RENOVATIO

ARCHITECTURE AS FILTER

JEREMY WOOLLEY
RENOVATIO

ARCHITECTURE AS FILTER

by

Jeremy Scott Woolley

A thesis submitted in partial fulfillment of the requirements for the degree

of

Master of Architecture

in

Architecture

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 2008
APPROVAL

of a thesis submitted by

Jeremy Scott Woolley

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citation, bibliographic style, and consistency, and is ready for submission to the Division of Graduate Education.

Christopher Livingston

Approved for the Department of the School of Architecture

Steve Juroszek

Approved for the Division of Graduate Education

Dr. Carl A. Fox
STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master’s degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with “fair use” as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Jeremy Scott Woolley

April 2008
# TABLE OF CONTENTS

Preface: Butte’s Beginning..........................................................................................................................1

Introduction: A New Organic Architecture........................................................................................................9

1. A New Organic Architecture........................................................................................................................11

   A Brief Look at Phytotechnologies.............................................................................................................12
   Pytoremediation..........................................................................................................................................13
   Microremediation.........................................................................................................................................14
   Constructed Wetlands and the Living Machine.........................................................................................17
   Constructed Wetlands Used to Remediate Heavy Metals........................................................................20
   Risk.............................................................................................................................................................23
   The Potential of Phytoremediation in Butte...............................................................................................25

2. Architecture Working With Nature: Case Studies.......................................................................................27

   What is Biomimicry......................................................................................................................................29
   Deep Sea Glass Sponge..............................................................................................................................30
   30 St. Mary Axe, London.............................................................................................................................36
   Eastgate Centre, Harare..............................................................................................................................44
   Council House 2.........................................................................................................................................47

3. Biomimicry in Architecture..........................................................................................................................53
TABLE OF CONTENTS, (CONTINUED)

Pit Architecture........................................................................................................................55
More Than Just Healing the Land..................................................................................................56
Beyond Remediation.....................................................................................................................57
A New Home For Research............................................................................................................59
Program.......................................................................................................................................61
Code Analysis..............................................................................................................................62
The Pit and the Spread of Contamination..................................................................................66
Biomimicry and Bio-Utilization....................................................................................................73
4. The Architecture as Filter...........................................................................................................75
   Biomimicry in Systems.............................................................................................................77
   Biomimetic Water Filtration.......................................................................................................82
   Water Filtration Process...........................................................................................................84
   The Facility and Construction...................................................................................................87
   The Process of Tree Removal..................................................................................................89
   The Program Within................................................................................................................91
   The Education of the Public......................................................................................................94

References.......................................................................................................................................101
   Footnotes.................................................................................................................................102
   Endnotes.................................................................................................................................103
This project set out to investigate the potential for architecture, and architectural systems, to become an element of filtration for contamination in both water and soil. To do this, investigation into Biomimicry, or the use of nature as inspiration, as well as Phytoremediation, the use of plants for the filtration and breakdown of contaminants, was done and then applied to architectural design. The project became the filtration of roughly three million gallons of highly toxic water that enters the Berkley Pit, in Butte, Montana, every day. This particular solution would then prevent the potential catastrophe of negligence to the rising water level within the derelict mining pit.
In May of 1864, William Allison and G.O. Humphreys searched for gold in a place others had ignored, thinking that the Summit Valley, modern day Butte, Montana, was ultimately empty of anything valuable. Due perhaps to desperation for fame and riches, or a notion leading them there, Allison and Humphreys staked claims in and around this area, which would later be known as the ‘richest hill on earth’. Initially looking for gold, the prospectors soon discovered that this valley, and subsequently the mountains surrounding it, was filled with a cornucopia of precious metals.

Not too long after unearthing many metals Allison and Humphreys made their ultimate discovery, the copious amounts of copper which would soon become the entire driving force behind the Butte mining industry. This discovery led to an influx of miners of copper, and other metals, creating many small mining communities around each new mining shaft. It was these mining communities and the miners themselves that created the initial mining identity of Butte.
Jacob Osterg, in *Sketches of Old Butte*, describes the presence of these miners in this community: One of the thrilling sights of older Butte, prior to and including 1929, was the home coming of miners working the day shift. At four thirty, with the first of a mighty chorus of whistles, the rivers of men began to flow from the hill, down North Main Street, down Anaconda Road, and down the long, wooden stairs, in ant like procession, onto East Broadway. Of the 22,000 men employed by the eighteen mining companies, during 1919, when Butte’s population exceeded 100,000, the greater number of workers flowed southward when the shift ended.

Overflowing the worn and nail studded sidewalk on Anaconda Road, the men trudged in the roadway, often halting wheeled traffic when the flow was heaviest…

Through the aid of these thousands of workers, the hills surrounding the Butte area were slowly revealing their hidden treasures. However, there was much more to Butte’s history and beginnings than just the workers and the metals. There was the corporate battle between multiple companies aiming to mine the most out of these mountains.

**The Beginning of the End**

These rich hills of Butte brought more than just workers. They also brought many entrepreneurs and wealthy individuals seeking to grow their wealth by providing services and machinery necessary for mining operations to be successful. In the end this transformed Butte’s mining industry into more of a corporate enterprise. Although starting from humble beginnings, such as William Allison or G.O. Humphreys, mining
companies would soon become part of a larger corporate machine, that which became Marcus Daly’s Anaconda Copper Mining Company in 1881. 3

In *A Brief History of Butte, Montana*, author Harry Freeman, includes a study by E.B. Braden, United States Assayer in charge of the Montana district at the turn of the century. 4 Braden discusses the amount of copper mined from Butte between 1882 and 1899. He found that from 1883 to 1889, Butte went from producing 21.4 percent of domestic copper to producing 41 percent of the world’s copper supply. 5 This progression only spurred the desire to mine even more copper, producing many more companies over the next few decades. Once more, Jacob Osterg describes the effect of the mines, and subsequently the miners, on the city of Butte.

After 1900, Butte was firmly established, both as a commercial city of some importance and as a world famous producer of metals… From 1914 to 1920, the period of World War I and the boom following, eighteen mining companies operated in Butte, chief amongst them the Butte and Hecla, Davis–Daly, Butte and superior, North Butte, East Butte, Butte and Calumet, Clark and the Anaconda Company. Approximately fifty mines, producing copper and zinc, as well as lesser quantities of other metals, reared their giant metal frames along the hill above Butte and Meaderville, with other mines scattered along the slope of the long hill and situated in residential areas black smoke poured from rows of shining stacks topping the steam plants necessary to generate power for each mine hoist. 6

The Anaconda Copper Mining Company continued to grow, despite several leadership changes, starting
with the death of Marcus Daly in 1900. By the middle of the twentieth century, the intricate conglomerations of mineral veins throughout the mountains were beginning to run dry. This reality was due to over mining which caused the Anaconda Copper Mining Company to research new avenues towards mining the remnants of copper and other metals. With the

One of the defining characteristics of Butte is its mining heritage. The evidence of the past can be witnessed through the plentiful Iron Derricks, also referred to as Headframes, spread throughout what is now modern day Butte.

Over the, almost, two centuries that mining occurred in this location, several miles of mining shafts were created and currently are becoming the vessel in which new water is ever increasing the size of the notorious Berkeley Pit. \textsuperscript{25}
new leadership of Cornelius Kelly, the Anaconda Copper Mining Company sought after:

…Improvements … in hoisting efficiency and ventilation, but Butte’s overall output remained stagnant and labor costs remained high with major underground mines reaching a depth of 4,000 feet. At this depth, Butte miners encountered an increasingly lower grade ore, leading to the abandonment of some of Butte’s older shafts and the pursuit of more efficient mining techniques.7

This then led the Anaconda Copper Mining Company to experiment with alternative mining methods, which eventually evolved into block caving, which “divided the ore body into massive blocks measuring 120 x 120 feet, which were then undercut and moved by gravity to where the crushed rock could be scraped, loaded and hauled to the shaft for hoisting.”8

Although this practice was fruitful for a while, once more the Anaconda Copper Mining Company desired more production and came to the concept of pit mining. After opening of the Berkley Pit in 1955, the company had great success at extracting copper, however, after the almost thirty years open pit mining, dire implications for the future generations of Butte, and the Pacific Northwest, were left to be dealt with.

The Threat of the Pit

Five miles east of the present city of Butte raises the extreme apex of the eastern and western watersheds
of the Rocky Mountains. Waters governed by the levels thus established start upon their widely separating courses, those descending the western slope following their devious ways – under the successive names of Silver Bow Creek, and Deer Lodge, Missoula, Flathead, Pen D’Oreille, Clarke’s Fork and Semiacquitaine Rivers – into the Willamette River below Portland Oregon, and thence to the Pacific Ocean… To Silver Bow creek belongs the distinction of being the stream whose rise is further east than that of any other stream whose waters eventually reach the Pacific.

With the Silver Bow Creek a mere 1.5 miles from the edge of the Berkley pit, several concerns arise from the potentially harmful contents that are slowly rising within the Pit. Ever since the mining companies ceased pumping water from the Pit in the mid 1980’s, water has slowly risen. This water, however, is highly contaminated with heavy metals and the byproducts from almost three decades of mining in the Pit and almost a century of vein mining in the area. With a pH of 2, the water is heavily contaminated with, to name a few toxins: copper, zinc, arsenic, and lead.  

Many believe that left unchecked the water level in the Berkley Pit will, in a matter of less than two decades, rise to the level of the groundwater and water table found in and around the Butte area. This poses the concern of the possible elimination of Butte’s current population through migration or poisoning. This in itself is a worry, however. Many are under the impression that this would be the extent of the negligence of the Pit contamination. This is not the case, as the EPA (Environmental Protection Agency) has produced multiple studies on this area due to its contamination. One study in particular
focused on the cleanup of the nearby Silver Bow Creek. Although it was already once contaminated due
to mining waste and waste dumping, it has since been cleaned. During the study by the EPA, the potential
impact of the rise of the acidic water from the pit may or may not have been realized. The Silver Bow is
one of the main tributaries of the Clark River, which in turn is one of the tributaries the Columbia River.
This particular river runs through the state of Washington, but also between Washington and Oregon, with
many cities along its banks, including Portland, Oregon, and Vancouver, Washington. The effect of the Pit
on the Silver Bow is potentially catastrophic beyond the aspect of Butte as a viable community.

The scenario described above only takes into consideration the impact on the creek and the
subsequent rivers. However the range of contamination would spread beyond the initial tributaries to the
rivers and the irrigation throughout the region. This, in turn, would decimate not only the water table and
ground water of the area, but also has agricultural and many other social and environmental implications.
The worst case scenario is the contamination of the entire Columbia River Basin.

This type of environmental destruction is not new. Similar catastrophic situations have already occurred
in other countries: one major catastrophe was in Bangladesh.

A major ecological disaster occurred in Bangladesh though an ill-conceived project promoted by the WHO
[World Health Organization] to “improve” the supply of drinking water for millions of peasants in the
Ganges delta, who had previously relied on the river. Numerous boreholes were sunk, penetrating substrata rich in arsenic-bearing minerals. Several years elapsed, during which vast numbers of people daily imbibed considerable quantities of arsenic, before any harm was noticed. As a result, millions of people are now suffering from chronic arsenism… or arsenic poisoning… \[1\]

The Berkley Pit’s contamination is currently at a point where the implications of this pollution are avoidable.
Organic architecture has been viewed as an interpretation of the relationship between architecture and nature. The term “Organic Architecture,” coined by F.L. Wright, is interpreted as architecture that works with nature rather than against it. This aspect of looking to nature in a partnership tends primarily to be translated through the form of the architecture, and while particular functions of a building that could be emulated; somehow in the functionality of a building the outcome is typically based on an aesthetic of form. This thesis seeks to illustrate a new idea of what organic architecture is, and what a new organic architecture could be. A new organic architecture would use functions from nature as inspiration for architectural systems prior to the attribution towards form. Architectural function would mimic functions found in nature, such as organic remediation systems. This shifts traditional concepts of architecture resulting in Architecture taking the role of an environmental remediation tool.
To clarify, Environmental Remediation is pertaining to the act of cleaning contaminants from a particular site, whether in water or in soil. Furthermore, organic remediation, or Bioremediation, is the use of biological systems that naturally occur to clean the toxins and waste from a given site. In this study, it is the bioremediation systems and functions that serve as the inspiration for architectural systems. It will be this translation from biological systems to architectural systems that will result in architecture becoming a remediation tool.

Throughout this study, an investigation of filtering systems in nature will follow, including research into phytoremediation and biomimicry. Next, examples of how architecture has used similar models from nature for solutions to design problems, such as the Swiss Re building in London, the Eastgate Center in Zimbabwe, and the Council House 2 in Australia. Finally, a culmination of the research into the natural systems, previous architecture, and Butte will come together to create an architecture that becomes a remediation tool.
A NEW ORGANIC ARCHITECTURE
AND THE FUNCTION IN WHICH ARCHITECTURE IS MIMICKING

CHAPTER ONE
A BRIEF LOOK AT PHYTO TECHNOLOGIES

Natural systems, and their functions, provide ecological solutions to potentially hazardous problems. These systems can become models for architectural systems to emulate. In this particular study, not only is the hazard of mining investigated but a potential solution found in nature, such as bioremediation. This is to be emulated by architecture. To have architectural systems emulate bioremediation, one must look deeper into some of the techniques in bioremediation; in particular phytoremediation and microremediation. Phytoremediation is the use of plants to remediate, or clean, contaminated soil and water. Microremediation, on the other hand, is the use of microbes, such as bacteria, and fungi within the roots of the same vegetation used in phytoremediation to clean toxins from soil and water. There is collaboration between microremediation and phytoremediation, and essentially they are the epitome of cooperative functions in nature serving as inspiration towards an architectural system. The use of phytoremediation and microremediation is referred to as Phytotechnologies.

In An Overview of Phytotechnologies, David T. Tsao defines phytotechnologies as the use of “vegetation to contain, sequester, remove, or degrade inorganic and organic contaminants in soils, sediments, surface waters, and ground waters.” The contaminants mentioned by Tsao refer to anything that is in soil or water
to the extent that it becomes toxic to the organisms in and around the area. Here, plants and microbes in the root structure are used to remediate these toxins becoming an organic solution, rather than more traditional, non-organic means of remediation that may or may not actually cleanse the area of contaminants.

**Phytoremediation**

To understand this collaboration of phytotechnologies, the uses of phytoremediation should be examined. There are many areas that can use phytoremediation as a remediation technique for a variety of contaminants. “Phytoremediation is used to clean up waters, soils, slimes, and sediments from pesticides…fuels, explosives, organic solvents…heavy metals, and radioactive contaminants.” Phytoremediation is primarily used in the breakdown of organic waste, such as human and animal waste, which has contaminated either soil or water. However, the more pressing issue is the ability of these phytotechnologies to remediate inorganic materials. Focusing on the effects of phytotechnologies on heavy metals, especially in and around mining facilities (mines, dump sites, refineries, etc.) will help influence architectural emulation.

One case of heavy metals around mining facilities is that of Butte, Montana, and the Berkley Pit, where there are toxic levels of Copper, Lead, and Zinc. Not only are there heavy metals, but there are byproducts of these heavy metals in the form of arsenic.
Arsenic is the byproduct of many metals, such as copper, lead, iron, nickel, cobalt and other metals, most of which have been mined at one time in the hills of Butte. Arsenic is perhaps the most toxic contaminant found in the Berkley Pit. These are the majority of toxins found in the area. Phytoremediation systems provide the potential solution to the problem though a natural means. Phytoremediation and Phytotechnologies in general, absorb and process other heavy metals beyond those mentioned above.

**Microremediation: Microbes and Fungi that make it work**

The collaboration between vegetation and microbes is important for the success of the natural remediation of contaminated sites. This partnership will be applied toward architectural systems later in this study. In the end, the plant itself offers two main functions: housing microbes that help break down the toxic material, such as heavy metals, contaminating the area and then absorbing the material into the root system, once broken down. Tsao goes on to describe:

> The subsurface environment in the vicinity of vegetation is highly bioactive. Plants and soil microbes have evolved highly complex symbiotic and synergistic relationships that provide the plant with protection, nutrition, and enhanced water uptake capacities while the soil microbes are provided with an enhanced nutritional environment from which to thrive. This region of soil is known as the rhizosphere and contains multiple biological processes that are pertinent to phytotechnologies.
Marta Cabello in *Fungi in Bioremediation* also describes this process. Knowledge of plant microorganism interactions is of great importance for bioremediation and phytoremediation... Plant roots strongly influence the surrounding environment, producing the so called ‘rhizosphere effect’ in which microbial populations are qualitatively and quantitatively altered with, reciprocally, their metabolism directly affecting plant biology and the accompanying biota.¹⁷

Many of the phytoremediation sites once plagued by heavy metals and contamination in general use the collaboration between the vegetation and the microbes and fungi found throughout the root structure to optimize results. This by no means should reduce the benefit of the plant itself; however once more; a symbiotic and collaborative aspect of phytoremediation is represented. One case is the use of Cattails in constructed wetlands (referred to later in this section) where the main purpose of the plant itself is to provide a habitat for the microbes. This relationship alone should be in many ways a prime example of how architecture and architectural systems could follow a successful example found in nature and apply it to architecture.

Fungi are of fundamental importance as decomposer organisms and plant symbionts (mycorrhizas) and can comprise the largest pool of biomass (including other microorganisms and invertebrates) in soil (Wainwright, 1988; Metting, 1992). They can be dominant in acidic conditions, where the mobility of toxic metals may be increased (Morley *et al.*, 1996), and this, combined with their explorative filamentous growth habit and high surface area to mass ratio, ensures that fungi are integral bioactive components of major environmental cycling process for metals and other elements including carbon, nitrogen, sulfur and phosphorous (Gadd and Sayer, 2000). ¹⁸
This represents the importance of these microorganism and fungi in the role of decomposition of toxic materials that are inorganic, for instance in this study, remediation of toxic levels of heavy metals in soil and water. Architecture could become part of this system, similar to the plant, housing smaller systems that breakdown the heavy metals. Here, the architecture itself would somehow contain the separation between organic and inorganic materials. The symbiotic relations between plant life and microbial systems will be imperative to this study and the investigation into future systems in architecture that emulate nature.

In the aspect of the imitation and emulation of something found in nature, or biomimicry, function based mimicry in architecture usually translates into the form rather than the function. However, utilizing systems such as the symbiotic bond between microorganisms, and fungi, with the plant roots, there could be infinite ways of translating this collaboration of systems into architectural systems.
** Constructed Wetlands and the Living Machine **

There are two practices that utilize the relation of phytoremediation and microremediation in the aspect of water remediation: constructed wetlands, which serve multiple purposes besides remediation; and the “Living Machine,” separated biospheres which act as a series of natural filters. Unfortunately much of the success, and subsequently research, is focused on the breakdown of organic toxins by these methods. Essentially the removal of the organic toxins by the aquatic vegetation, and, more importantly, the microbes break down the toxins prolonging the existence of not only the plant but also the habitat itself. Both constructed wetlands and the Living Machines perform this task, the difference is the level of human involvement.

…The Living Machine, a biological wastewater system created by John Todd that uses a series of assembled ecosystems to cleanse water. Anaerobically treated sewage enters a greenhouse that contains a series of tanks, each of which contains various species of bacteria, algae, plants, snails, fish, and other creatures. These animals and plants break down the sewage as it passes through. The result is “waste” water that exceeds EPA drinking water standards.\(^\text{19}\)

In the case of Living Machines, the main difference is the human involvement, which in most cases is much higher than that of constructed wetlands. The benefit of a Living Machine that is confined indoors is the potential for it to process and remediate the waste year round. Pertaining to Living Machines,
another difference between it and constructed wetlands is the smaller influences from animals beyond fish. Although the Living Machine is highly dependent on collaboration between organisms and vegetation, constructed wetlands are even more so.

Constructed wetlands are a form of bioremediation that uses the partnership of the two systems of phytotechnologies: phytoremediation with native aquatic plants as well as those pollinated by local and transient fauna; the other, also extremely important, is the use of microorganisms in the method of microremediation. The use of these two methods in conjunction with each other becomes most effective in the remediation of biological waste found in water.

This technique utilizes nature to the fullest, providing an area for the body of water, including some preliminary plant life, such as cattails. Constructed Wetlands depend on many natural aspects, such as animal and plant life interaction, essentially cross pollination. There are two main types of plant life used in constructed wetlands that are most productive in the cleansing of waste: plants above water, and plants that are mostly below the water’s surface. Both bring different approaches to cleaning of the waste water and both are plants native to the area to provide not only a xeriscape methodology, but also to provide the best solution to the cleaning process. The types of plants that are primarily above the surface are usually such things as shrubbery or cattails. These plants in particular are utilized for their ability to create
When dealing with Phytoremediation, the plant root systems become extremely important. In the first image (above) it shows a variety of vegetation and the root structure of each. (Left) This is one of the more influential plants when discussing constructed wetlands. The Cattail not only helps with the breakdown of material but also provides shelter for many types of fauna that help with the success of constructed wetlands.
microbes faster than other types of plants by converting sunlight into oxidized soil particles through their roots. The other type of vegetation is known as floating or free floating aquatic plants, such as water lilies. These are primarily beneath the surface of the water absorbing contaminants through the root structure. Compared to their land based counter-parts, the floating vegetation are particularly helpful for their ability to extract pathogens, metals, and other pollutants while also extracting nutrients for themselves from the waste. A key part of constructed wetlands is the indigenous animal life that inhabits the area. The animal life that makes the most impact is water fowl, such as ducks and geese. These animals are integral mostly in the pollination of most types of the vegetation contributing in the clean-up process.

From the aspect of collection of heavy metals, a similar situation and similar problem occur, once the plant has collected and absorbed a certain amount of heavy metals, it then becomes toxic on a more condensed level. The common solution to this at this time is removal or destruction of the toxic plant. There are other solutions, however, to the accumulation of metals in plants, such as the actual harvesting or mining of the metal once accrued.

**Constructing Wetlands Used to RemEDIATE Heavy Metals**

The mining, electroplating, tannery, steel works, automobile, battery, and semiconductor industries are faced with the problem of heavy metals in their effluent streams, which harm the soil and the waterways... Unlike
organic contaminants that can be degraded to harmless products, metals cannot be further transmuted or mineralized to a totally innocuous form. Their oxidation state, solubility, and association with other inorganic and organic molecules can be varied so that they are made harmless.\textsuperscript{20}

Constructed wetlands, through the use of plant life collaborating with the microorganisms throughout the root structure, can also be utilized beyond the degradation of biological waste; they can be utilized to remediate water contaminated with heavy metals. In much of mining waste, the byproduct associated with water is a highly acidic, and heavily contaminated by metals. Although the material being remedied is inorganic, the process still requires the partnership of the vegetation and the microbes. There are two mechanisms by which metal removal by bacteria can occur. The first is the oxidation of the [metal]... the second is the collection of the [metal] in capsules and slime layers surrounding the organism.\textsuperscript{21}

Once more looking back towards the Berkley Pit in Butte, a similar system of remediation might be part of the solution.

Phytoremediation is an integral part of constructed wetlands, and the removal of heavy metals. In these circumstances plants are used to breakdown to some extent, and accumulate much of the heavy metal which contaminates the soil and water. There are, however, several plants that absorb large quantities of heavy metals and these particular plants are referred to as hyperaccumulators.\textsuperscript{22} As previously mentioned, many of these plants are destroyed, yet in some cases there is a chance to extract metals from them.
The process in which constructed wetlands work is extremely simple yet important (Above). The waste product comes through the feed pipe in liquid form, then begins to be processed through the root structure of plants. This is most often used as a replacement to septic tanks so facilities can lower the human impact by processing human and animal waste (Right).
The Risk

With every benefit, there is almost always some disadvantage. With phytoremediation, one particular disadvantage is the risk of planting invasive vegetation or vegetation foreign to the area. Using a potentially invasive plant to remediate a site has two sides: the benefit of removing the contaminant, however at the potential cost of the ecosystem around it. Although the phytoremediation would remedy the contaminated site using an environmentally friendly method, the use of invasive plant life may or may not destroy native flora. If, for instance, poplar trees were used to remediate a particular contaminant from riverbanks, yet the poplar tree was not native to the area, there is a high chance of the poplar’s survival due to lack of natural consumers. Then the displacement of many local species of flora, in essence would destroy the local ecosystem.
There is another element of risk not yet investigated. Although there is the risk of introduction of potentially invasive flora, there is a different risk associated with the alteration of the genetic makeup of the plant life itself. At the University of Washington, biological scientists are studying the effect of rabbit genomes in the alteration of poplar trees. The aim of that study was the production of an artificially created Hyperaccumulator for phytoremediation. With the altered poplar plants, the hopes of the scientist lie in the possibility of the modified species to absorb pollutants quicker, but also in larger quantities. There is however a conundrum with the new technologies of plant alteration. In an article of the Seattle Post, journalist Lisa Stiffler interviewed University of Washington professor, Andrew Light, about this topic:

> When it comes to the pollution consuming poplars, “it’s really a question of trading some of the unknown risks of planting genetically modified trees with the positive environmental benefits… This is a real dilemma for the environmental community.”

There is also the element of the unknown ramifications of genetic alteration towards tools of environmental remediation. With these two elements of phytoremediation with altered plants, which becomes the lesser of two evils: leaving the pollution to possibly become more toxic, and possibly spreading its toxicity, or to introduce a potentially invasive species of “genetically modified” plants?

There are two potential solutions incredibly important to this study: the use of indigenous plant life that can perform the same tasks as foreign plants or, the use of non indigenous plants, if necessary, that
could be confined in some aspect of architecture, removing the risk of introduction of alien plants to the area. With the utilization of native species, or if necessary using confined, potentially invasive species, the risk for occurrence such as this would be avoidable. There is, however, another solution to this.

Through the study of these systems, an emulation, or mimicry of these systems in architecture would remove the potential risk of introduction of foreign plant life. Is there a better way of utilizing the initial systems of bioremediation, such as biomimicry in architecture?

The Potential of Phytoremediation in Butte

Although there is an element of risk with introducing not only foreign species but also the unknown effects of introduction of hybrid species of plants and trees. Two main species of plants, cottonwood and poplar trees in particular, possess a characteristic extremely valuable to this project; the ability to absorb and filter up to ten gallons per day. This is relevant in the case that phytoremediation is used to remediate the Berkley Pit.

There are, however several limitations to the abilities of the cottonwood and the poplar. One particular limitation pertaining to the remediation of the Berkley Pit is the tolerance and ideal pH of water
and soil for the two trees. For the ideal performance in remediation when pH becomes one of the issues, a pH between 5 and 8 are necessary to produce not only an ideal remediation scenario but also keep the toxin from decimating the tool meant to clean and detoxify the material, in this case water and soil.

Poplar and cottonwood trees are not the only plant type that can do this type of remediation work, however they are the most likely to become one of the primary tools if phytoremediation is used. Other plants that would work in soil remediation are such things as: grasses, cabbages, mustard plants, and sunflowers. Flora that would work in water remediation would be those found in constructed wetlands: once more grasses and cattails, as well as what would normally be considered weeds, such as dandelion and others that fall under the nettles species. Once more, however, pH becomes an issue when remediation of either water or soil, the ideal level is between a 5 and 8 on the pH scale.
ARCHITECTURE WORKING WITH NATURE
CASE STUDIES

CHAPTER TWO
“Structural materials in nature exhibit remarkable designs with building blocks.”

- Science Magazine (8 July 2005)
Once more, Wright’s term, Organic Architecture, was focusing on architecture that works with
nature rather than against it. Much like Wright’s Organic Architecture this new organic architecture
relates to nature around it as well yet in a different way. Looking to the nature, such as the glass sponge
or phytotechnologies, architects can utilize skeletal or other systems from an organism and vegetation
to influence innovations in structural, mechanical, or material systems. Furthermore, the use of these
systems to remedy contamination or waste in or around the area of the building also becomes an integral
part of this new organic architecture. A potential solution to this problem might be Biomimicry.

What is Biomimicry?

Although the action of biomimicry has occurred since time began, the term is relatively new in
how it applies today. The term comes from Janine Benyus, founder of the Biomimicry Institute as well
as author of *Biomimicry*. Benyus describes biomimicry as “a new science that studies nature’s best ideas
and then imitates these designs and processes to solve human problems.”27 One inspiration from nature
would be systems or functions of vegetation or organisms that solve similar problems encountered in the
design of architecture.
From a practical viewpoint, Biomimicry is more than emulating a form in nature; biomimicry emulates the function that has heavily influenced the form. Inspiration for many technologies has come from nature.

Shark skin has inspired new textures for airplanes and swimsuits to make them more aerodynamic. Lotus leaves have inspired a new paint that has a self cleaning surface. Perhaps the most famous example is that of Velcro, which is patterned after a burr – a seed pod that sticks to your clothing.23

Here many products have gained the inspiration from nature. If Organic architecture is working with nature, then a new Organic architecture is going a step further, not only working with, but gaining inspiration from successful functions and systems in nature. Emulating such systems as phytotechnologies in architectural systems could provide an answer to environmental issues such as that of the Berkley Pit.

In biomimicry one particular organism may provide inspiration for multiple systems and functions. These organisms provide insight for innovation in structural and mechanical systems in architecture. One such organism pertaining to the study of biomimicry in architecture is that of the Deep Sea Glass Sponge.

The Deep Sea Glass Sponge: Porifera Hexactinellida

The name Porifera means “pore bearing,” and sponges are porous filter feeders. They are distinguished
from all other animals by having internal water chambers lined with special flagellated feeding cells called
choanocytes, or collar cells.

A sponge is essentially a cluster of cells and tissue like cell layers forming channels through which water
circulates. Water and minute suspended particles are drawn in through many small pores in the body wall as
a result of the beating flagella on the choanocytes [collar cells].

At a depth of 1500 feet below the surface of the ocean lives a myriad of organisms. At this depth
great pressure is placed on the organisms, in turn it greatly affects their skeletal structure. So it is surprising
to find that one such organism at this depth is structured by bones of glass, conventionally thought to be a
rather brittle material. The Glass Sponge is made up of an “intricate, cylindrical cage like structure…with
lateral (“oscular”) openings (1 to 3 mm in diameter).”
The diameter of the cylinder and the size of the oscular openings gradually increase from the bottom to the
top of the structure. The basal segment of the Euplectella Sponge (Glass Sponge) is anchored into the soft
sediments of the sea floor and is loosely connected to the rigid cage structure, which is exposed to the ocean
currents and supports the living portion of the sponge responsible for filtering and metabolite trapping… the
characteristic sizes and construction mechanisms of the [Glass Sponge] skeletal system are expected to be
fine tuned for these functions.

One may begin to think if the organism is made out of glass; it probably has a relatively short life.
However, it is actually the contrary that happens. Due to the intricate structural complexity of the skeletal
Biomimicry is the use of nature to inspire solutions to human problems. In many cases biomimicry has occurred over the past millennia even to the beginning of man. More recently one can look to swimsuits inspired by sharks (Above) or even the invention of velcro from a burr (Below) as design being inspire by nature 


system, the life of the organism is prolonged, and in some cases, sponges “may be more than 200 years old.”

Beyond simply the age of these creatures, the element of their skeletal constitution alone should be of incredible importance to architectural approaches towards structure.

The structural complexity of the glass skeleton in the sponge… is an example of nature’s ability to improve inherently poor building materials. The exceptional mechanical stability of the skeleton arises from the successive hierarchical assembly of the constituent glass from the nanometer to the macroscopic scale. The resultant structure… in the sponge skeleton represent[s] major fundamental construction strategies such as laminated structures, fiber–reinforced composites, bundled beams, and diagonally reinforced square grids…

However, the skeletal structure goes beyond the creation of a glass structure able to withstand the inherent pressure at that depth of the ocean. There are elements that can influence the forms of structural elements, whether using glass, or some other, innately stronger material.

…The structural properties of biosilica (glass in organism) observed in the Hexactinellida sponge (Glass Sponge)...[consist of] nanometer scaled silica spheres [which] are arranged in well defined microscopic concentric rings glued together by an organic matrix to form laminated spicules. The assembly of these spicules into bundles, affected by the laminated silica based cement, results in the formation of a macroscopic cylindrical square lattice cage like structure reinforced by diagonal ridges. The ensuing design overcomes the brittleness of its constituent material, glass, and shows outstanding mechanical rigidity and stability.

Through the utilization of forms and layers, a typically fragile material creates a phenomenal structure withstanding similar forces applied to architectural structures.
The sponge in itself is a prime model for architectural mimicry looking at the skeletal structure made of an incredibly brittle material, but also other characteristics, for instance, the filtration capabilities. This is but just one example of how natural systems and organisms can begin to influence and inspire architectural systems and functions.

The sponge, or the porifera, is an extremely unique creature that offers a variety of systems that could be emulated in architecture. Utilizing a quality found in all of the variety of sponges, filtration of water, architectural systems could benefit tremendously, primarily mechanical systems. In this particular study, the filtration quality is especially important to emulate in architectural systems. With this in mind, the architecture would become the remediation tool.

Biomimicry in Architecture

Making the most of the characteristics of Biomimicry, several architects have utilized ideas in nature to improve architectural systems and structures. Three that stand out are Foster and Partner’s 30 St Mary Axe in London, Mick Pearce and Arup on the Eastgate center in Zimbabwe, and Pearce again with the Council House 2. In all of these instances, the architecture is mimicking the function of an organism, or organisms, unique in nature. This is done by looking at termite mounds regulating temperature with a passive cooling strategy, or the glass sponge inspiring an innovation in structure and natural ventilation.
The Glass Sponge becomes a very interesting subject of inspiration, whether it inspired the 30 St Mary Axe tower in London or not, much can be learned from the completely glass skeletal structure of this creature. With the diagonal grid on the exterior of the glass skeleton, water naturally flows through the openings filtering the water for particles in which the creature can feed upon. Creature like the Glass Sponge can provide invaluable information as to filtration through structure, whether water or air.
These examples are all small steps towards a new organic architecture and express how systems in nature can inspire innovation in architecture.

30 St. Mary Axe, London England

Prior to any of the development into the current Swiss Re building, there was originally a much larger project by Sir Norman Foster for this site: the London Millennium Tower in 1996. Designed to be 400 meters tall (or roughly 1200 feet), the tower was designed to have more than 1.5 million square feet of floor area. By 1997 the idea and the support began to fade away, and by 1998 Foster was investigating new solutions for the site.

During the redevelopment of the office building, an evolution of design occurred. Slowly departing from the original 400 meter tower, the Swiss Re came closer and closer to the relative heights of the
surrounding towers in the area. The final height became 130 meters (or roughly 400 feet). It was at this point when Sir Norman Foster created somewhat of the final design; however, it would take more input than just his architecture firm: it would take structural consulting from Arup Associates, an international engineering and architecture firm. It was the addition of this new member of the design team that would ultimately bring ideas from nature as solutions to structural and aerodynamic issues prevalent in tall buildings.

In the case of the structure, the diagonal grid in which the members were placed, revolve around the center of the structure creating somewhat of a column free, open office plan. To make this work, however, took many developments and design iterations that eventually led them to the ‘egg’ shape of the complete design. The origin of the design of the structure itself is debated; however, the final design was heavily influenced by those of Arup Associates.

The structural steel diagrid (diagonal bracing) developed by Foster and Partners in association with Arup was fundamental to the realization of the radical form conceived for the building. The external diagrid responds to the curved shape of the tower, providing vertical support for the floors and allowing for the provision of column free internal spaces.

One could see that the glass sponge inspired the Swiss Re building, in some manner resulting in
an example of biomimicry in architecture. Although some within the office deny any inspiration from nature, it becomes difficult not to compare the somewhat lattice structure of the Swiss Re Building with the natural glass structure of the glass sponge. Although the form of the building may not have taken inspiration from nature, perhaps the design of the structural system itself drew from its muse: nature. It was, perhaps the ideas that came with Arup engineering when they joined the design team. The design of the project itself utilized the structure and subsequently, much like the actual organism, the opportunity of simulating natural air flow through the building. This became an emulation of the way the sponge circulated and manipulated the water in and around its glass structure. Perhaps, that similarity was lost in translation because of the difference between the circulation of water in the organism, and the circulation of air in the architecture.

Whether Foster or others admit or deny the coincidence of similarities between the structure and that of the glass sponge, there are still elements within this building that promote natural systems through use rather than mimicry. With the diagonal grid of the structure, the shifting of the floor plates offered a possibility to make the most of natural filtration of indoor air. In several of these openings, small gardens are used to filter air flow from beneath and from that particular floor plate as well. This alone displays a change in thought for air filtration and mechanical systems within architecture. This particular piece of
architecture represents a collaboration of systems. With the form of the structural diagrid, this promoted natural ventilation and fresh air that travels throughout the building, and with these sporadic garden spaces, natural filtration of air occurs within the building.

The low energy ventilation strategy for 30 St Mary Axe reflected Swiss Re’s aspiration to make the building an exemplar of environmentally friendly design. The environmental concept for the tower was developed in tandem with the parametric modeling of its structural form.

The advantages of the curvaceous form were, in this respect, considerable. Instead of wind forces being pushed downwards, as in the rectangular high rises of an earlier generation, wind would flow around the tower, producing positive pressures on the windward aspect with negative pressures on the sides of the building, a perfect driving force for cross flow natural ventilation. External air is drawn into the building through motorized perimeter windows placed in each atrium, which also act as intermediate buffer zones to protect office spaces from excessive draughts.39

It is the integration of systems, mechanical and structural, that create an environmentally minded solution to typical architectural systems problems.

This tower in downtown London, although in a different setting than the Berkley Pit in Butte Montana, provides a precedence of looking towards nature for solutions. Whether through the inspiration of the structure from nature, or even through the ventilation and structural collaboration for indoor air quality, the 30 St Mary Axe tower still changes the traditional thought of systems in architecture.
The natural ventilation follows the diagrid structure (Above) and in places needs to be released to avoid uplift and issues with differing pressures from inside and out (Left).
The mapping of skyscrapers is important especially when concerned with how the structure with react to wind. At the 30 St Mary Axe tower, the effect of wind is two-fold. The first application of the structure and subsequently the shape of the building is the resistance to wind forces (Left and Above Left). The other aspect of wind interaction with the structure is natural filtration of the internal air quality. Natural air comes from street level and flows upward through the diagonal grid of the tower (Above Right).
Towards the completion of the design diagrams such as these helped explain the idea that, in conjunction with the diagrid structure, the floor plates would shift slightly creating a diagonal void in which sun can enter areas of the building that may not always receive natural sunlight, but also provides a path for the air to travel upward throughout the tower providing a natural ventilation system.

Throughout these sun and wind pathways are small atriums that utilize the natural air filtration of plants to once again look to nature for an energy efficient solution to typical office structure problems. 

These preliminary drawings show the step towards the final design with the open air entrance and the importance of the diagrid.
Eastgate, Harare, Zimbabwe

Another example of nature inspired architecture, once more aided by the consultants of Arup Associates, was the Eastgate center in Harare, Zimbabwe by architect Michael (Mick) Pearce. For this endeavor, like 30 St Mary Axe in London, they explored the aspect of airflow through a building. In this case, however, they investigated the characteristic of temperature stability inside of a structure found in nature. To do this, study was conducted into the workings and sectional components of termite mounds. Within the termite mounds the structure the channels throughout the mounds, regulate the temperature within a 1 degree of 31 degrees Celsius. The external differences range from 3 degrees Celsius to 42 degrees Celsius. The architectural design was then based on the systems similar to termite mounds.

In proportion to their inhabitants, these [termite] mounds are giant skyscrapers, yet they have consistently cooler interior temperatures than the surrounding air. The termites control the temperature by opening and closing vertical ventilation shafts, introducing water to evaporate in certain areas, and flapping their wings to move air.

The model in nature inspired Mick Pearce and Arup to develop new ways to ventilate and provide
mechanical comfort in architecture without the use of excess energy. The design called for fans that brought in fresh air in the atriums at the base of the building pushing fresh air towards the top with excess heat. The heat would then be flushed through hollow vents in between the floors. At night, a similar process would happen except in reverse. The cooler night air would be pushed into the space from the hollow floors, and then would be drawn throughout the rest of the building, bringing the temperature to a more moderate level.\textsuperscript{42} This process is a method of passive cooling.

The result of this was the consumption of only 10\% of the energy that other buildings of this type and size use in the area of Harare\textsuperscript{43}. However it took more than passive cooling throughout the building to achieve such a significant result. It required consideration towards solar heat gain as well. In this, the glazing throughout the exterior was minimized to about 25\%, and thick walls and shading devices were also implemented.\textsuperscript{44} This can be attributed once more to the structural elements of the termite mound and the collaborative natural systems within it.

The separate systems of Eastgate work collaboratively as well in order to create a passive cooling system that regulates the temperature both day and night throughout the building. Elements of this design and the approach of a biological model for temperature stability influenced Mick Pearce to some extent, mostly because similar methods can be witnessed in his architectural design of the Council House 2, in Melbourne, which replaced the original Council House.
The Eastgate Centre in Harare, Zimbabwe (Left Above), is a prime example of Biomimicry in Architecture. The problem facing the architect, Mick Pearce, was to design a structure that sustainably kept the building cool in a hot climate, a method known as passive cooling. For this challenge, Pearce sought the aid of Arup Associates to help with the creation of a passive cooling system.

By investigating local termite mounds (Left Bottom), nature's skyscrapers, Pearce and Arup discovered that the mounds keep the interior space at a constant temperature. This example in nature inspired Pearce and Arup to create a natural system that used the airflow as well as the night air to keep the structure relatively cool without the use of an HVAC system.
Council House 2, Melbourne, Australia

Although the previous two buildings dealt with lifecycle decrease in usage by utilizing natural systems, this next example goes beyond reducing lifecycle energy usage, its systems remediate contamination and the architecture becomes what is known as “regenerative architecture”. Regenerative architecture is architecture that not only decreases the ecological footprint of the building on the site, but also begins to remediate waste around the area or even from throughout a city as is the case with the Council House 2. The Council House 2 not only uses passive cooling systems like Eastgate, but uses other systems for the treatment and reuse of water.

Many similarities exist between the Council House 2 (CH2) and the previous examples of architectural biomimicry. Like the Eastgate Development, CH2 was also designed by the architect, Mick Pearce, but beyond that, similar elements of the ventilation systems were inspired by nature as well. Once more, like the Eastgate Development, and 30 St Mary Axe, the approach to interior air circulation became one of the primary sustainable strategies. Mick Pearce, once again, used the biological precedent of the termite mound for yet another piece of architecture.45

Pearce utilized many systems to create a passive heating and cooling ventilation system. What
makes this building unique is the different character from most office buildings. Typical office buildings use air recirculation for 85% of the ventilation. The CH2, however, utilizes 100% fresh air avoiding any recirculation of air. With fans and the introduction of undulating floor plates, natural ventilation occurs, but beyond that, the utilization of multiple systems brings more to the character of the Council House 2.

The inclusion of water treatment and reuse within the building was also integral to not only the water usage but also once again the ventilation and temperature control. With filtration and the use of various water systems, temperature and environmental controls within the building can then become regulated using alternative methods.

There are several ways in which this building approaches the participation of water in the CH2, but primarily it all stems from the remediation of waste water. First, the building systems draw waste water from the city sewer that is connected to the building. Through studies, the city commission of Melbourne discovered that 95% of the contents of the sewer pipes were water based. This allowed Mick Pearce to design into the Council House 2 what is known as a Multi Water Reuse system. This system separates the solid from the liquid waste but then passes the water through a series of filters creating gray water. This water is then an integral part in regulating the temperature in a sustainable fashion.

Once the water has gone through the filtration, there become a myriad of paths in which this water
travels throughout the CH2. In one manner, the water is transferred into the basement with what is known as a phase change system, which utilizes the interaction of 30,000 small metal balls filled with a “eutectic salt mixture” which freezes at 59 degrees Fahrenheit. The frozen metal balls then cool the water. Once this occurs the water is transferred back to the top of the building where it was originally filtered, and lets the temperature of the water effect the air temperature during the night time hours.

There is another aspect of water usage in the manner of regulating temperature, mostly in the case of cooling surrounding air. Through the method of evaporative cooling, and an element of the building known as Shower Towers, water is sprayed out of large shower heads past ventilation windows and lands on a glass roof four stories below. All the while, the water being used is recycled, and then re-collected and recycled once more. This allows for two major contributions of the CH2, the natural cooling through the evaporative cooling method, but also the use of recycled water rather than potable water to perform this method of cooling.

There are many more methods in which the council house uses to regulate temperature, and sunlight throughout the building. Such methods as computer operated louvers that control the amount of heat gain that enters the building or ventilation chimneys that release excess heat from the building. This piece of architecture is a step towards architecture becoming a remediation tool.
In the Council House 2, also design by Mick Pearce, the goal was to give back more than what was taken from the earth. Much like Eastgate, a passive cooling strategy was sought after, as well as water treatment. To aid in the passive cooling, ventilation towers (Above Right), utilize rotating fans (Yellow) to draw warm air out of the building at night. Another part of the system is the operable louvres (Above Left) that regulate the amount of solar heat gain to the building. An element of the architecture that aids in ventilation and lowering the carbon footprint is the vertical gardens (Left).\textsuperscript{54}
What this diagram presents is the many passive systems that the Council House 2 uses in operation. Such systems as Passive cooling, water filtration and reuse to aid in passive cooling, as well as vertical gardens that help with cooling as well as aiding the air quality of that portion of Melbourne Australia.
The Art of the Remediation Tool

All of these pieces of architecture represent more than just sustainable architecture, but a change of thought in the approach to what sustainable truly means. Through the use of models from nature, a collaboration of architectural systems created better ecological and working environments. These are models of how systems in architecture can become remediation tools. In the focus on regenerative architecture, the art in architecture must not be forgotten.
“Those who look for the laws of nature as a support for their new works collaborate with the creator.”

– Antonio Gaudi\textsuperscript{51}

“We become immune to the negative forces in our environment – and that is when they do us most harm!”

– Christopher Day\textsuperscript{52}
Pit Architecture – Qualitative Program

As previously mentioned, the implications of neglect towards the issue of the water level rising in the Berkley Pit would most likely result in the further contamination of the local waterways in and around Butte. Furthermore, the outcome of this negligence would slowly spread throughout the Columbia River Basin and the impact the rest of the Pacific Northwest. This would then affect the flora and fauna, the agriculture, and finally the habitable areas in which life in general can dwell.

Once more looking back to the city of Butte, and the threat of the pit, an opportunity arises for architecture to become the solution. But not just architecture, rather, the collaboration between architecture and nature, with systems, such as those found in the glass sponge and the systems of phytotechnologies. In doing this, there becomes hope for the city of Butte, and subsequently the area throughout the Columbia River Basin. If something is not done within the next two decades, in the respect of remediation, a catastrophic outcome beyond the limits of Butte and Anaconda might develop.

Nature provides a multitude of systems that could be utilized to remediate such contaminated areas as the Berkley Pit. Revisiting many of these systems such as constructed wetlands, or systems of
organisms, nature once again becomes the muse of a restorative and regenerative architecture: a new organic architecture.

More than Just Healing the Land

Although it is the aim of this study to clean and heal the problems with the waste of mining in Butte, there is still a necessity for this architecture to provide more than the cleansing of contamination in and around the Pit. The architecture that will treat the contamination should also become a place to house those who help with the cleaning process, the residents of the remediation structure.

One simple solution that will be carried into the architecture is the use of gardens. With the use of gardens in atrium spaces, as well as on the approach to the structure, gardens will serve multiple purposes. The two primary purposes of these gardens would be to provide a natural way to filter indoor air, similar to 30 St Mary Axe, but also providing a visual comfort to the workers in the architecture.

To be healing, a place must be harmonious. This means bringing change as an organic development so that new buildings seem not imposed aliens but inevitably belong where they are, responsive to their surroundings… But places – and buildings – must be nourishing to the human being. 53

With the addition of green space, both in and outside of the structure, the area will provide a
healthier work environment, as well as areas of reflection and relief with the connection back to nature.
The other benefit of these gardens is the representation of natural filtration that can become tangible symbols for all of the other systems of remediation and cleansing throughout the architecture.

Beyond Remediation: A Self Sustaining Architecture

In this architecture, not only must it clean the water of the Pit, but it must also be self sufficient in the sense of creating a zero ecological footprint, providing its energy, and waste management throughout the building. This can be done through a variety of technologies already known, both organic and man made. Furthermore, it must also eliminate any carbon emissions that might otherwise be a byproduct of the architecture.

It would appear that... the best chance of rescue lies with the built environment because buildings in use or in the course of erection are the biggest single indirect source of carbon emissions generated by burning fossil fuels, accounting for 50% of total emissions. If you add the transport costs generated by buildings the UK government estimate is 75%. It is the built environment which is the sector which can most easily accommodate fairly rapid change without pain. 54

Although the remediation of the water in the Pit is the main objective of this architectural study, it is still important to keep in mind the lifecycle costs, both capital and environmental, of the architecture.

With the implementations, besides the mechanical systems required to clean the water in the
Berkley Pit, other sustainable practices must be upheld in the design. This can be done by employing not only alternate energy sources, but also remediation systems within the architecture, biodegrading any
waste produced by the architecture or the inhabitants, similar to the Council House 2 in Melbourne.

This will be a major element within the architecture, for it must go beyond simply cleaning mining waste, it must also utilize technologies previously mentioned as well as many sustainable strategies to produce energy, without dependence upon Butte and the city systems. The system that would be responsible for the biodegradation of waste would be a smaller, contained, fusion between a constructed wetland and a living machine providing two benefits with its presence. Beyond the breakdown of waste, it would show a connection to nature to the inhabitants of this structure.

This however only solves one aspect of the need required by such a structure. With the addition of turbines, solar panels, passive heating and cooling, natural ventilation, as well as a myriad of other known strategies, the architecture itself would become a self sustaining system, much like those in nature that architecture is emulating.

A New Home for Research

The architecture, and ultimately the project, is more than simply a remediation center and regenerative architecture, it provides a space where further research in the fields of Biomimicry, Phytotechnologies, and Remediation can occur. But beyond this simple research, the architecture itself can then educate the
local community, the nation, and perhaps the world about these technologies.

This architecture will provide research from two different aspects. The first being the traditional sense of research where highly trained professionals experiment different methods of environmental remediation. However through this architecture there would be a new type of research, more along the lines of educating the public. Through the architecture as a whole, the systems making a regenerative and environmental remediation tool serve as a larger tool of education towards the subject of environmental remediation. Also through the spaces within this, small areas of natural spaces such as the gardens previously mentioned would also serve for the public to begin to research and educate themselves and others on the processes of remediation and biomimicry of those systems.
A New Organic Architecture for Research – Quantitative Program

Public Spaces
- Lobby/ Education space........................................5,000 s.f.
- Lab Space..........................................................20,000 s.f.
- Classrooms / education space.................................5,000 s.f.
- Office space.......................................................15,000 s.f.
- Living Machines (2)..............................................15,000 s.f.
- Restrooms/ locker rooms......................................5,000 s.f.
- Mechanical for self sustaining architecture..............5,000 s.f.
- Storage..............................................................5,500 s.f.
- Education walkways/ circulation...........................115,000 s.f.

Filtration Spaces
- Filtration Tanks.................................................50,000 s.f.

Total Program.....................................................225,000 s.f.

Platform Spaces
- Tree Platform (2)................................................4.5 million s.f.
The Code:\footnote{\textsuperscript{55}}

With the variety of spaces within the remediation center, segments of the International Building Code and ANSI will be investigated to support the practicality of this architecture.

Occupancy Type

Being more than simply a remediation center, but also a research facility, and a place of learning, there are three main occupancy types according to the 2006 International Building Code.

303.1 Assembly Group A. Assembly Group A occupancy includes, among others, the use of a building or structure, or a portion thereof, for the gathering of persons for purposes such as civic, social or religious functions; recreation, food or drink consumption; or awaiting transportation.\footnote{\textsuperscript{56}}

Pertaining to this project, there will be several spaces that allow for the gathering of people, such as the entry space that may have portions of the space dedicated to educational showcases or the like.

Although there are educational spaces throughout the facility, it would not fall under the educational spaces portion of the code, \textbf{SECTION 305 – Group E}, due to the inclusion of students beyond the 12\textsuperscript{th} grade. The educational areas would also fall under the assembly group due to the nature of the space itself.
Rather than typical classrooms, the spaces would be interactive educational areas for visitors to learn more about the dangers of mining contamination and remediation of this danger.

SECTION 309 - MERCANTILE GROUP M

309.2 Quantity of hazardous materials. The aggregate quantity of nonflammable solid and nonflammable or noncombustible liquid hazardous materials stored or displayed in a single control area of a Group M occupancy shall not exceed the quantities in Table 414.2.4(1).

The spaces that would fall under this category would be the laboratory spaces. This is where there would be the potential for hazardous material from the Berkley Pit that will be studied, or used in studies of remediation.

414.2.5 Hazardous material in Group M display and storage areas and in Group S storage areas. The aggregate quantity of nonflammable solid and nonflammable or noncombustible liquid hazardous materials permitted within a single control area of a Group M display and storage area, a Group S storage area or an outdoor control area is permitted to exceed the maximum allowable quantities per control area specified in Tables 307.1(1) and 307.1(2) without classifying the building or use as a Group H occupancy, provided that the materials are displayed and stored in accordance with the *International Fire Code* and quantities do not exceed the maximum allowable specified in Table 414.2.5(1).

311.3 Low-hazard storage, Group S-2, Includes, among others, buildings used for the storage of noncombustible materials such as products on wood pallets or in paper cartons with or without
single thickness divisions; or in paper wrappings. Such products are permitted to have a negligible amount of plastic trim, such as knobs, handles or film wrapping.

Metals from the remediation process may be stored or any element used to remediate the acidic mining water that may have some remnants of metals will be stored in these areas. The purpose of this is for the interim periods between research subjects towards minimal or no waste from treating the water.

SECTION 312 - UTILITY AND MISCELLANEOUS GROUP U

312.1 General. Buildings and structures of an accessory character and miscellaneous structures not classified in any specific occupancy shall be constructed, equipped and maintained to conform to the requirements of this code commensurate with the fire and life hazard incidental to their occupancy.

This in particular discusses the building type of the actual remediation elements and systems within the architecture. It would be difficult to identify its occupancy type at this time other than GROUP – U.

Allowable Building Heights and Areas

SECTION 507 - UNLIMITED AREA BUILDINGS

507.1 General. The area of buildings of the occupancies and configurations specified herein shall not be limited

Type I construction does not have limits on area or height. This particular type of construction is necessary
due to the need for a large space due to the program.

Construction Type

SECTION 602 - CONSTRUCTION CLASSIFICATION

602.1 General. Buildings and structures erected or to be erected, altered or extended in height or area shall be classified in one of the five construction types defined in Sections 602.2 through 602.5. The building elements shall have a fire-resistance rating not less than that specified in Table 601 and exterior walls shall have a fire-resistance rating not less than that specified in Table 602.

602.1.1 Minimum requirements. A building or portion thereof shall not be required to conform to the details of a type of construction higher than that type, which meets the minimum requirements based on occupancy even though certain features of such a building actually conform to a higher type of construction.

602.2 Types I and II. Type I and II construction are those types of construction in which the building elements listed in Table 601 are of noncombustible materials, except as permitted in Section 603 and elsewhere in this code.

Fire rating of a minimum of 2 hours is required due to the Group M space.

Means of Egress

1003.6 Means of egress continuity. The path of egress travel along a means of egress shall not be interrupted by any building element other than a means of egress component as specified in this
chapter. Obstructions shall not be placed in the required width of a means of egress except projections permitted by this chapter. The required capacity of a means of egress system shall not be diminished along the path of egress travel.

1014.2 Egress through intervening spaces. Egress through intervening spaces shall comply with this section. Egress from a room or space shall not pass through adjoining or intervening rooms or areas, except where such adjoining rooms or areas are accessory to the area served, are not a high-hazard occupancy and provide a discernible path of egress travel to an exit.

The Pit and the Spread of Contamination – The Site

The Berkley pit at its shortest distance across is .6 miles, or 3170 feet, and at its longest distance is just over a mile. To become not only an architecture that would remediate the site, but also becomes a symbol of this new organic architecture, the architecture will use the Pit to become a paradigm shift for the population of Butte. This architecture must be an architecture that is a symbol and a tool for environmental remediation but also not forget about the environment it will be created in. To accomplish this, many aspects and characteristics of the site become integral to the project. Such elements as the spread of contamination within the city of Butte, wind direction to not only harness energy, identification of solar
angles throughout the year as well as many other elements of the site.

In concern to the spread of contamination, this particular map designates the main areas of contamination from mining and the levels of toxicity. Even the head frames that litter the hillsides in and around Butte contain some level of the toxic elements within the Pit. However there is also another element of this contamination hidden in the hills to the east: several mine dump sites from the decades of mining reside a few miles east of town.

In concern to the physical characteristics of the site, two main features are necessary to understand is the wind direction and the solar angles throughout the year once again. The prevailing wind in the area comes out of the west by South west providing a potential for the installation of wind energy devices.* The other opportunity pertaining to sustainable energy is the use of solar energy in one manner or another as previously mentioned in the qualitative program. For this, the sun charts of the area, provided by University of Oregon, become invaluable.

There is currently a facility on the edge of the Berkley Pit that is used to filter water. The filtration and treatment that occurs at this particular facility is not nearly to the level at which this project will filter and remedy the problem of the Pit. The purpose of the current treatment center is rather the pumping of water to extract copper and nothing else. The end result of this is only the extraction of copper considering
the content that is not “treated” is then returned to the Pit and no remedy to the solution is made. 58

The final important characteristic of this site is water level, and all that the “level” of water entails. The level at which the water table in and around Butte, including the Silver Bow Creek, is currently at 5,410 feet above sea level. When checked in 2004, the water level of the contents of the Berkley Pit was measured at 5,243 feet above sea level. It also currently contains about 36 billion gallons of water. The study done for the Pit by EPA mentioned that by 2018, to prevent the water from reaching the level of 5,410 feet above sea level, several million gallons will be pumped annually, treated and “any treated water not used for mining will be ‘safely’ discharged into the Silver Bow Creek.”59
Even if the treatment plant pumps “several million” gallons annually, that alone would not keep the water level from rising and only delay the disaster at hand. The actual amount that must be pumped in order to keep the water level the same throughout the year is a little over one million gallons of water per year. The reason for this is the amount of water that enters the pit daily. Roughly three million gallons of water per day enters through former mine shafts and into the acidic lake that is the Berkley Pit. That means in order to successfully keep the water level of the Pit stationary, three million gallons of acidic water must be pumped daily and filtered. This would prevent the disaster at hand but also provide a healthy solution for the community and the region.

As for the rest of Butte, similar to the Berkley Pit, anything that was once used for mining such as the Head frames that are littered upon the hills, or the Pit itself, lie derelict only acting as reminders of the past and the potential problems that this mining community have bestowed upon future generations.
(Above) This is a map depicting the many mining communities throughout what is modern day Butte. (Left) This comparison shows the change not only to Butte but the significance that the Berkeley Pit had on some of the communities such as Meaderville.
When dealing with the Berkeley Pit, the main issue to be concerned with is the rising water level. In 1987 the water level was roughly 600 feet above the bottom of the Pit. When this diagram was created in 2003 the water level rose to a height of 5239 feet, more than 1,000 feet in sixteen years. It is predicted that the water inside of the Pit will raise roughly 12 inches per year, due to the ever increasing volume of water flooding the former mining shafts.

The Pit receives about three million gallons of water per day which is roughly one billion gallons of new water every year! When last checked, the current volume of water within the Pit is around 36 billion gallons of water with varying pH levels as well as increased metals towards the bottom of the acidic lake.\textsuperscript{10}
The realization that the centuries of mining had created, in some cases, the proverbial monster, caused the EPA (Environmental Protection Agency) to institute the Berkley Pit and the surrounding areas as part of the largest superfund site to date. A small treatment facility (Above) has been constructed however it simply filters out the copper and other valuable minerals while disposing of the sludge back into the acid lake.

The spread of the contamination from mining is great but the heart of the problem is the Pit itself.
**Biomimicry and Bio-utilization**

The next step is to take the research and with further study, create an architecture that filters contamination through its systems. In the design, this will be accomplished through Biomimicry, mimicking systems in nature such as the Glass Sea Sponge, constructed wetlands, and phytoremediation. On top of that, the architecture will utilize nature to finish the filtration process and release the filtered water back into the atmosphere through transpiration.
THE ARCHITECTURE AS FILTER
ARCHITECTURE OF THE BERKLEY PIT

CHAPTER FOUR
With the consideration of three million gallons of freshly contaminated water entering the Berkley Pit at a pH of 2.39 per day, the facility itself had to be created for the monumental task of filtering and the redistribution of such an amount of water. To accomplish such a task, not only did
Biomimicry become an invaluable tool, but also the use and byproduct of phytoremediation. The primary task of this structure would be to filter the initial contamination from a pH of a 2.39 up to a more moderate pH of a 4.5, or ideally a pH of a 5. This is primarily the case to filter most of the minerals for further refining that are the main contaminants within the pit, but also the water would then be distributed to 750,000 poplar trees to absorb the filtered water. From this point the trees, which can absorb anywhere from 2 to 10 gallons of water per day, would further filter the water and transpire it back into the atmosphere. Overall, this facility resides over 4.5 million square feet within the Berkley Pit, floating atop of the acidic pool. Both the act of keeping the structure buoyant, as well as filtering 3 million gallons of water per day, in this particular case, look to nature for aid.

**Biomimicry in Systems**

Not only is the task of filtering the contaminated water of a size that is only rivaled by the very host of the contamination a feat in and of itself, but for the best potential to not only remedy the problem of the rise in water level, but to educate the world with its presence, this structure shall float within the walls of the old mining pit. In the case of the structure which displaces the weight of the facility to the
surface of the water, which through the physical laws of surface tension and capillary action, create an unusual foundation for this facility. If that were not the only thing, the structure would be constantly subject to the corrosive qualities of the very water in which it is floating. For the solution of this potential problem, organism in nature proved to become the inspiration for the structural system in which would not only displace weight along the surface of the water but also withstand the constant barrage of acidic corrosion.

**Exoskeleton**

The first portion of the structure that contains everything within is referred to as the
exoskeleton of the structural piece simply because it absorbs the load of the rest of the unit and transfers them to the interior core, which is made of multiple precast hollow pieces. The exoskeleton takes its inspiration from a rather common source, which would be insects, such as beetles. The main purpose of the exoskeleton is to restrain and control interior structure that is constantly moving. Inside of this piece of structure is a threaded track, similar to nut or bolt, which helps move the structural core down as each piece corrodes and dissolves into the pit.

The Core

This particular element of the structure is integral to how it combats corrosion. Each piece is seven and a half feet tall and link to the piece below it. In nature, a plant known as the Horsetail Fern, or
Snakegrass, survives through a similar means. To elongate its life, the Horsetail fern creates several small pods rather than a stalk, so when a natural predator begins to consume the plant stalk, the root systems are not pulled from the soil. Instead, the closest pod releases to save the rest of the organism. A similar system works with this element of the structural piece, where as one portion deteriorates, its replacement is moving within the exoskeleton down towards the surface water. The pieces that make up the core are, within the exoskeleton, restrained from spreading out and distributing the structural load across the surface water and utilize not only the surface tension of the water within the Pit, but are also hollow at strategic points to utilize capillary action. The capillary action is especially important due to the amount of air pressure that causes most of the living column to float.
The Extendible Member

This final piece of the constantly moving column utilizes one particular creature that displaces its own weight atop of the water through surface tension. The end result of the Water Strider displacing its weight is the change of the surface of water. The change is from a liquid to a more flexible membrane in which the weight and load of an object can actually be transferred to the water. In order for this to all take place several variables, such as the correct temperatures, are required. In the case of the Berkley Pit 54 degrees or colder temperatures are ideal for surface tension to occur, which once again causes the Berkley Pit in Butte to be the ideal location for this, considering the average temperature in Butte is roughly 38 degrees.
Biomimetic Water Filtration

Filtration of the water in and of itself is a task, however, looking to nature and systems from nature, filtration, through biomimicry could be accomplished unlike most water treatment facilities. In the filtration systems within the architecture, the natural precedences were both the Glass Sponge, and constructed wetlands, both previously mentioned. The organism of the sponge and ecosystem of the wetland show how nature can process and breakdown contamination, or filter liquid, both becoming ideal for this situation.

In the case of the sponge, its glass skeleton filters water for particles in which the organism can consume. Similarly, in the facility, a mechanism highly resembling the sponges exterior structure would filter and cause water movement through rotation. With the aid of a turbine, the water would move up a tube from the surface of the pit and enter the first stage of the filtration, which will be more in depth later in this section.

The way that this particular part of the filtration would work is very similar to the glass sponge’s
structure and how it filters particles through rotation and movement. The larger particles get trapped in the small holes throughout the structure and then get processed down to the organism. In the sense of water treatment, especially at the Berkley Pit, a similar process would occur, where through movement and rotation, larger particles of metal would be filtered being the first stage of filtration, while at the same time, collecting metals that could then be refined and harvested.
**Water Filtration Process**

The process of water filtration is an integral part of what the facility was designed for. But to filter, and ultimately keep the water level stagnant, the filtration had to be approached from a new angle. While looking at constructed wetlands, but also how nature filters contamination through all organisms, the water from the pit would undergo several levels of filtration as it moved throughout the facility.
The first step would be to utilize the tube and filtration system that mimics the Glass sponge. In that respect the water would move up the tube and begin its filtration journey by first filtering larger particles of copper, lead, iron, and zinc.

From there the next step would be to transfer the water from the primary tubes to secondary tanks, which would filter the water until enough of the contamination was filtered to reach a pH of a 4.5 or ideally a 5. Here, it would undergo, similar to the constructed wetlands, a series of filters that range in scale from beginning to end.
The final step is then the distribution of the water throughout the facility to all of the trees. The water would leave the filtration center, and travel through the floor decks of the facility. From there, the water would then travel through pipes within the Hollow Structural Steel, to reach its destination of the groves of poplar trees.
The Facility and Construction

Although the two systems, structure and water filtration, draw inspiration from nature, they are but a small piece to the larger picture of the facility. The main goal of the facility is to filter the water, however, through this filtration, many economic byproducts would occur through the entire course of the water pathway as well as what essentially makes up this structure. Although once complete, the total area is 4.5 million square feet, it is actually composed of 220 smaller units, that within them are even more focussed and broken down into self sustaining units. One unit is 144 feet square, and is made up of four distinct layers and elevations. The top layer is where the groves of trees are located, the trees integral to the end of the water filtration. On this layer, 16 groves of 9 poplar trees reside 175 feet above the waters surface. This height becomes important simply due to the estimated danger level by the EPA or the Berkley Pit, which is the altitude of 5410 feet above see level, and 175 feet above the current water level.

The next layer is an open floor, where the trees would then be harvested (the process later in this section). This level is 50 feet below the tree platform taking into consideration the height of the poplar
trees around the time they are harvested, which is around 50 feet.

Over the next 25 feet below that level contains not only several lateral bracing points, but is also where the water is distributed to the trees from the facility. Finally the last level before the floating structural members, is the layer of the unit in which precast structural members would be set on tracks to be moved into the location desired above the structural member. Once there, it would begin to link to the piece below it, and eventually become the piece that is slowly corroding while floating in the Berkley Pit.
The Process of Tree Removal

Now that the idea of the Unit has been established, the process of the trees shall now be explained in more detail. Although the 750,000 poplar trees that would inhabit this installation are not the primary tool for water filtration, they still play an integral part in the final step of the water cycle within this facility, which is the final destination for the filtered water and final part of the filtration process. The trees, however, after 15 to 20 years, becomes a byproduct of the facility and can then be harvested through sustainable means. The cycle of the tree begins with the placement of the rootball and sapling of the poplar grove within the greater unit. Packaged within a biodegradeable netting, the
A sapling would be hoisted through a series of mechanisms to the height of the rest of the level. At this stage, the tree would then go through the next 15 to 20 years filtering and processing the final step of the water cycle of this facility until it was ready to be harvested. By this time, the netting would have biodegraded and the tree heavy. The next step, the harvestable tree would then fall through a trap door and land on the open floor deck 50 feet below. Once there, it would be trimmed and then transported off of the floating structure.
The Program Within

Although the facilities primary function is to filter the contamination and process the water of the Berkley Pit through Biomimetic systems and Bioremediation, the secondary purpose of the facility would be the research that would go on, as well as administrative spaces for the offices of the tree removal, and so forth. The main spaces within are in actually large open spaces so the program can be extremely flexible within the two public spaces in the center of the overall facility. The lab spaces would be present with the appropriate mechanical systems, such as chemical hoods, so further research could be done in the fields of remediation as well as the biological and chemical makeup of algae and
the water of the Pit. In both cases, there would be a constructed wetland within the facility to process human and biological waste created in the facility.

The next element is the area in which the public can observe the filtration in its second stage. Although it wouldn't constantly be a public place, it would be open to visitation for educational purposes on occasion. Within this portion of the facility, the elements of initial filtration could be replaced through hatches in the floor as well as the filters in the second stage of filtration could also be replaced. The filters, full of heavy metal particles, would then be sent off of the platform to be processed and the filter would return once all of the particles had been removed.
This is the portion of the facility where the biomimetic systems of filtration would be located. The majority of the floor plan is consumed by the filtration tanks but there are walkways, and exits, in compliance with fire code, so in the case of large educational groups occupying the space, safe exits for the patrons would be accommodated.
The Education of the Public

The final portion of the project would simply be to educate the public, meaning the residents of Butte, and Montana, as well as the rest of the world of the dangers of negligence towards highly contaminated areas, such as the Berkley Pit. The first level of education would be the sheer size of this project within the Pit. Not only would the cause an individual to pause and take note, but spark curiosity towards its purpose. In this it would become a search for self education finding out the reasons as to why this facility was placed where it was.
This is the overall size of the facility within the Berkley Pit, not only showing the current water level in dark blue, but also highlighting the critical level at 5410 feet in the dark red.
The main source of education in the facility would be the experience of the viewer, rather than formulated classrooms and teachers designated simply for the purpose of education. There would be an open room set up in case a class room or large space was required, but for the most part, the educational aspect of this project would come from the experience of the viewer. Whether walking through the trees on the top level, or observing the constructed wetland from within the facility, the patrons of this center
for remediation, would, in essence, educate themselves through observation of the facility around them. The other half of the experience and self education would be the shear monumentality of the scale of the facility, considering the structure, as well as the trees all ranging from 25 feet to 50 feet from any given platform.
And so ends a chapter in the journey towards an architecture that can filter and become a remediation tool in and of itself. This could become more than simply a dream where other areas of the world could perhaps look to nature and find that architecture could, in fact, become a tool in which to clean the contamination and become a new organic architecture, a living architecture.
REFERENCES
Footnotes

* In some respects, there are a multitude of remediation techniques; however the non organic means that are mostly used pertain to the activity of excavating and dredging contaminated soil and contaminated waterways. The problem with this particular method is although there is removal of the toxins from that particular site; the toxic material is consolidated and transported to a landfill. This does not necessarily remedy the problem but rather relocates and passes off the problem to someone else.

* In this particular instance, there became a third element of risk, that of human endangerment. Not from the altered plant, but from eco terrorists aiming to halt any further scientific investigations.

* All of the text in **BOLD** is directly taken from the 2006 International Building Code

* Although Wind Turbines fall into this category, it should not limit the potential for the design of such elements during the design phase of this project.
Endnotes

1 Brian Skovers Butte and Anaconda Revisited. Butte Mining District, p.3
2 Jacob Ostberg. Sketches of Old Butte. Miners of Old butte, p. 14
3 Skovers, Butte and Anaconda Revisited. Emergence of a Silver/Copper District, p.5
4 Harry C Freeman. A Brief History of Butte, Montana. Greater Butte, p.62
5 Freeman, A Brief History of Butte, Montana. Greater Butte, p.62
6 Ostberg. Sketches of Old Butte. Butte’s Best Years, p.13
7 Skovers, Butte and Anaconda Revisited. Growth of the Anaconda Copper Mining Company p. 13
8 Skovers, Butte and Anaconda Revisited. Growth of the Anaconda Copper Mining Company p. 13
10 “Berkley Pit Conditions” <www.pitwatch.org>
11 Kvesitadze, G. Biochemical Mechanisms of Detoxification in Higher Plants. Environmental Contaminants, p. 21
12 Tsao, David T. An Overview of Phytotechnologies., Advances in Biochemical Engineering Biotechnology., v. 78, editor David Tsao. 4
14 “Silver-Bow Creek” EPA
15 Kvesitadze, G. Biochemical Mechanisms of Detoxification in Higher Plants. Environmental Contaminants, p. 21
16 Tsao. Advances in Biochemical Engineering Biotechnology v. 78 Phytoremediation. P.7
17 Marta Noemi Cabello. Fungi in Bioremediation. Microrhizas and Hydrocarbons, p. 456
24 Paul Shukovsky. “2 Plead Guilty in eco terror arson at UW.” Seattle Post. 5 October 2006.
31 Ibid, 278.
54 All of the information was interpreted from the 2006 International Building Code
55 International Building Code 2006
56 Rough estimate with the tools associated to GoogleEarth.
57 Content from Pitwatch.org at the Berkley pit
58 Content from Pitwatch.org at the Berkley pit