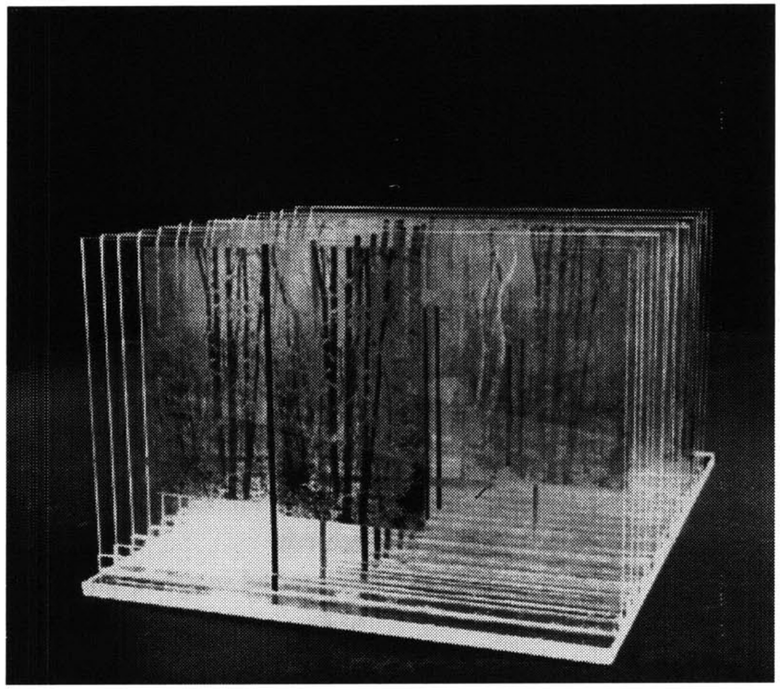


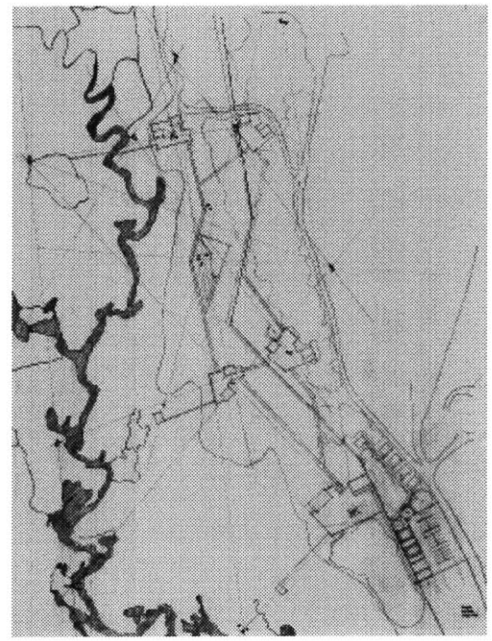
sun rising over hills, defining **outlines** in shades and reflections
of leaves **filtering** light for tall grasses below
where insects hum and jump into hungry croaking mouths
of frogs **hiding** amidst dark spaces spaces underneath their canopy of sedge
as hawks fly above, eye **piercing** undergrowth for mouse
chewing on recently waylaid nut, now scampering
from sound of **footsteps** of children
exploring
testing
probing
for signs of birth and **death** and in between
where space lies defined by trees and sky and **time**

walking through **time** condensed like that thick sweet milk in vietnamese coffee
displaced by technology to other sites of destruction and **rebirth**
grounded in space while walking beneath overstory
hiding quiet secrets of cycles below
predating **time** as we conceive it
and determining **life** for time as we may never know

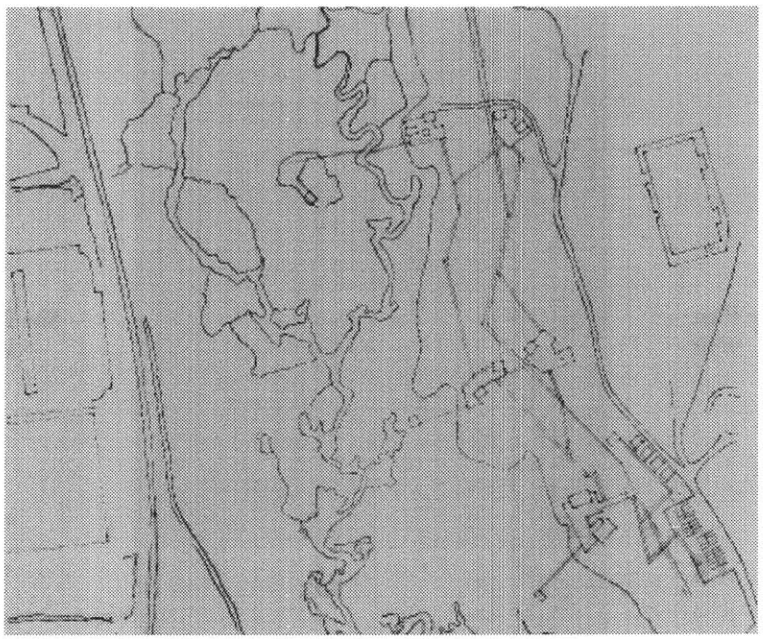
60 ill. 21
Initial concept model.



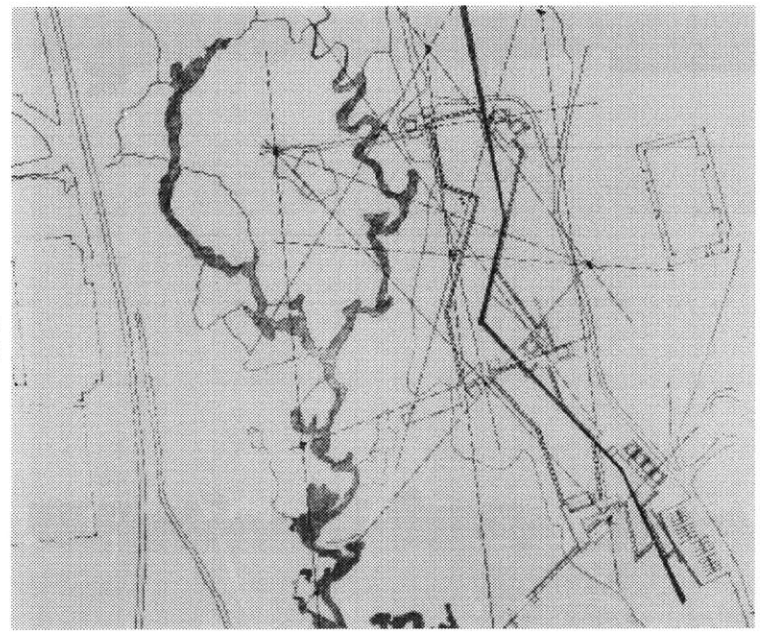
Site Plan
9/30



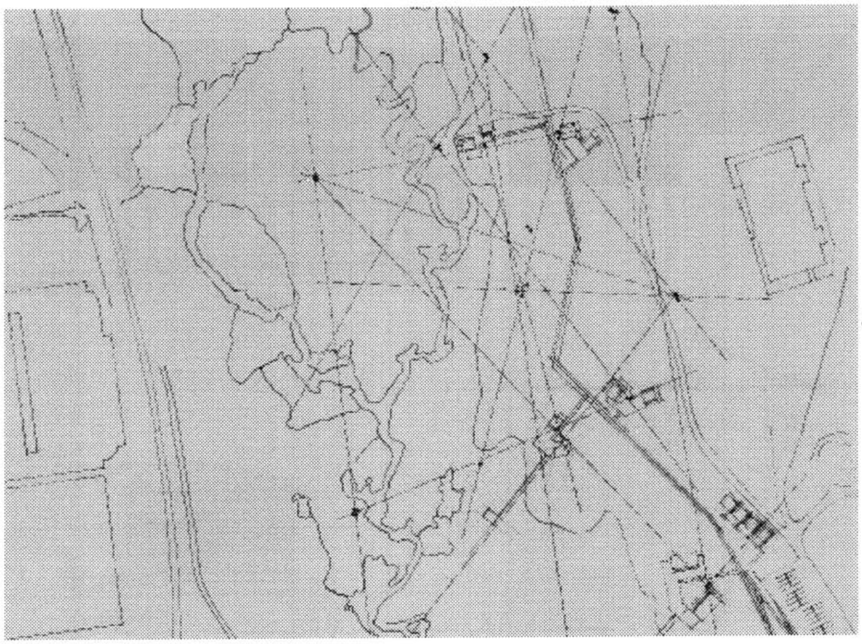
Site Plan
10/7



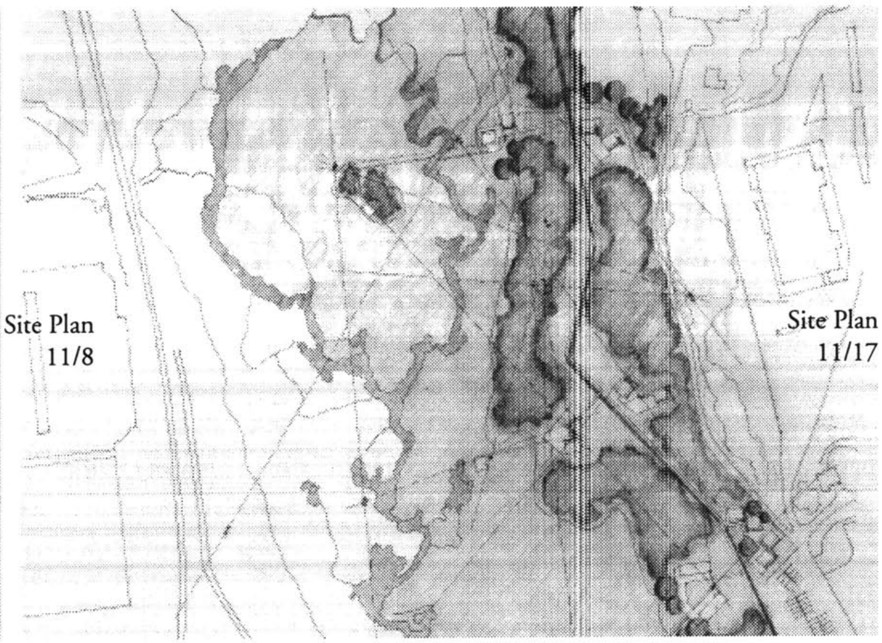
Site Plan
10/28



Site Plan
11/6



Site Plan
11/8



Site Plan
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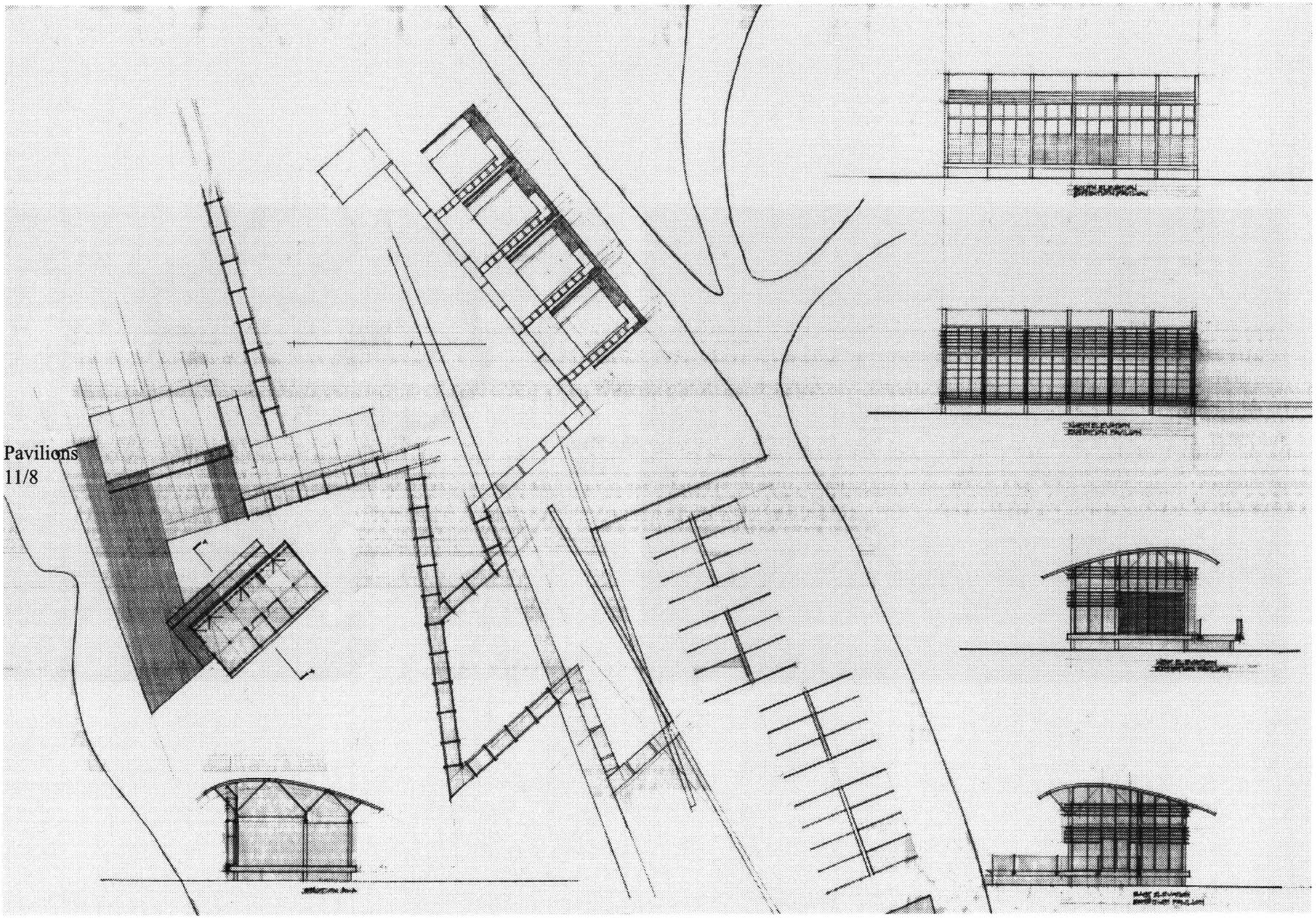

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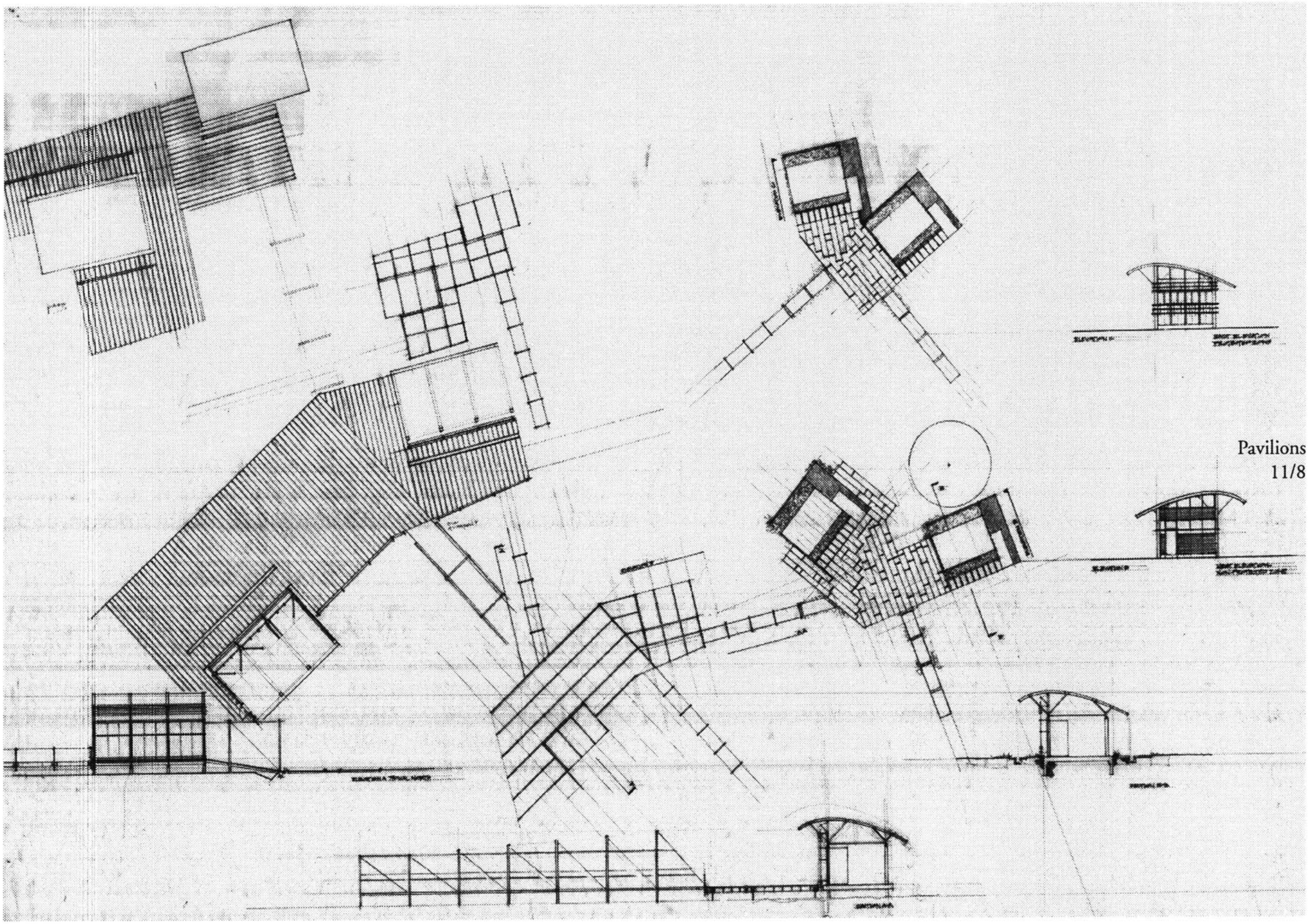
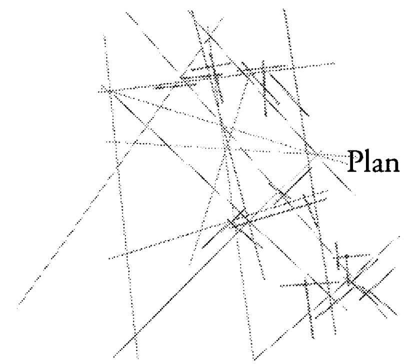
Pavilions
11/8



Pavilions
11/8



Plan

67

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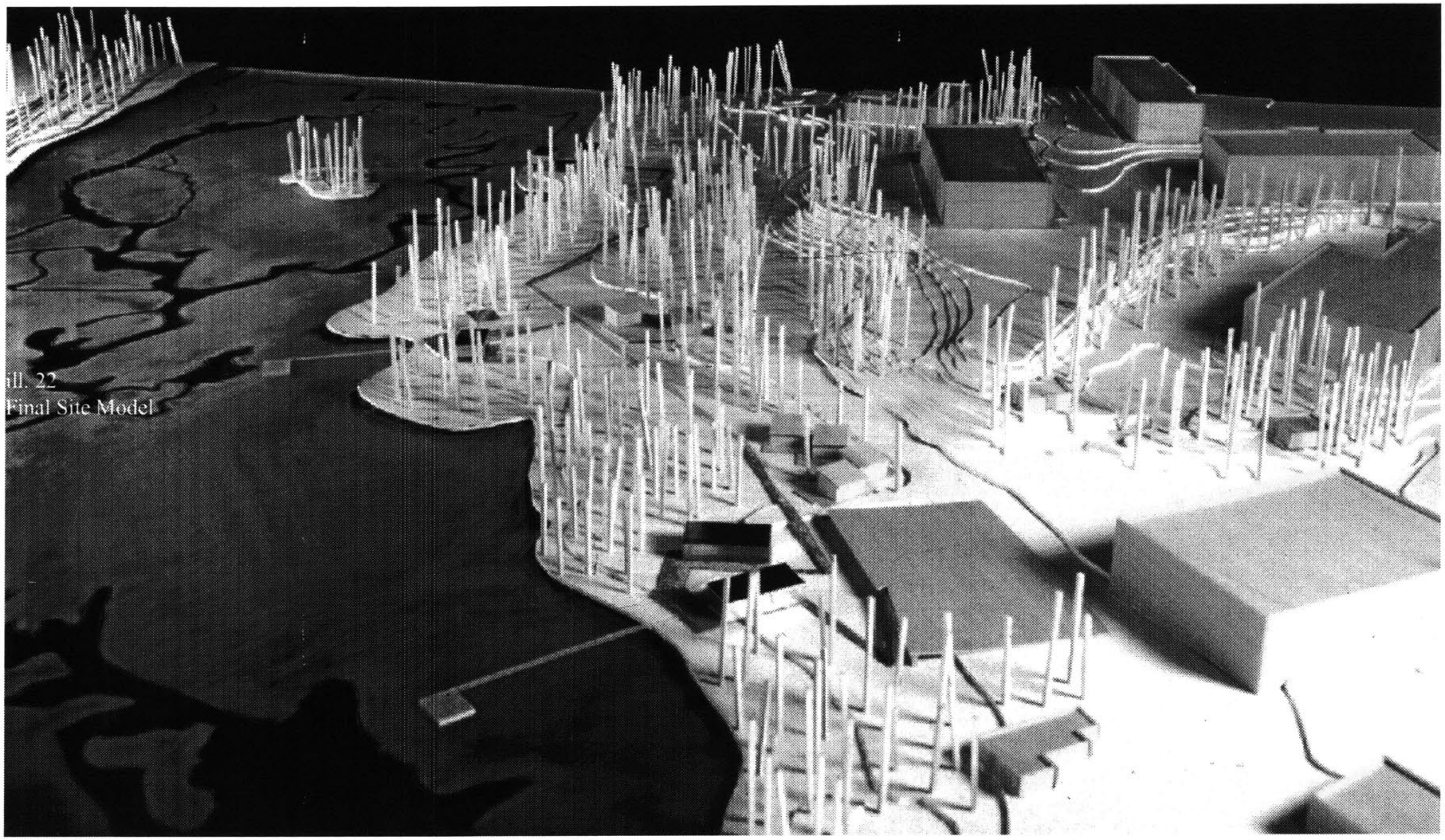
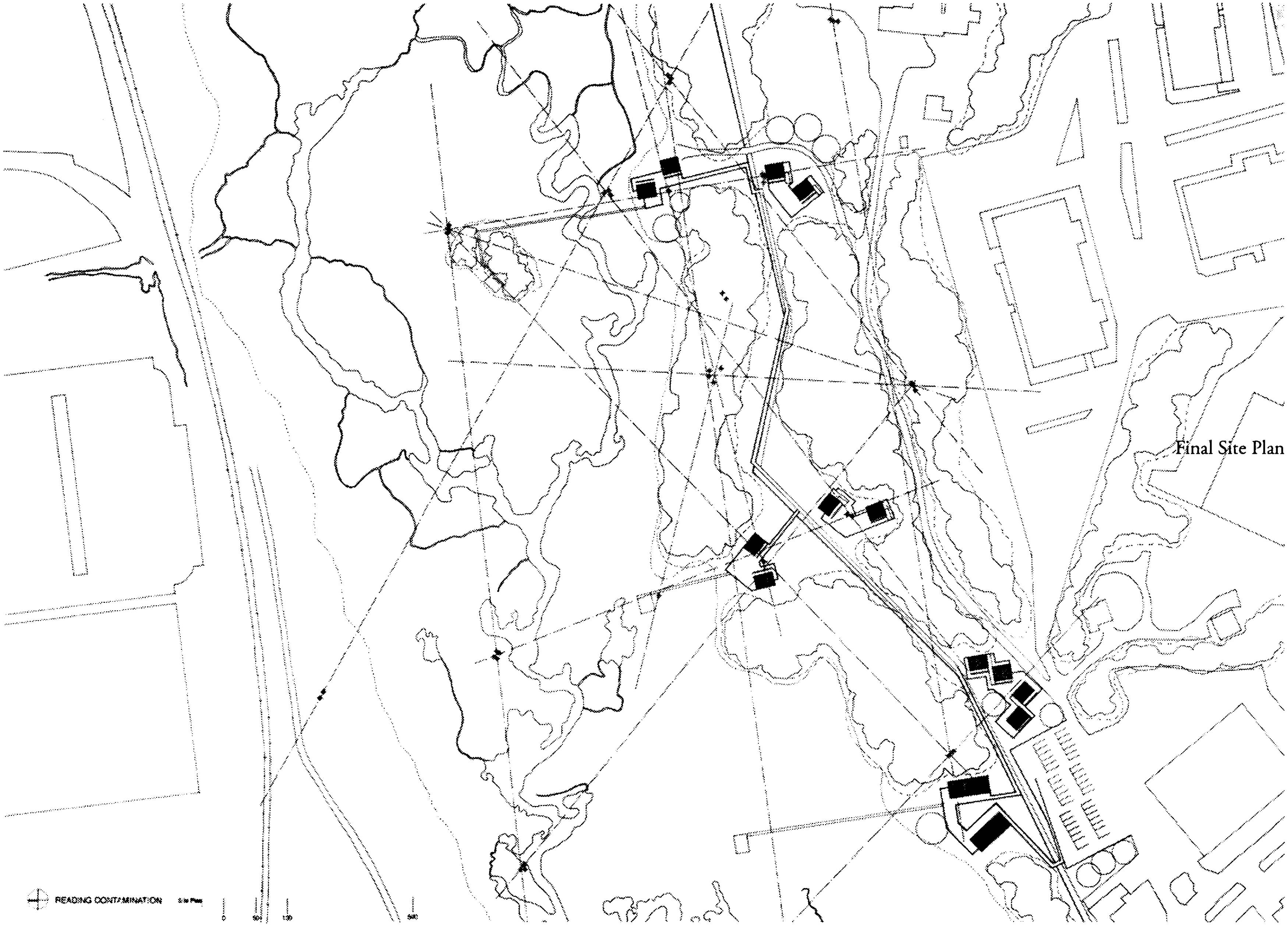
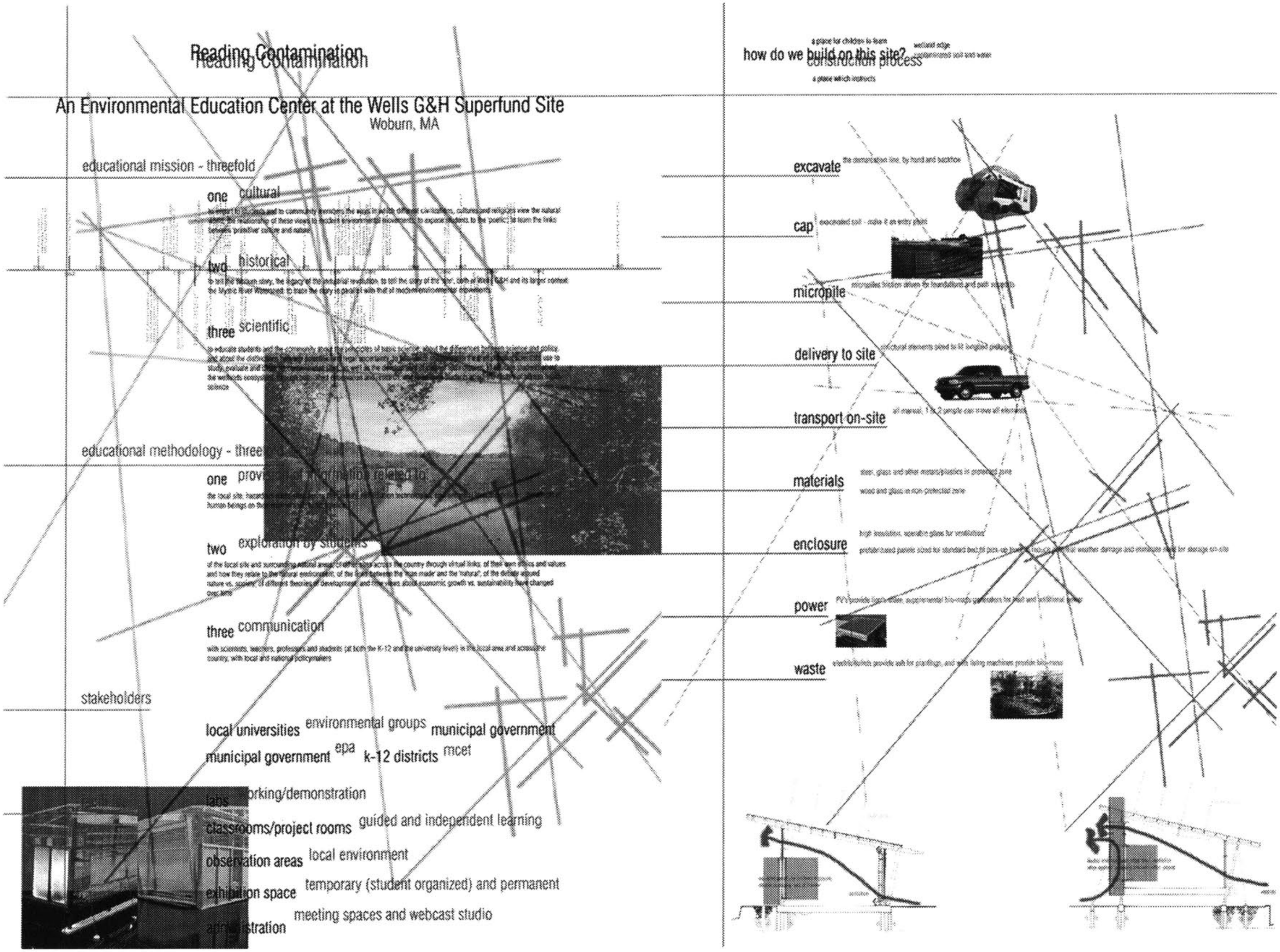


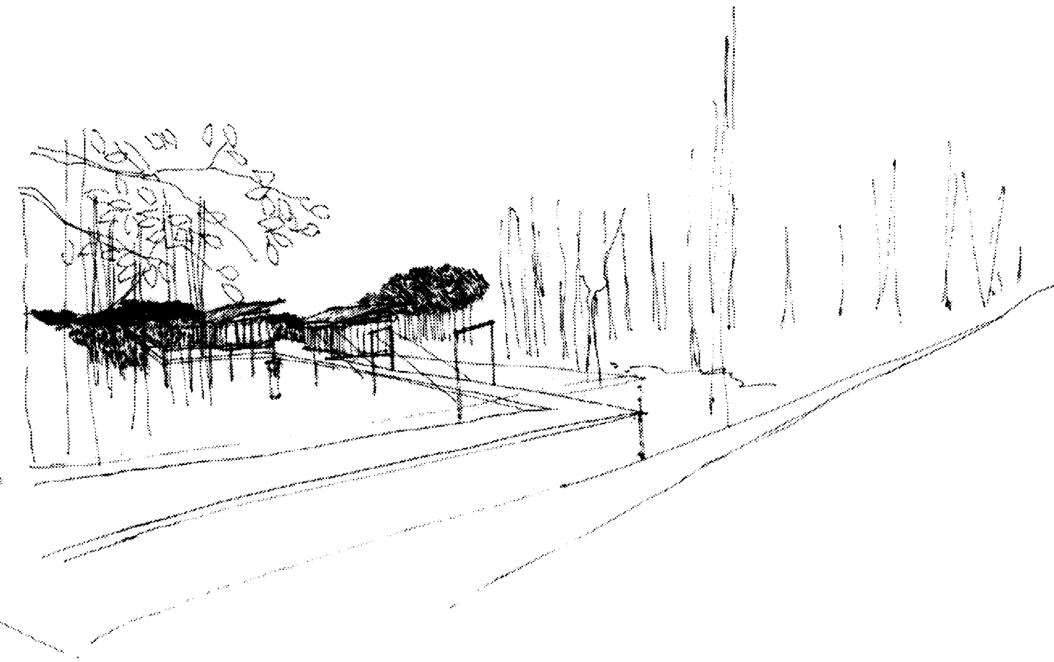
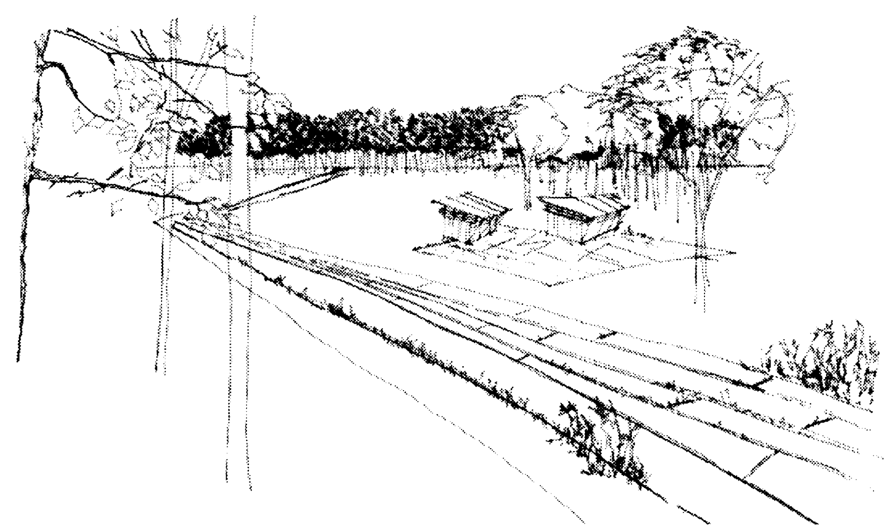
ill. 22
Final Site Model

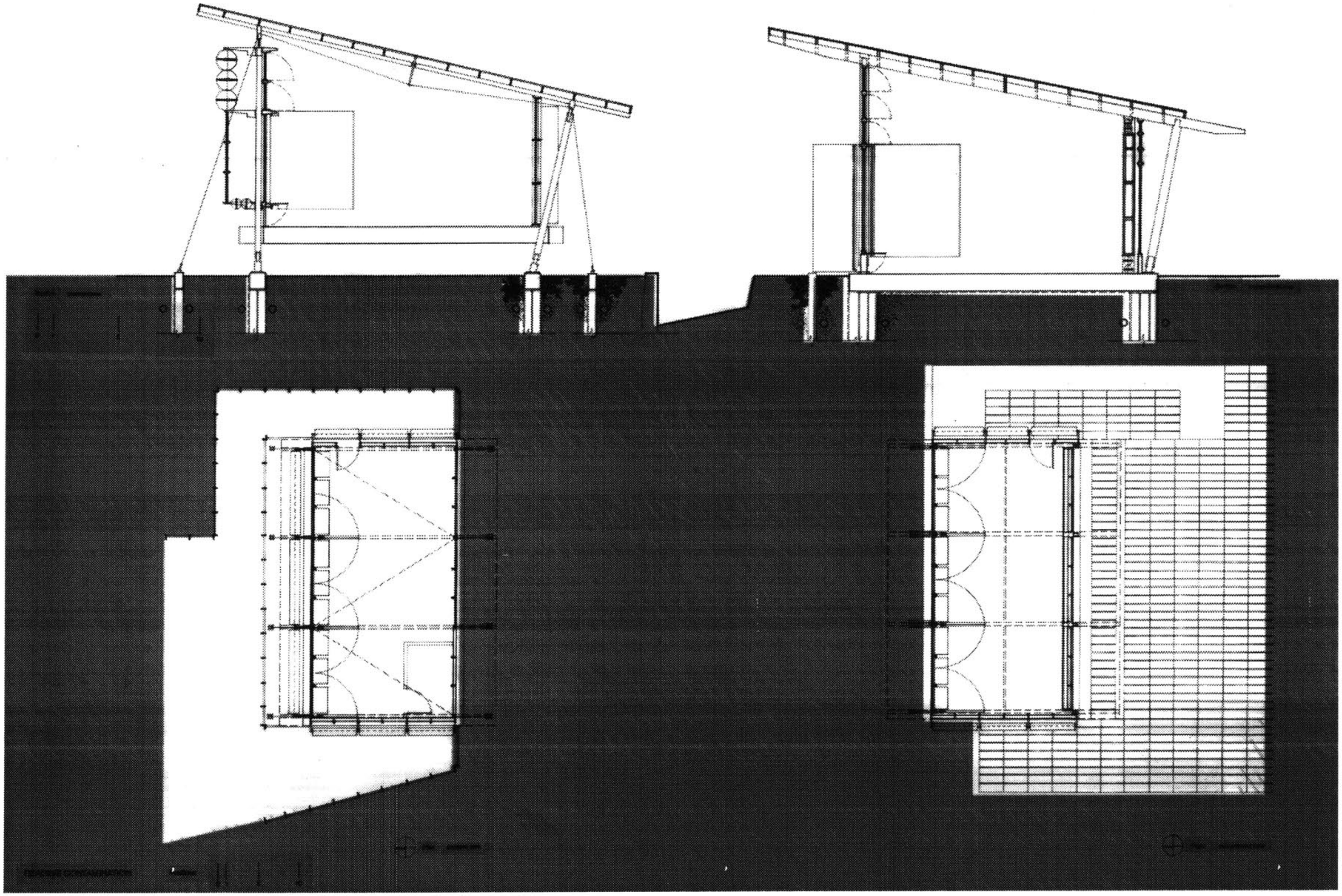


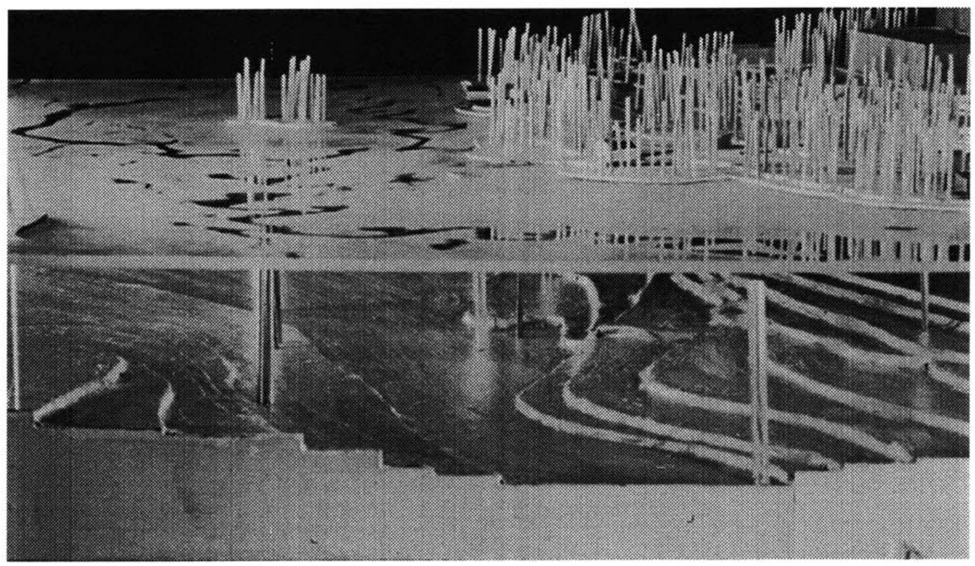
Final Site Plan

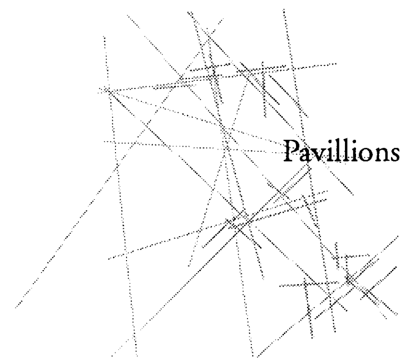


Reading Contamination
An Environmental Education Center at the Wells G&H Superfund Site
Woburn, MA
educational mission - threefold
one cultural
two historical
three scientific
educational methodology - three
one
two
three communication
with scientists, teachers, professors and students (at both the K-12 and the university level) in the local area and across the country, with local and national policymakers
stakeholders
local universities
environmental groups
municipal government
municipal government
epa
k-12 districts
mcet
labs
working/demonstration
classrooms/project rooms
guided and independent learning
observation areas
local environment
exhibition space
temporary (student organized) and permanent
administration
meeting spaces and webcast studio
a place for children to learn
wetland edge
how do we build on this site?
construction process
contaminated soil and water
a place which instructs
excavate
the demarcation line, by hand and backhoe
cap
micropile
delivery to site
transport on-site
materials
steel, glass and other metals/plastics in protected zone
wood and glass in non-protected zone
enclosure
high insulation, operable glass for ventilation
power
waste







Pavillions

Pavilions (Protected Zone)

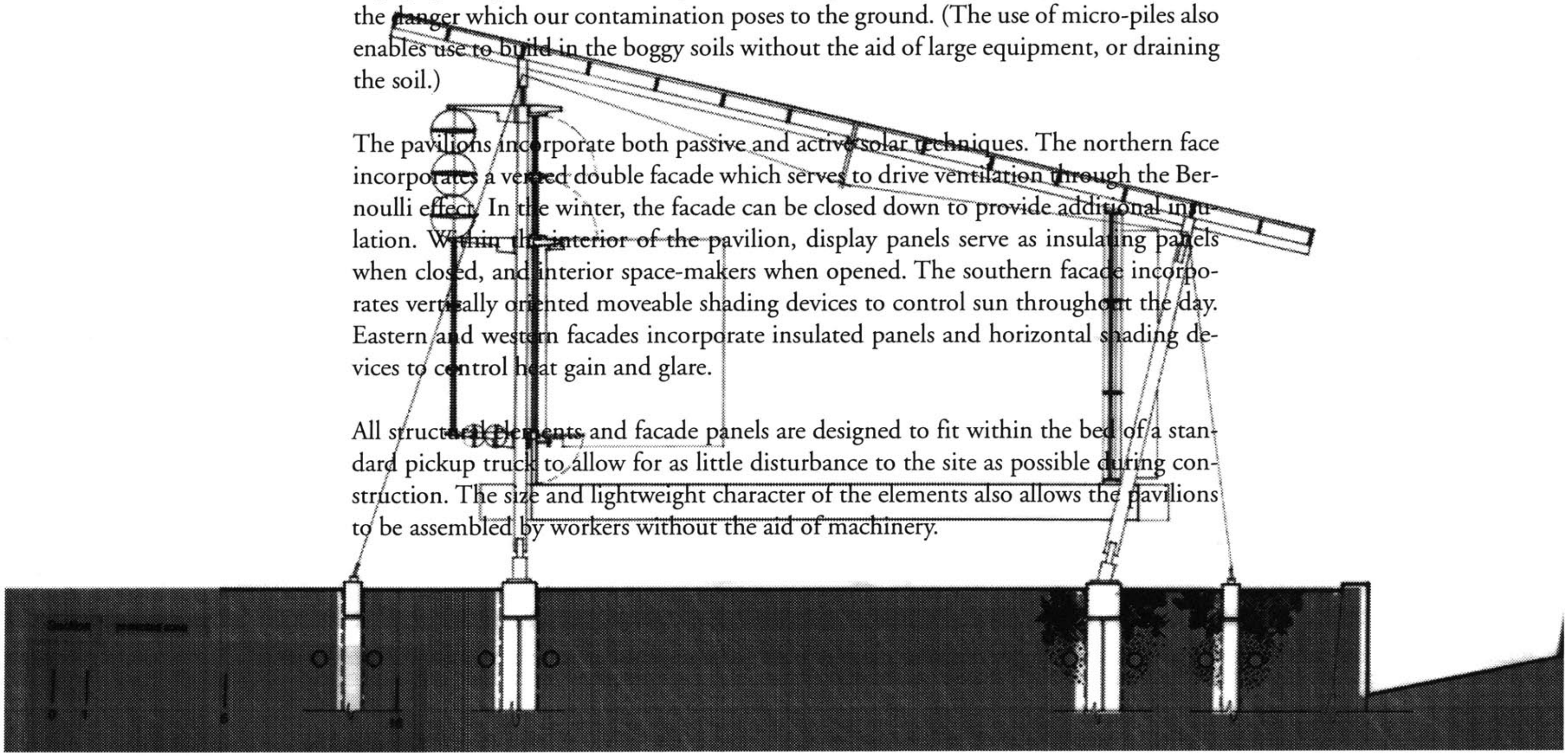
The pavilions seek to demonstrate both passive and active techniques available to control energy use.

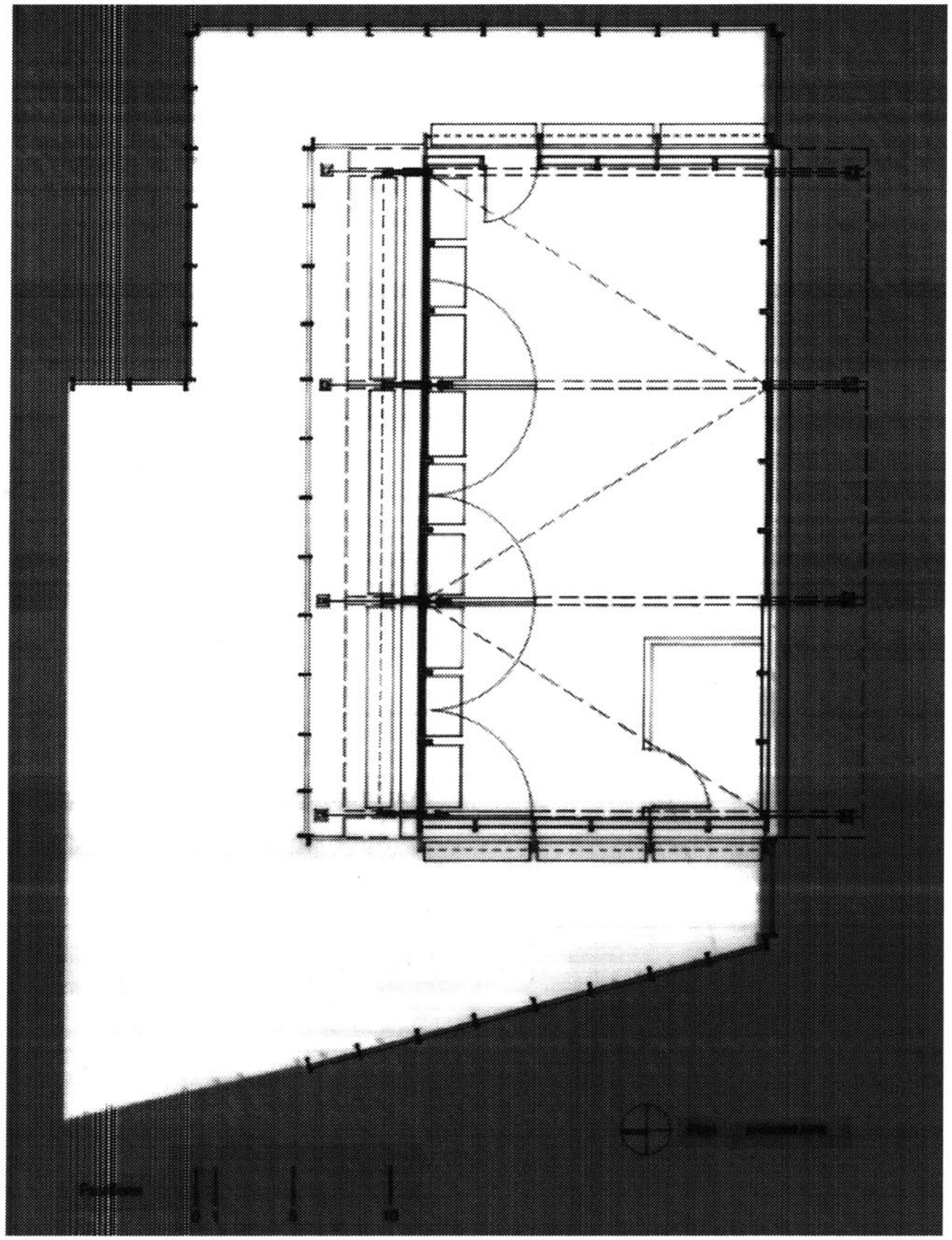
Pavilions within the protected zone are constructed of (non-natural) materials. The presence of these materials within the protected zone emphasizes the invasion of contamination within the wetlands.

The pavilions and paths within the protected zone are lifted above the ground, with micro-pile foundations. The lifting of the pavilions and paths restricts the users from engaging the ground, reinforcing both the danger of contaminated ground to us, and the danger which our contamination poses to the ground. (The use of micro-piles also enables use to build in the boggy soils without the aid of large equipment, or draining the soil.)

The pavilions incorporate both passive and active solar techniques. The northern face incorporates a vented double facade which serves to drive ventilation through the Bernoulli effect. In the winter, the facade can be closed down to provide additional insulation. Within the interior of the pavilion, display panels serve as insulating panels when closed, and interior space-makers when opened. The southern facade incorporates vertically oriented moveable shading devices to control sun throughout the day. Eastern and western facades incorporate insulated panels and horizontal shading devices to control heat gain and glare.

All structural elements and facade panels are designed to fit within the bed of a standard pickup truck to allow for as little disturbance to the site as possible during construction. The size and lightweight character of the elements also allows the pavilions to be assembled by workers without the aid of machinery.





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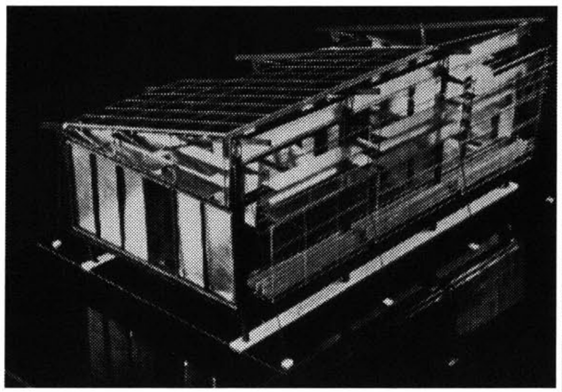
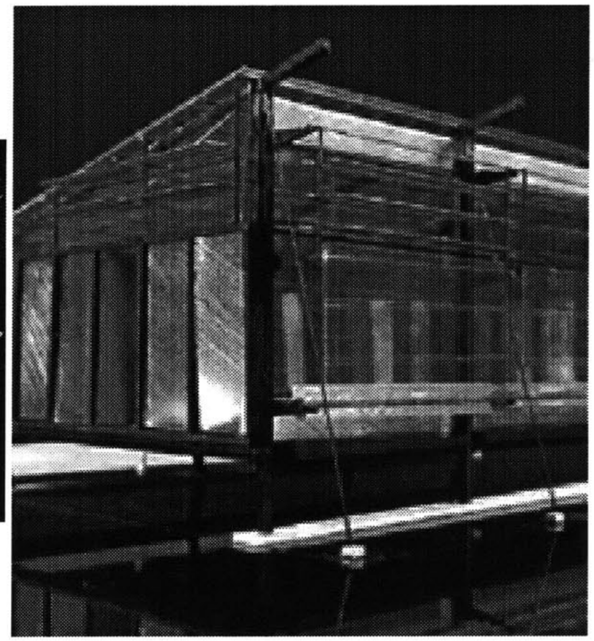
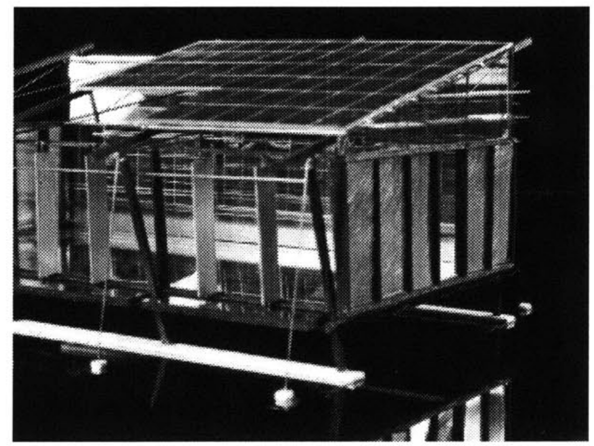






ills. 23, 24, 25 and 26 (Facing page) Final Pavilion (Protected Zone) Model

Pavilions (Non-Protected Zone)

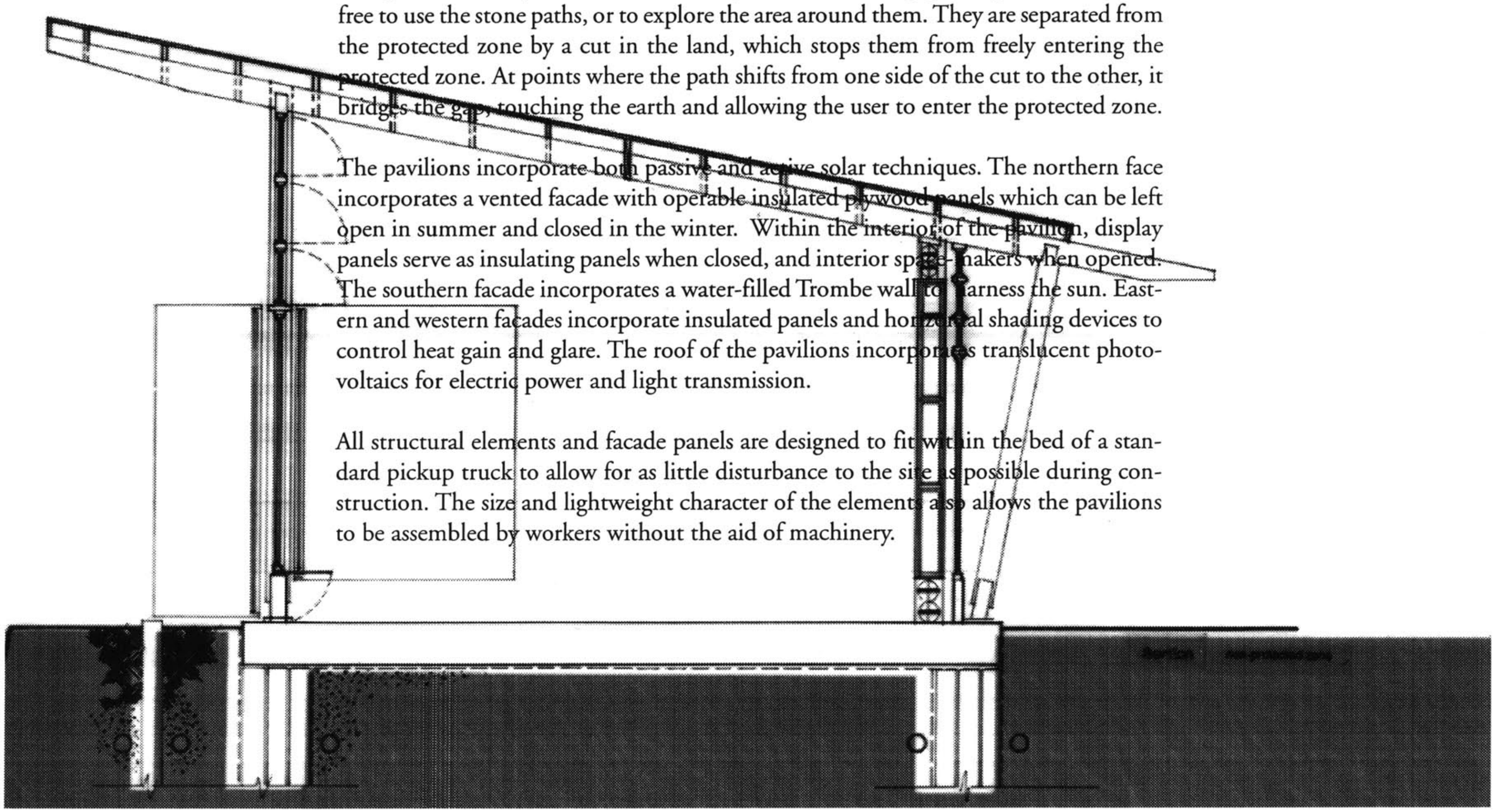
The pavilions seek to demonstrate both passive and active techniques available to control energy use.

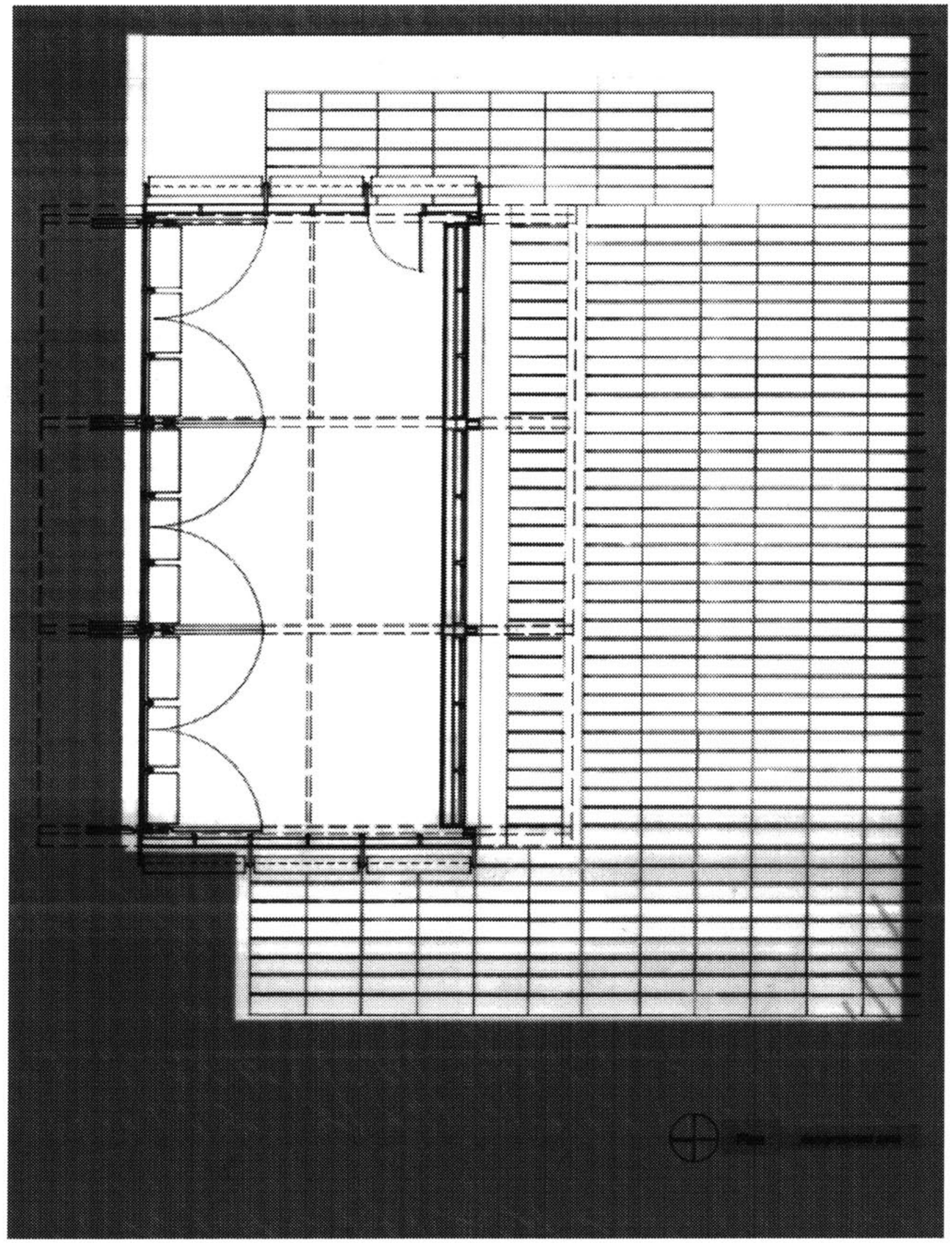
Pavilions within the non-protected zone are constructed of (natural) materials: wood and glass.

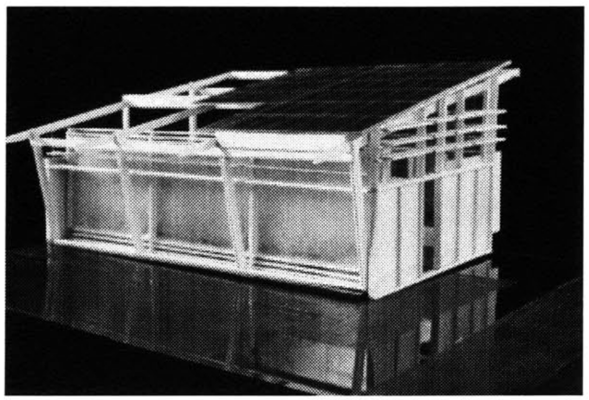
The pavilions and paths within the non-protected zone engage the ground. Users are free to use the stone paths, or to explore the area around them. They are separated from the protected zone by a cut in the land, which stops them from freely entering the protected zone. At points where the path shifts from one side of the cut to the other, it bridges the gap, touching the earth and allowing the user to enter the protected zone.

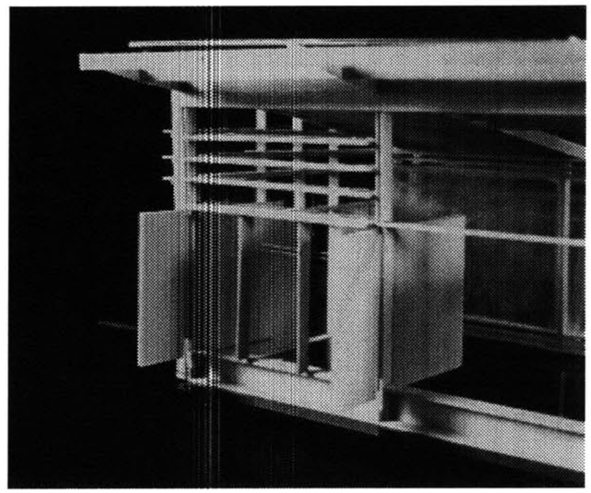
The pavilions incorporate both passive and active solar techniques. The northern face incorporates a vented facade with operable insulated plywood panels which can be left open in summer and closed in the winter. Within the interior of the pavilion, display panels serve as insulating panels when closed, and interior space-makers when opened. The southern facade incorporates a water-filled Trombe wall to harness the sun. Eastern and western facades incorporate insulated panels and horizontal shading devices to control heat gain and glare. The roof of the pavilions incorporates translucent photovoltaics for electric power and light transmission.

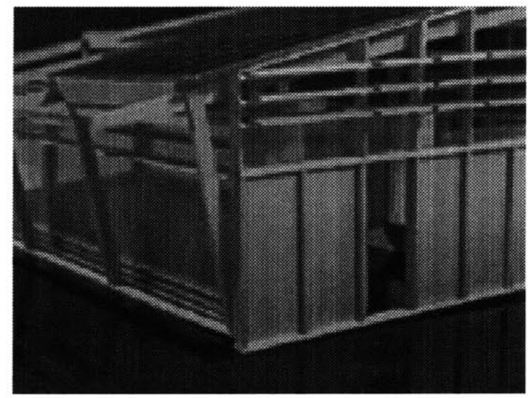
All structural elements and facade panels are designed to fit within the bed of a standard pickup truck to allow for as little disturbance to the site as possible during construction. The size and lightweight character of the elements also allows the pavilions to be assembled by workers without the aid of machinery.











ills. 27, 28, 29 and 30 (Facing page) Final Pavilion (Non-Protected Zone) Model

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Illustrations

ill. 1 Rotch Visual Collection, Landslides.
ill. 2 Rotch Visual Collection, Landslides.
ill. 3 Schama, p....
ill. 4 Aerial photo taken in 1986 for Professor Harry Hemond, MIT Parsons Laboratory
ill. 5 ibid.
ill. 6 Massachusetts Division of Fisheries and Wildlife
ill. 7 ibid.
ill. 8 ibid.
ill. 9 ibid.
ill. 10 ibid.
ill. 11 ibid.
ill. 12 Photo by author
ill. 13 ibid
ill. 14 ibid.
ill. 15 ibid.
ill. 16 ibid.
ill. 17 ibid.
ill. 18 ibid.
ill. 19 NRC p. 40
ill. 20 NRC p. 53
ill. 21 Photo by author
ill. 22 ibid.
ill. 23 ibid.
ill. 24 ibid.
ill. 25 ibid.
ill. 26 ibid.
ill. 27 ibid.
ill. 28 ibid.
ill. 29 ibid.
ill. 30 ibid.

Biography

Rebecca Lynn Berry was born on May 31, 1973 in Landstuhl, Germany. After completing her secondary education in Arlington, Virginia, she came to MIT, where she received a Bachelor of Science in Art and Design, and a Bachelor of Science in Political Science, in 1995. For four years, she was a Research Assistant to Professor Nazli Choucri in Political Science in the area of Sustainable Development. While at MIT, she received the Robert A. Muh UROP Award for Outstanding Undergraduate Research in Economics and Political Science in 1994, and upon graduation she was awarded the Boston Society of Architects William E. Chamberlain Award for Achievement in Architectural Design. She was also the recipient of the Ann. T. Beha Traveling Fellowship in 1998.

90 “I went to the woods to live deliberately...”

Walden

Henry David Thoreau