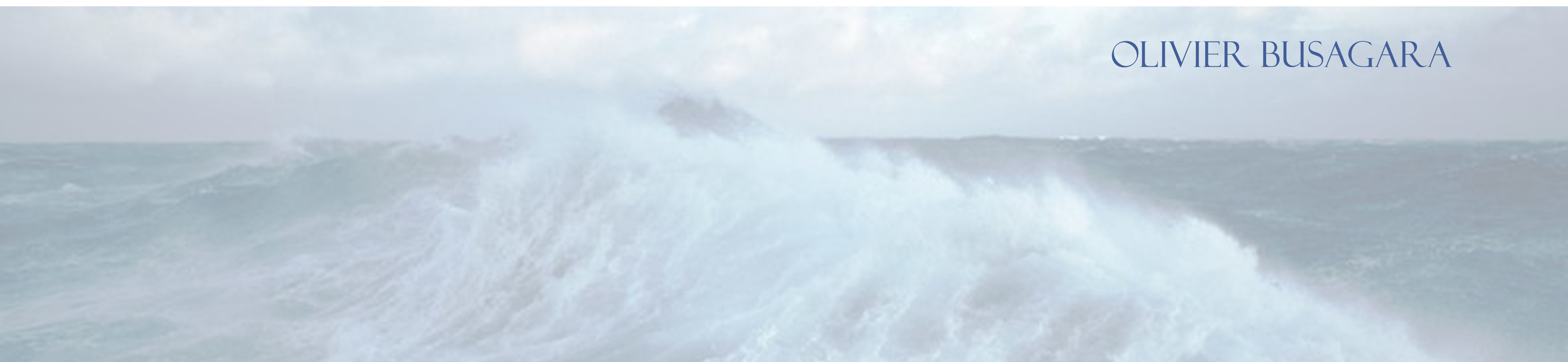
DESALINATION & ARCHITECTURE



OLIVIER BUSAGARA

Desalination & Architecture

A Design Thesis Submited to the
Department of Architecture and Landscape Architecture
of North Dakota State University

By **Olivier Busagara**

In Partial Fulfillment of the Requirements
for the Degree of
Master of Architecture

Primary Thesis Advisor

5/4/12
Thesis Committee Chair

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Fargo, North Dakota

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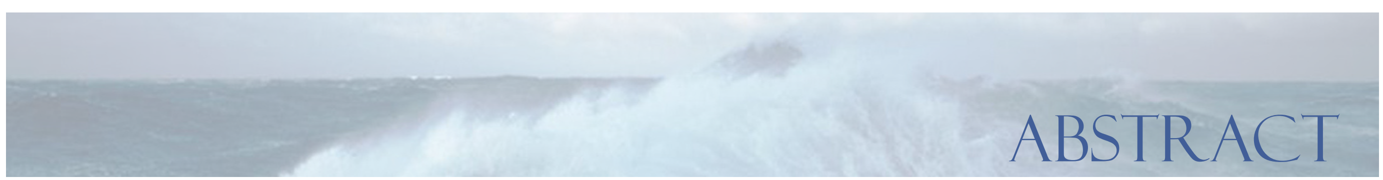
This thesis project will focus on how a desalination plant can benefit the environment. As population grows, climate changes, and local water scarcity heighten, desalination of brackish water and seawater is increasingly considered as an option for a source of fresh water to meet anticipated demand. Desalination could also help restore water levels in places such as Lake Mead, where insufficient rain and snowfall in the Rocky Mountains have caused the lake water level to fall well below drought levels. Finding innovative ways to use the remaining salt in architectural application, such as building non-load bearing walls, could then help lower the rising salinity of seawater caused by global warming and pollution.

Architecture: The Architecture is a desalination plant on Lake Mead in Nevada.

Keywords: desalination, environment, restore, growing population, seawater, global warming



Can desalination be used as a way to provide freshwater to restore the environment in places such as Lake Mead, while using the salt architecturally to keep a closed loop?

STATEMENT OF INTENT

Typology: Desalination Plant

Claim: If no action is taken, Lake Mead could dry out by the year 2020, leaving eight million Americans without enough fresh water and electricity. Rising seawater salt levels could also reach catastrophic proportions.

Actor: Las Vegas and surrounding populations
Action: Lake Mead depletion
Object: Lake Mead Conservation
Manner of action: Sustainability

Premises:
Las Vegas and surrounding communities have faced a steady population growth during the last two decades. At the same time, the Rocky Mountains in Colorado have witnessed record high temperatures and a decline in snow and rainfall in recent years. These factors have lead to an unprecedented depletion of the area's main freshwater source, the Lake Mead reservoir.

Theoretical Premise/Unifying Idea: Bringing in seawater from the California coast, desalting it, then dumping it in the lake will help restore freshwater levels at Lake Mead. Using salt in architectural applications, such as building non load-bearing walls, could help reverse what is happening at Lake Mead and also help lower the cost of desalination and rising seawater salt levels.

Project Justification: Las Vegas and its surrounding populations will soon face serious freshwater shortages if we let Lake Mead dry out. Rising seawater salt levels are also threatening our environment.

PROPOSAL

Water is among the things that make Earth different from most other planets known to science. It is what makes Earth inhabitable to all living organisms. Humans have always depended on water to conduct a vast majority of their daily activities. Without water there would be no life and conditions would be very different on Earth.
But massive population growth in the 20th century and post industrial revolution pollution have put a threat on the supply of fresh water in some areas on Earth.

Although many good things can be attributed to the rise of the industrial age, a hefty price in terms of pollution had to be paid by society. Huge amounts of burning fossil fuels and other destructive industrial activities have left toxic chemicals trapped in the atmosphere, often ending up absorbed by the oceans, and slowing arising their acidity and salinity.

In recent years, an urbanization movement has taken place all across the world. People are leaving their farms and villages, switching to the city-life, and so cities are growing faster than ever before globally. The city of Las Vegas has undergone similar changes.

Las Vegas and surrounding communities get the majority their fresh water from Lake Mead. It is the largest manmade reservoir in the U.S., created by Hoover Dam damming the Colorado River. More than 90 percent of its waters come from melting snow and rainfall in the Rocky Mountains of Utah, Colorado, and Wyoming. But factors, such as large-scale population growth and shortfalls in snow and rainfall due to ecological changes caused by global warming have led Lake Mead to lose more water than it is taking in, depleting it to near catastrophic levels. If no action is taken, Lake Mead water levels will deplete to a point where the Hoover is no longer useful, and it may potentially dry out by the year 2020.

In conclusion, a desalination plant would help restore Lake Mead freshwater levels. North Pacific Ocean seawater from the California coast would be desalinated and dumped into Lake Mead. Using solar and wind energy, salt would be mined out of seawater and innovatively used architecturally. This plant would also serve as an educational facility to raise awareness of pollution, renewable energy, sustainability, and conservation of our planet among students and the the general public.

The Lake Mead Desalination Plant (LMDP) will provide fresh water to over eight million people in the states of Arizona, Nevada, and California. It will ensure that the one million acres of farmland irrigated by Lake Mead have sufficient water for many years to come. It will also ensure that the Hoover Dam power plant receives enough water to continue producing electricity for farms and desert cities, such as Las Vegas. The LMDP will serve as an educational facility to the general public to raise awareness of what is happening to Lake Mead, and what can be done to prevent disasters. It will also include a research center for students and engineers to explore ways salt can be used architecturally.

Pipe Line

A pipeline will be built across California, starting on the coast and leading to the site on Lake Mead. It will serve as the supply line for seawater, connecting a pump station in California to the Lake Mead Desalination Plant.

Desalination Plant

A state-of-the-art desalination plant will refine seawater supplied by the California pipeline, dumping refined freshwater into Lake Mead and trapping salt for structural research and application.

Renewable Energy Farm

A wind and a solar panel farm will harvest sun and wind energy to power the desalination process.

Structural Salt Research Labs:

Engineering research labs will collect the salt from the seawater and innovatively find ways to make it usable in architectural ways, such as non-load bearing walls, insulation, decoration and more.

Educational Facility

Educational galleries will provide a learning environment for students and the general public, emphasizing on the conservation of Lake Mead, desalination, structural salt, and sustainability.

Named after the commissioner of the U.S. Bureau of Reclamation, Elwood Mead, Lake Mead is located on the Colorado River about 30 miles Southeast of Las Vegas, on the borderline of Nevada and Arizona in the Mohave Desert. It is a large body of water extending some 112 miles behind the Hoover Dam, approximately holding 28,500,000 acre feet of water divided into nine smaller bodies. The site will be located on the sout-west side of the lake on the Boulder Basin, near Interstate 515.

Figure 1-1. Regional map.

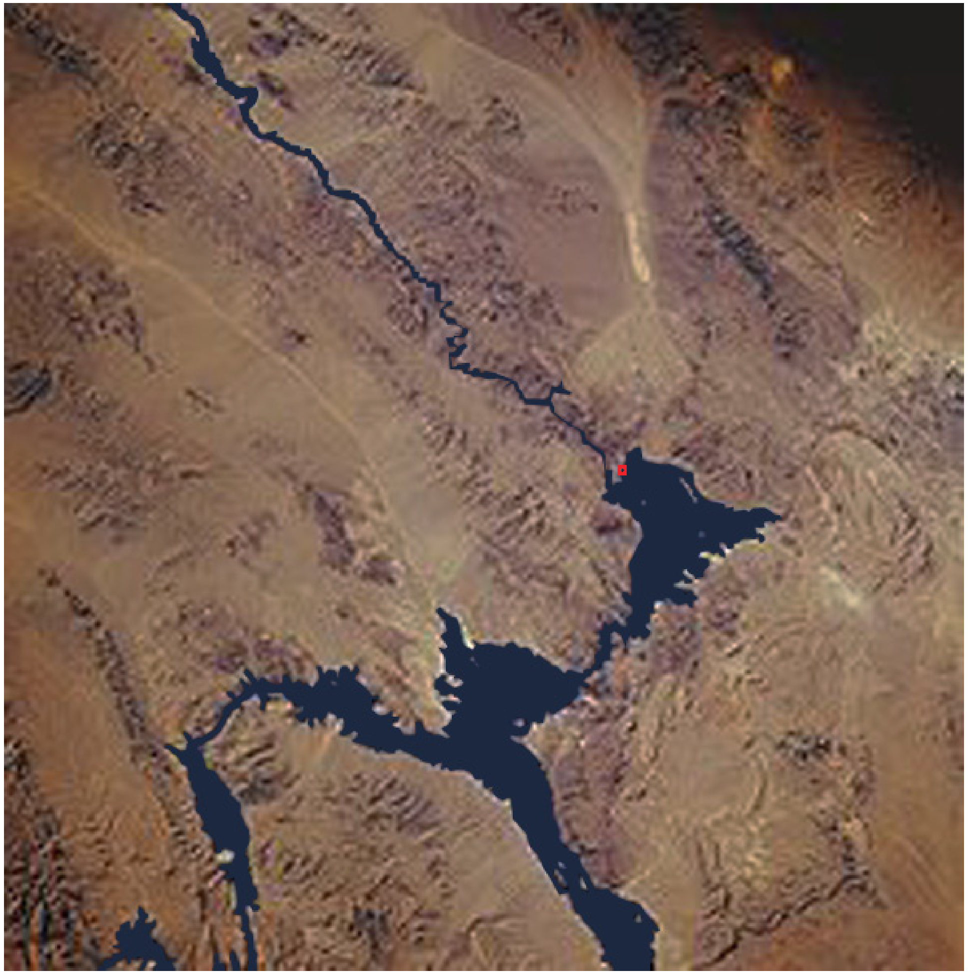


Figure 1-2. Map of Lake Mead.

Archaeological evidence dating as far back as 10,000 years ago has identified several Native American cultures to have inhabited the Colorado River region. Found archaeological artifacts tell a story of a much more temperate climate. These cultures practiced hunting, gathering, and early farming. The 1800s brought white settlers, following the advent of rail transportation and the discovery of gold and silver in southern Nevada. In the 1930s, The Hoover Dam was built to control flooding, allow for large-scale irrigation and other industries, and to harness hydroelectricity. The large water reservoir created by the Hoover Dam became Lake Mead, and in 1964, the Lake Mead National Recreation Area became the first national recreation area in the US. (National Park Service)

The site

The main emphasis of this project is preventing the depletion of Lake Mead. It is an effort to protect and preserve Lake Mead and all its benefits. It is to ensure that a growing population of eight million Americans in Arizona, Nevada, and California has a reliable source of fresh water and hydroelectricity, and through sustainability, over a million acres of farmland have enough irrigation water for today and for future generations.

Research Direction

Research will be conducted in the following areas: theoretical premise/unifying idea, project typology, historical context, site analysis, desalination process, and solar and wind energy production.

Design Methodology

Design Methodology will include quantitative & qualitative analysis, graphic analysis, and 3D analysis. Research will consist of desalination and sustainability to support this analysis. Qualitative data will be gathered by site visit, archival and periodical research, and case studies.

Documenting the Design Process

The documentation of the design process will be done by biweekly submittals of the process/schematic sketches, photographs, and models. The data collect will be stored digitally for reference.

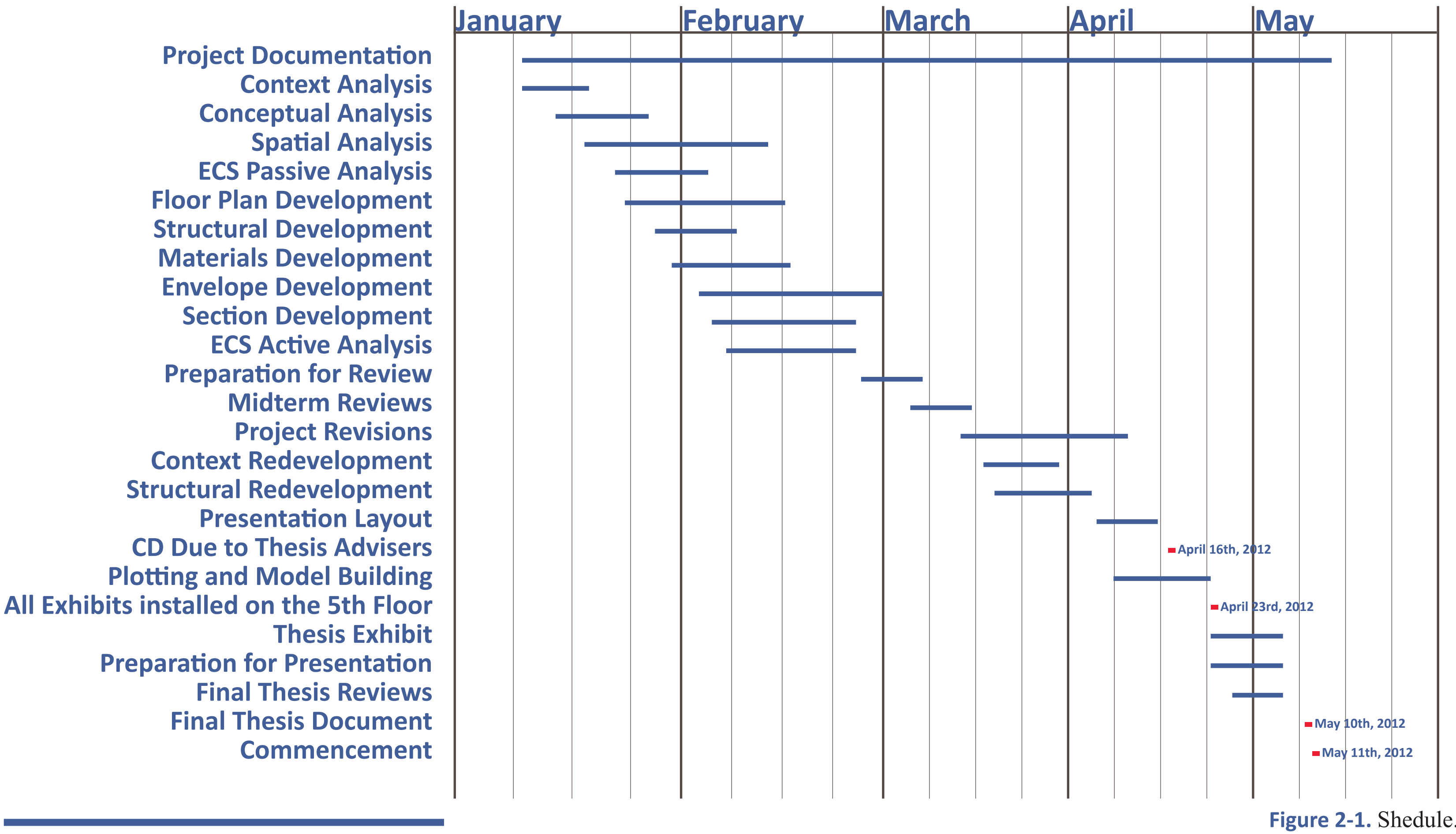
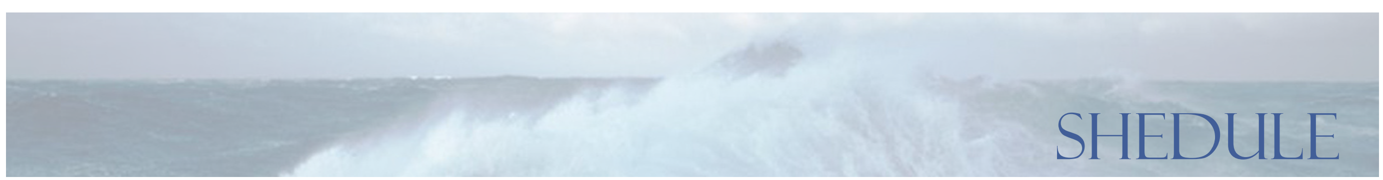


Figure 2-1. Shedule.



Second Year:

Fall 2008: Stephen Wisher
Tea House
Rowing Club
Spring 2009: Mike Christenson
Community Complex
Community Courtyard

Third Year:

Fall 2009: David Crutchfield
Probsfield Farm
Downtown Library
Spring 2010: Cindy Urness
Natatorium
Transit Center

Fourth Year:

Fall 2010: Don Faulkner
Vertical Community
Spring 2011: Paul Gleye
Blois Development
Place Rihour

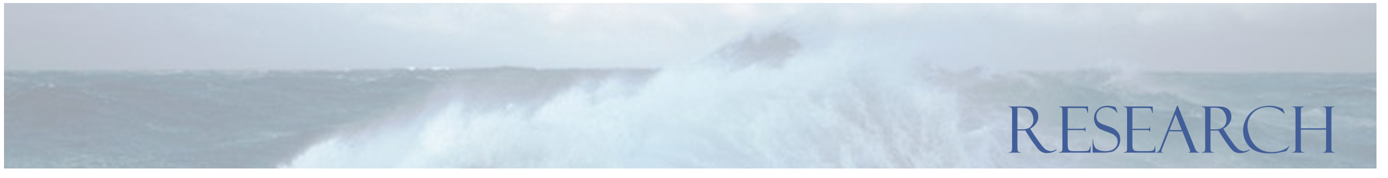
Fifth Year:

Fall 2011: Stephen Wisher
Artifact Creation

Ancient Sailors

Figure 3-1. Ancient sailors.

The idea to desalinate ocean salt water for human consumption is not a new one. Using small solar devices to mimic the hydrologic cycle (the natural cycle of evaporation and condensation fueled by the sun that produces fresh water on Earth), small-scale desalination has been practiced by sailors around the world for more than 2000 years. Still, less than a decade ago, large-scale desalination was too energy intensive and too expensive to be economically considered as a source for freshwater. In the article titled *"The cost of desalination"* published by Green Living Tips, it is stated that large-scale desalination was only practiced in the Middle-East, where the demand for freshwater outweighed the cost of energy. Today, this is no longer the case. 75% of the earth surface is cover with water, but 97% of it is ocean, salty seawater. Only 3% of all water on Earth is freshwater that can be used for drinking, irrigation, or industrial uses. And of that 3%, 69% of it is frozen in glaciers and ice caps. With changing climates and the global population expected to grow 50% over the next 50 years, the little freshwater available on Earth is dwindling at an alarming rate. Many countries recognizing that the world is on the brink of a water crisis have turned to desalination to address their water shortages. Already today, 300 million people in some 150 counties rely on desalinated water. Saudi Arabia, the United Arab Emirates, the United States, China, and Israel are the top five desalination markets (Green Living Tips). The most common method that accounted for more than 80% of global desalination in 2004 was the Multi-Stage Flash Distillation, which uses heat to evaporate brackish or seawater leaving salt behind.



Another type of large-scale desalination is the Solar Thermal method. Solar panels are used to gather the sun's energy, which is then used to power a heating device that boils the seawater. The boiling seawater releases a vapor that is then cooled and collected as fresh water. Relative to the amount of freshwater it produces, Solar Thermal desalination is not an efficient method of large-scale desalination because it requires a lot of space for the solar panels. A more promising method of large-scale desalination is the Reverse Osmosis method, or simply RO. In nature, osmosis occurs when two solutions of different concentrations are separated by a semi-permeable membrane. Water then flows through the membrane from the less concentrated solution to the more concentrated, in order to attain energy equilibrium. However, when pressure is applied to the more concentrated solution, nature is reversed, and water travels from the more concentrated solution to the less concentrated, hence the name reverse osmosis. Reverse osmosis desalination happens when pressure is applied on highly salty seawater. Water molecules are forced through the semi-permeable membrane, leaving sodium and other molecules behind. The result is freshwater on one side of the membrane and a very salty waste solution called Brine on the other side. Some of the reasons why desalination has not been a widely accepted source for freshwater in the past are the high heating energy costs in the Multi-Stage Flash Distillation method, the amount of spaces required by the Solar Thermal method, the high cost of semi-permeable membranes in the reverse osmosis method, and the environmental concerns associated with the brine waste disposal.

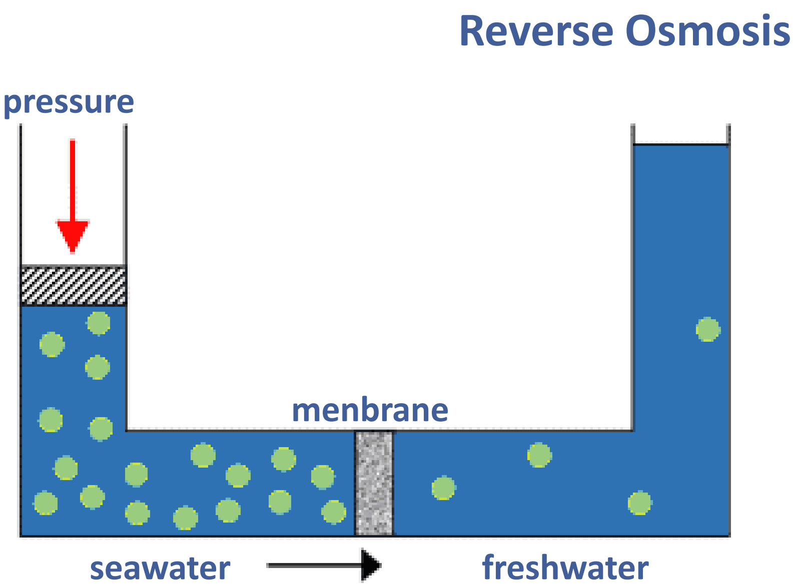


Figure 3-2. Diagram of the reverse osmosis desalination process.

Tampa Bay Plant

Figure 3-3. Reverse osmosis filters at the Tampa Bay desalination plant.

But recent advances in technology have significantly cut down the cost semi-permeable membranes, making desalination a supply option in places where it was historically too expensive. The U.S. Ecological Survey reports that it cost somewhere between $1000 and $2200 in 1998 to desalinate one acre-foot of water compared to $200 per acre-foot for freshwater purification. With the new technology, the largest U.S. desalination plant in Tampa Florida reported that the cost has dropped to about $650 per acre-foot in 2010. Since then, the *New York Times* has reported that even more recent advances in technology have helped plants recover close to 90% of the input energy involved in reverse osmosis, further helping the process become more economically feasible. With this new technology, desalination is now a less expensive way of obtaining freshwater for some coastal cities, compared to the traditional way of delivering it from ground or surface freshwater sources. General Electric has announced that in the near future, membranes derived from carbon nano-tubes could reduce the costs of reverse osmosis by an additional 75 percent. In parts of Southern California for example, it now takes more energy to pump freshwater from Northern California than it would take to make water from the sea. (Live Strong Magazine)

Colorado River

What this means is that the technological break-throughs and the continuing dropping energy intensiveness of desalination are making it possible for many U.S. coastal cities to consider desalination as a way to obtain freshwater. But what does this mean for inland desert cities facing serious freshwater shortages, like Las Vegas? Can desalination bring an answer to the Colorado River valley water shortage? Over 90 % of the water that Las Vegas and surrounding areas use comes from the Lake Mead reservoir, the largest manmade lake in the U.S. Located about 30 miles East of Last Vegas, it was originally created by the 1936 Hoover Dam damming of the Colorado River to control farmland flooding. More than 90% of Lake Mead's water comes from melting snow and rainfall in the Rocky Mountains. The presence of Lake Mead reservoir has unforeseeably triggered the rise of several desert cities in Nevada, Arizona, Southern California, and Northern Mexico, the largest one of them being Las Vegas. Today, a rising population of over eight million Americans and about one million acres of farmland depend almost entirely on the Lake Mead reservoir and the Hoover Dam for consumption and irrigation water and electricity. But in the last few decades, Las Vegas and the surrounding areas have undergone a steady population growth simultaneously increasing the demand for freshwater from Lake Mead. At the same time, 12 years of persistent drought in the Rocky Mountains have resulted in far less than normal snow and rainfall yields.

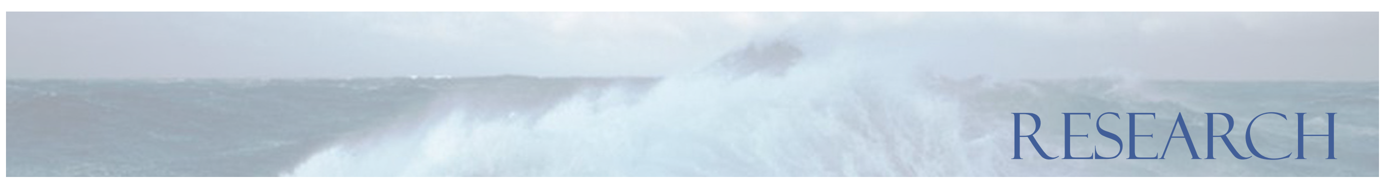
Figure 3-4. The Colorado River in the Mojave Desert.

Lake Mead

Figure 3-5. Lake Mead in Nevada.

These two leading factors have caused the Lake Mead reservoir to lose more water than it is taking, therefore depleting to its lowest level since the 1940s. As of August 2010, Lake Mead held 10.35 million acre-feet, just 37% of its capacity. The *Las Vegas Review Journal* reports that if the lake's elevation falls another 23 feet (the lowest level since 1937, when it was being filled for the first time), the Southern Nevada Water Authority will be asked to give the go-ahead to construct a proposed pipeline to tap ground water across Eastern Nevada. The 300 miles of pipe-network from Las Vegas to Delamar and Dry Lake valleys will cost an estimated 5 to 15 billion dollars and will take some 10 to 15 years to complete. Critics of the project expect it to cost more and to deliver less water than authorities have estimated. Some also fear that large-scale groundwater pumping in the arid valleys of eastern Nevada would threaten wildlife and the livelihoods of ranchers and farmers. Would not it make more sense to build a pipeline to Southern California where desalinated water would cost less instead? The Southern Nevada Water Authority argues that the permitting process between California and Nevada, environmental concerns, such as power generation, and the disposal of brine would make the process cost as much as the planned groundwater tapping pipeline. This is where architecture comes into the equation.

An ideal location, great design, and a sustainable disposal of brine are the missing pieces to the puzzle. Locating a desalination plant in the state of Nevada instead of California would eliminate the complicated permitting process of Nevada operating in California.



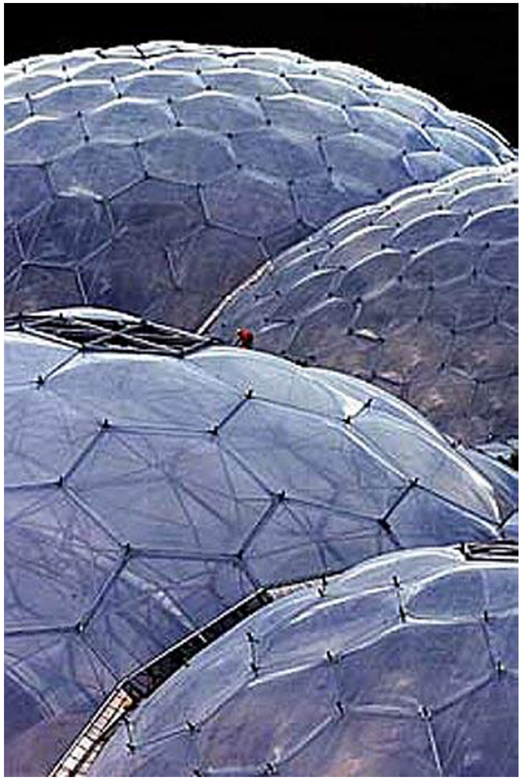


Figure 3-6. The Garden of Eden seawater greenhouse.

The only component needing permitting would then be the pipeline to bring seawater from the Californian coast. A site right by Lake Mead in the Mojave Desert would be ideal in two ways. There is enough sun energy and space to power the plant and dry brine for salt collection. That way, instead of putting the brine back in the ocean, it can find useful applications in places like art and architecture.
The design of a desalination plant plays a major role in how much energy it requires to operate, how much freshwater it yields, and how much it impacts the environment and the site it occupies. Many structural components of a desalination plant can be used to enhance the desalination process, at the same time helping to cut down on energy requirements. Two great examples of how architecture can enhance the desalination process are the Southern England Garden of Eden seawater greenhouse by Charlie Paton and Michael Pawlyn and Spain's Teatro Del Agua designed by Grimshaw architects. The Eden project is the largest scaffolding building ever built. It can house 35 soccer fields. It is designed to trap heat and condense water that is already in the air using no fossil fuel to create freshwater. The result is a large amount of freshwater created from thin air and used to irrigate an indoor garden. Like the Garden of Eden, the Teatro Del Agua uses no fossil fuel to mimic the natural hydrologic cycle, at the same time providing an excellent outdoor theatre.

Brine Pollution

Figure 3-7. Brine pollution.

It creates enough freshwater to supply a small city out of thin air for a small fraction of the price it would cost with traditional methods. Using relatively very little and renewable energy, the Teatro Del Agua has been called the Solar Thermal desalination plant of tomorrow. Icy seawater is pumped through a series of structural cold plastic pipes. The seawater is then sprayed onto an absorbent surface, and when sun heated air passes through this surface, it forces the vapor out towards the cold pipes where it condenses back into fresh water. The elimination of fossil fuel power generation incorporated in the design of a renewable energy large-scale thermal desalination plant makes it a very environmental friendly way to address freshwater shortages, even for a place like Lake Mead that is far inland. The only problem that remains is the disposal of the leftover highly salty solution brine.

This is another problem that can be solved architecturally. Much like desalination, using salt structurally and architecturally is also an old technique practiced in very salty parts of the world for many years. Sculptures and earthworks, such as the 1,500 ft Spiral Jetty on the shores of the Great Salt Lake by Robert Smithson, built with mud, salt crystals, basalt, earth and water have proved structural salt to last longer than 40 years, even underwater. At a time when sustainability and energy conservation are among the leading trends in architecture, architects such as Rick Joy have shown that great buildings can be designed primarily out rammed earth. And, in the Uyuni region near the Chilean Bolivian border, it is not uncommon to find houses that are built almost entirely out of salt.

Salt Hotel

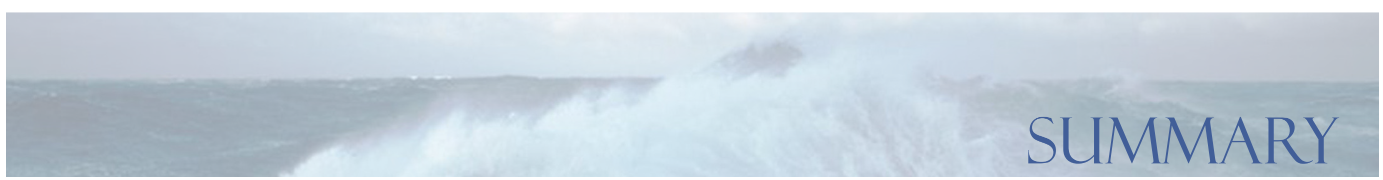
The Uyuni region houses the largest salt flat in the world, some ten billion tons of salt. One creative way the locals have responded to such an abundant resource is to use it structurally and artistically. Using salt blocks fused together by a cement-like water and salt mortar, architecture is created. A famous 15-bedroom hotel built out of salt, the Bolivian Moon Hotel, has even gone as far as equipping itself with furniture made primarily out of salt. Salt and rammed earth might not have the structural properties and characteristics of concrete and other widely used building materials, but they can certainly find a place in contemporary architecture in lightweight or non-load bearing applications. They are sustainable, abundant, and will leave less of an impact on the environment and site than some widely used materials. Structural salt made out of brine would help fight pollution by preventing waste brine from being dumped back in the ocean. With climate changes and pollution already raising ocean salinity and acidity, putting marine life at risk, one less thing we need is brine back in the oceans to aggravate the problem.

In conclusion, the ideal location, great design, and sustainable brine disposal can lead desalination in addressing water shortages in Southern Nevada and in other parts of the world. Using renewable energy and widely available resources, desalination can promote sustainability and help reduce global pollution.

Figure 3-8. Palacio del sal Hotel.

In summary, with changing climates and the global population expected to grow 50% over the next 50 years, the little freshwater available on Earth is dwindling at an alarming rate. Many countries, led by Saudi Arabia, the United Arab Emirates, the United States, China, and Israel, are turning to desalination in order to fulfill their growing water shortages. Although only a decade ago large-scale desalination was still too energy intensive and too expensive to be economically considered as a source for freshwater in the US, recent technological advances have made it a considerable option today. Promising large-scale desalination methods like reverse osmosis and renewable energy powered thermal methods are slowly replacing the more energy intensive Multi-Stage Flash Distillation. Today, it costs about $650 to desalinate one acre-foot of water, a price that has dropped from $2000 in 1998. In parts of Southern California for example, it now takes more energy to pump freshwater from Northern California than it would take to desalinate seawater. New technology by General Electric could reduce this cost an additional 75%. But what does this mean for inland desert cities facing serious freshwater shortages like Las Vegas?

Over 90 % of the water that Las Vegas and surrounding areas use comes from the Lake Mead reservoir, the largest manmade lake in the U.S. More than 90% of Lake Mead's water comes from melting snow and rainfall in the Rocky Mountains.



A rising population of over eight million people in Nevada, Arizona, Southern California, and Northern Mexico, and about one million acres of farmland depend almost entirely on the Lake Mead reservoir and the Hoover Dam for consumption and irrigation water and electricity. At the same time, 12 years of persistent drought in the Rocky Mountains have resulted in far less than normal snow and rainfall yields. These two leading factors have caused the Lake Mead reservoir to lose more water than it is taking, therefore depleting to its lowest level since the 1940s. If the lake's elevation falls another 23 feet (the lowest level since 1937 when it was being filled for the first time), the Southern Nevada Water Authority will be asked to give the go-ahead to construct a proposed pipeline to tap ground water across Eastern Nevada. The project will cost an estimated 5 to 15 billion and could threaten wildlife and the livelihoods of ranchers and farmers.

Architecture can help answer questions facing the Colorado River valley. Salt might not have the structural properties and characteristics of concrete and other widely used building materials, but it can certainly find a place in contemporary architecture in lightweight or non-load bearing applications. With the ideal location, great design, and sustainable brine disposal, a desalination plant can help Southern Nevada address water shortages. Structural salt made out of brine could help fight pollution by preventing waste brine from being dumped back in the ocean.

Bodegas Portia Winery

Figure 4-1. Roof access.

Figure 4-2. Exterior of the fermentation room.

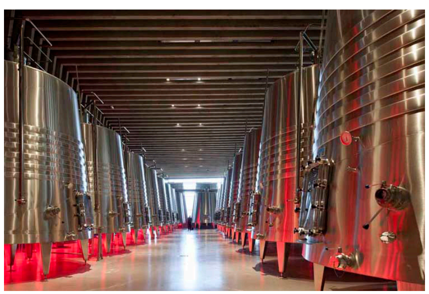
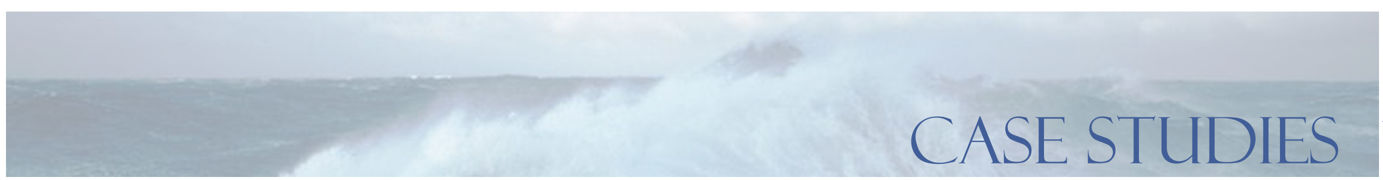


Figure 4-3. Interior of the fermentation room.

No matter the method of desalination (solar, reverse osmosis…) the process often starts with the fuel guzzling heating of brackish or seawater. Depending on the method, the boiling solution is either used to directly separate fresh-water vapor from salt, or it is used to ease the flow of the salty solution through membranes that physically trap the salt out of the water. With that being said, it is very important to address issues, such as fueling costs and condensation when designing a desalination plant.

Creating a pleasant working environment, placement and storage of heavy equipment, and controlling condensation are some of problems that Foster and Partners had to address when designing the Bodegas Portia Winery, located in the Ribera Del Duero region, in rural Spain. Foster and Partners use the natural topography of the site to create optimum working conditions and to aid the process of winemaking, while reducing the building's energy demands and visual impact on the landscape. For example, the parts of the building that contain the wine-ageing barrels are partly embedded into the ground to allow for the most favorable and cost effective conditions for ageing wine. This is a project that could have easily turned into a warehouse or factory-like working space, but through excellent material choice and organizations of spaces, its designers created a state-of-the art winery that promotes the well-being the workers and visitors.



Evelyn Grace Academy

Much like the Bodegas Portia winery, the Evelyn Grace Academy by Zaha Hadid and Architects is another building that gracefully blends in with its site. But, unlike the rural Bodegas Portia winery, the Evelyn Grace Academy does so in a predominantly residential urban neighborhood of London, UK. Its designers wanted an education facility that is different from the typical institutional atmosphere that is present in most schools, and that many students and teachers often dread. Instead, through natural lighting, great material selection and assembly, and natural ventilation, the Academy offers a learning environment that is spatially reassuring, thereby being able to engage the students actively. Strategic segregation of spaces puts the education ideology of "schools-within-schools" to promote healthy learning and progressive teaching routines to the test.

Figure 4-4. The Gymnasium.

Figure 4-5. Open court-yard.

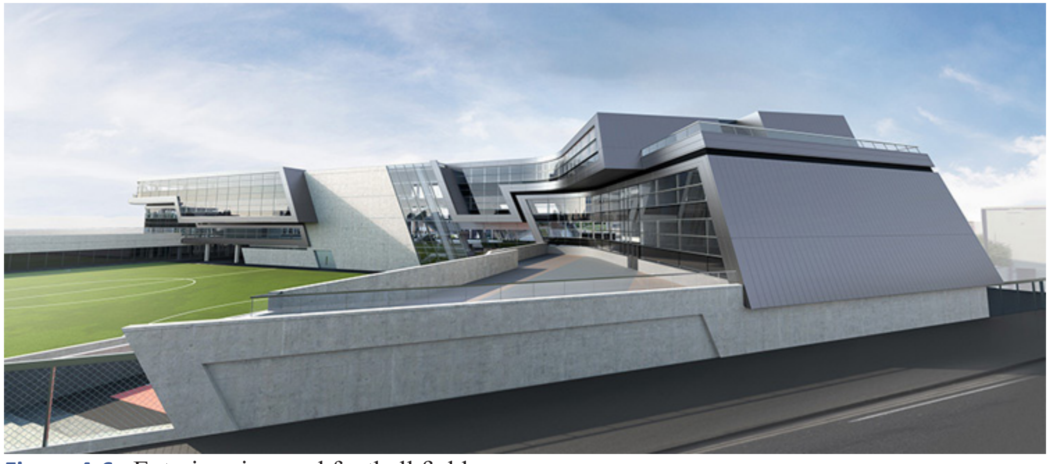


Figure 4-6. Exterior view and football field.

Teatre Del Agua

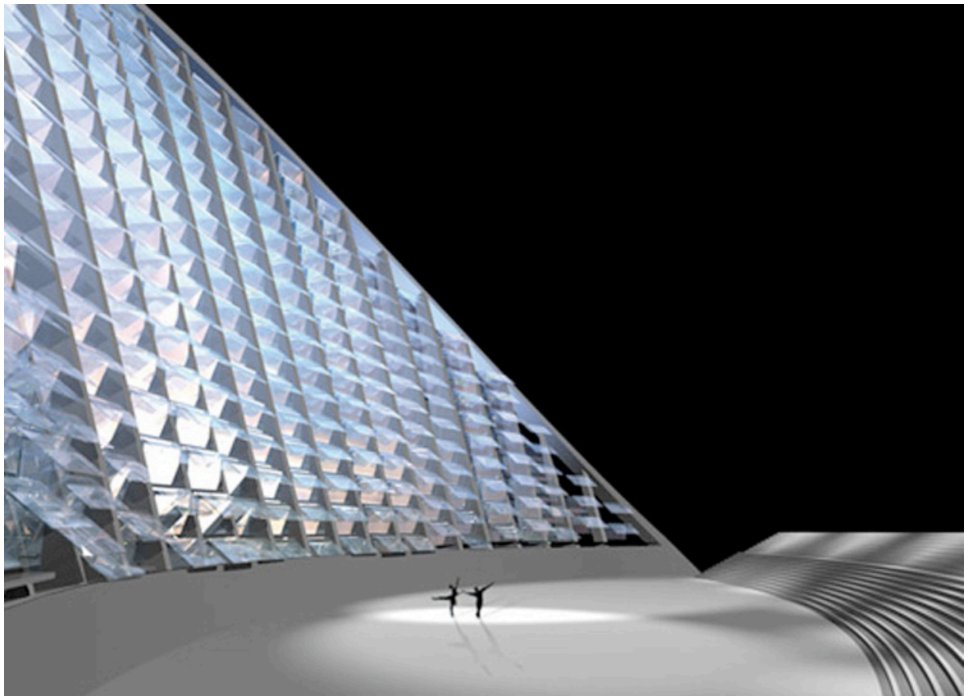


Figure 4-7. Rendering of the Teatro del Agua.

But perhaps a building that solves the social/economic and often political problem of how to address society's growing needs for fresh water is the Teatro Del Agua in Las Palmas, in the Canary Islands. This building is like the Bodegas Portia winery and the Evelyn Grace Academy in that it promotes the well-being of its occupants by questioning the status quo of design strategies, and using innovative new ways to solve not-so-new social problems. Designed to create thin air, the Teatro Del Agua takes modern desalination to another dimension. It uses natural ways similar to how the sun evaporates seawater to change it into fresh water in the shape of rain. Icy seawater is pumped through a series of cold plastic pipes. The seawater is then sprayed onto an absorbent surface, and when sun heated air passes through this surface, it forces the vapor out towards the cold pipes where it condenses back into fresh water. But, unlike the other two case studies and other desalination plants, the Teatro Del Agua needs no fuel to function. It harnesses the natural forces of sea, sun, and wind to create an unending supply of fresh water, while at the same providing a spectacular open-air theater for both the performers and the audience.

In conclusion, an architectural lesson to be learned from these three case studies is to never settle for the status quo. It is very important to always push boundaries during the design process, so that through innovative methods, our built environment can address social problems better, while leaving a smaller foot print on its site and nature.

BODEGAS PORTIA WINERY

FOSTER & PARTERS

Figure 4-8. Birds-eye view of the Bodegas Portia winery.

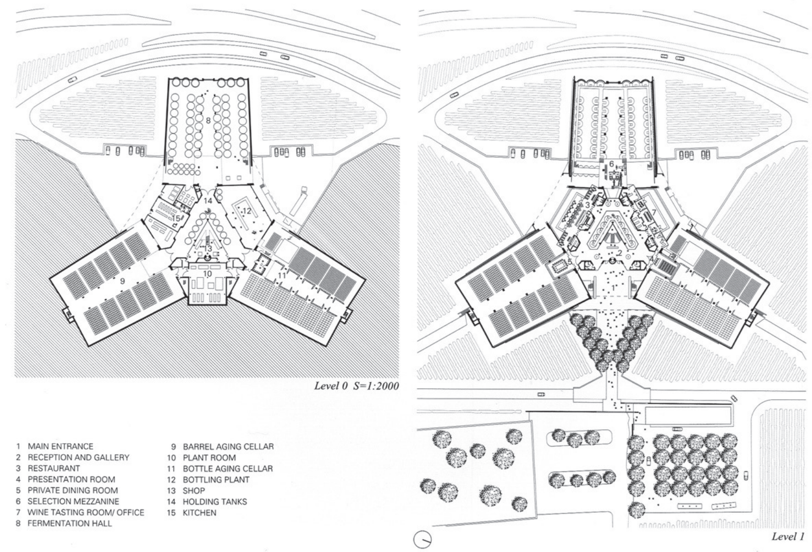


Figure 4-9. Plan.

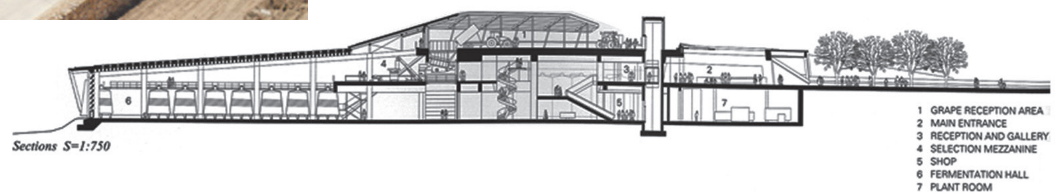


Figure 4-10. Section.

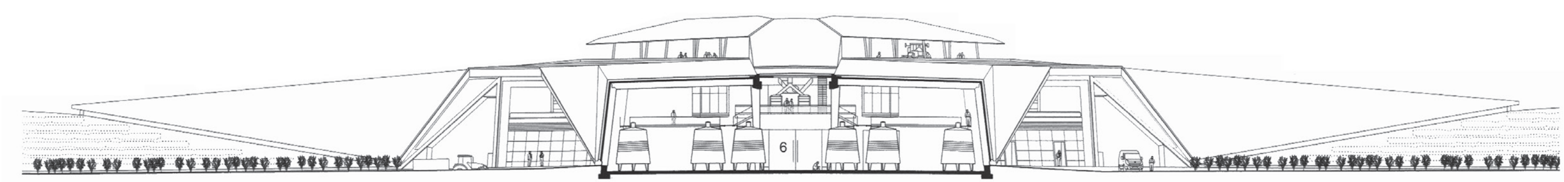


Figure 4-11. Elevation.

BODEGAS PORTIA WINERY

FOSTER & PARTERS

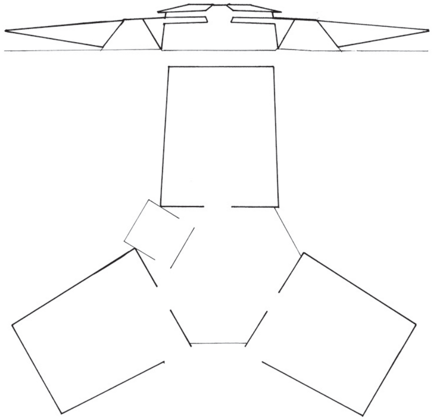


Figure 4-14. Plan to section.

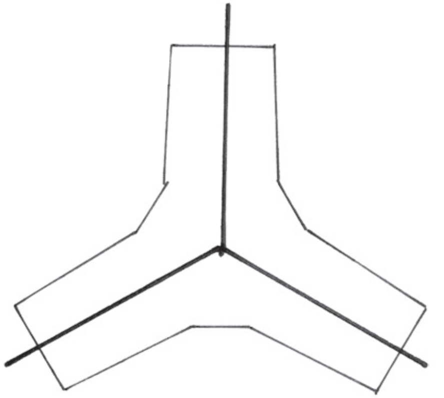


Figure 4-15. Geometry.

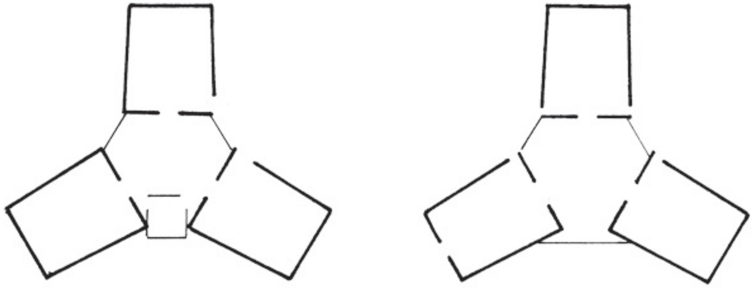


Figure 4-12. Structure.

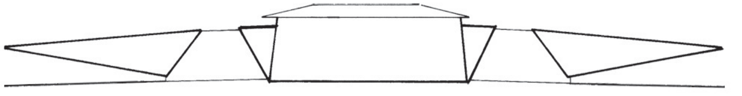


Figure 4-16. Massing.

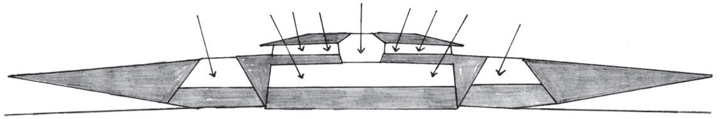


Figure 4-17. Natural light.

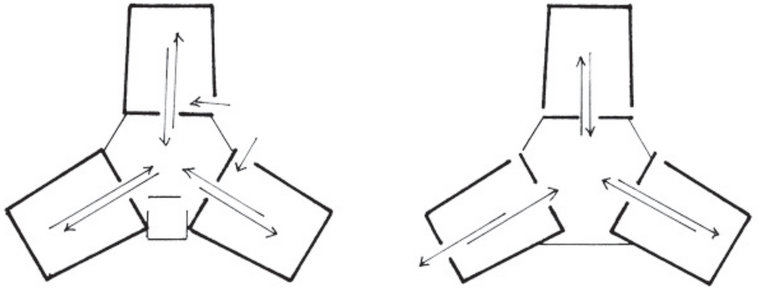
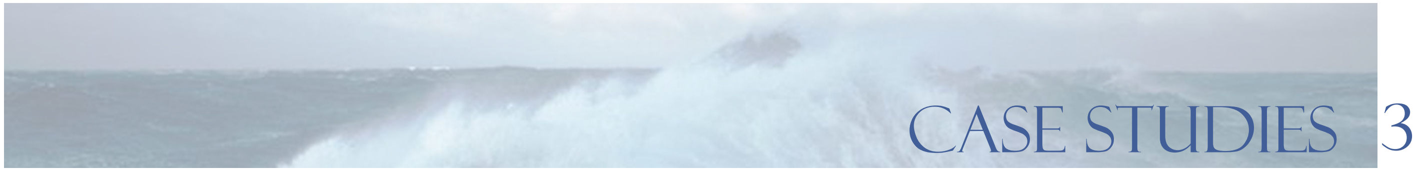


Figure 4-13. Circulation.

Figure 4-18. Hierarchy.



EVELYN GRACE ACADEMY

ZAHA HADID ARCHITECTS

Figure 4-19. Exterior view of the Evelyn Grace Academy.

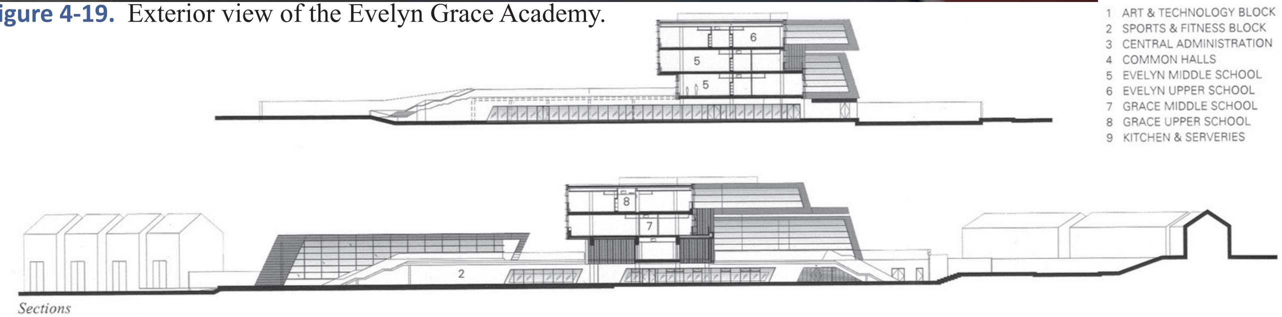


Figure 4-20. section

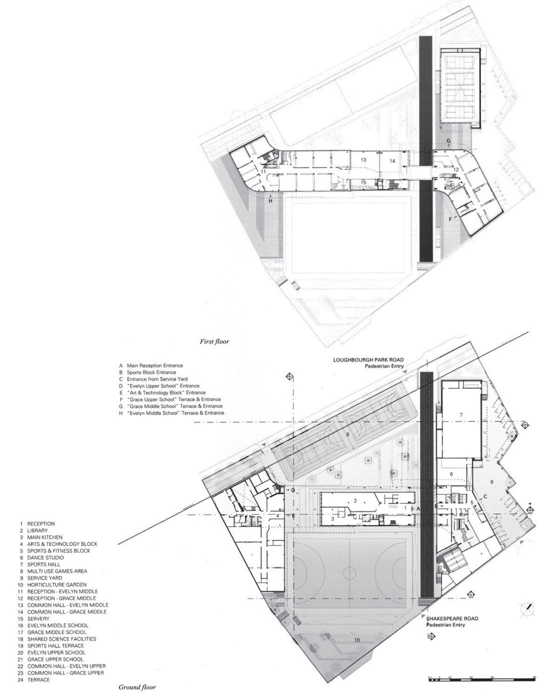


Figure 4-21. plan

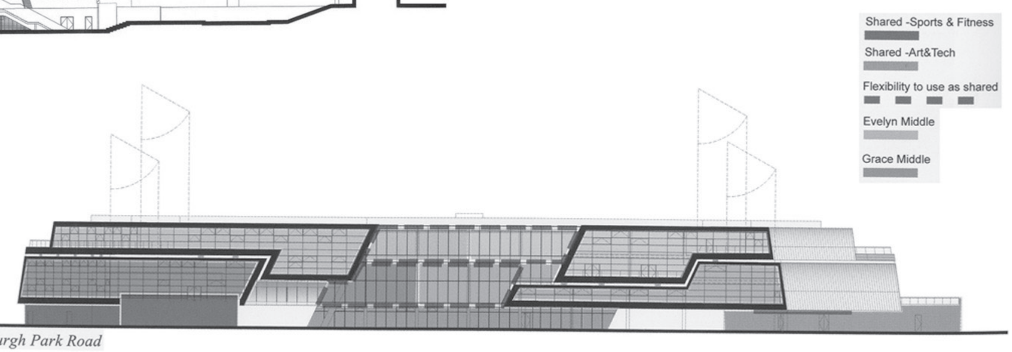


Figure 4-22. elevation

EVELYN GRACE ACADEMY
ZAHA HADID ARCHITECTS

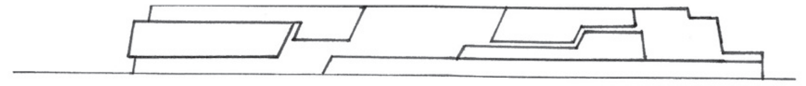


Figure 4-24. Massing.

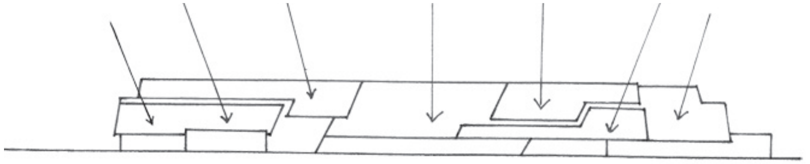


Figure 4-25. Natural light.

Figure 4-26. Hierarchy.

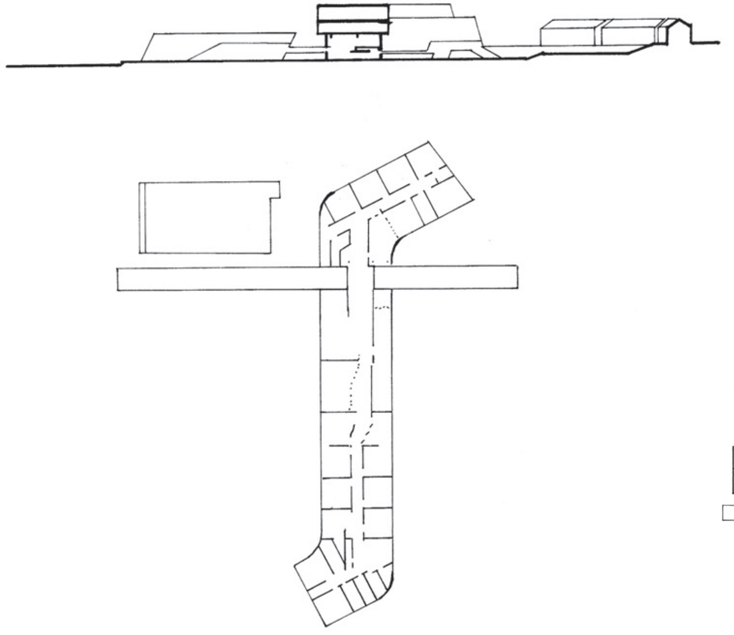


Figure 4-23. Plan to section.

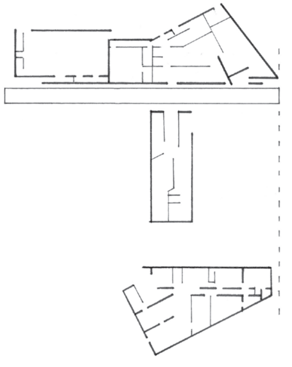


Figure 4-27. Structure.

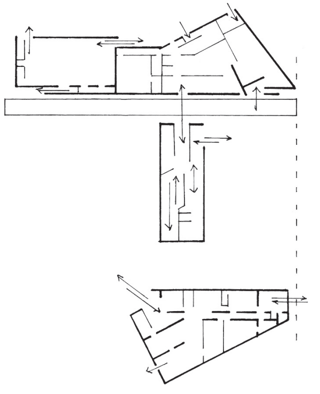


Figure 4-28. Circulation.

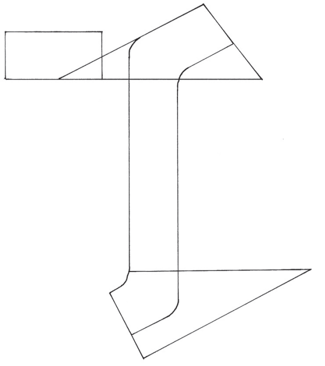
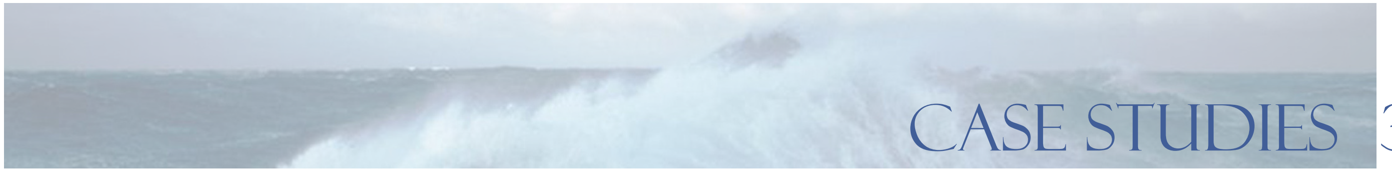


Figure 4-29. Geometry.



TEATRO DEL AGUA

GRIMSHAW ARCHITECTS

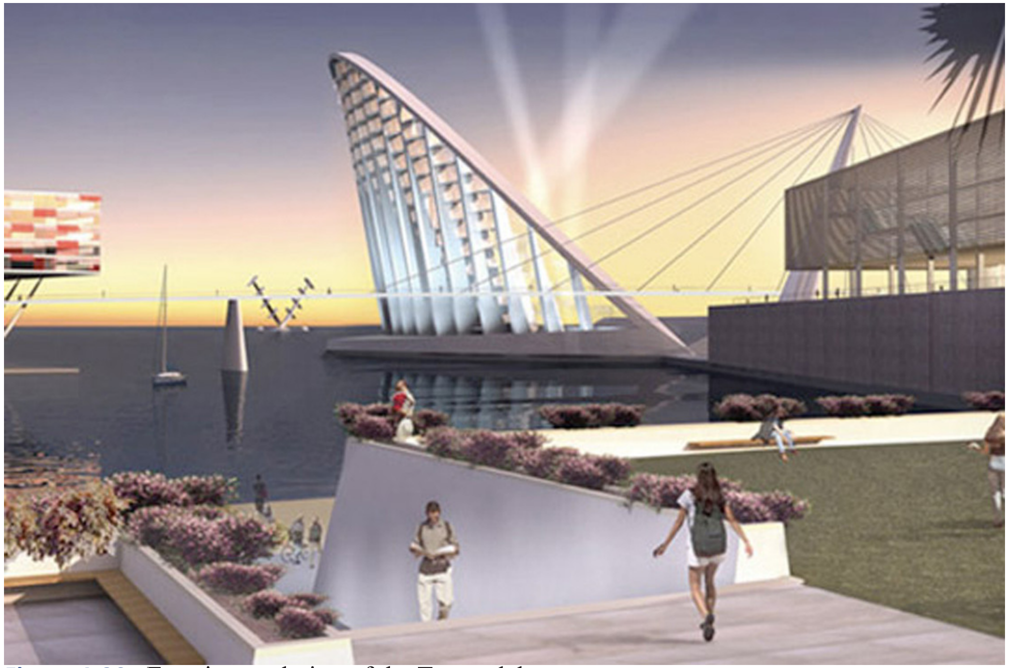


Figure 4-30. Exterior rendering of the Teatro del agua.

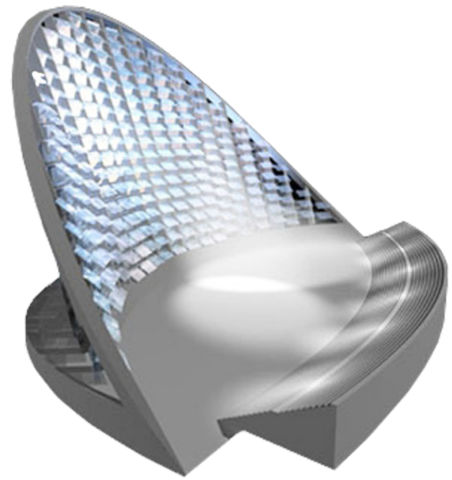


Figure 4-32. Perspective.

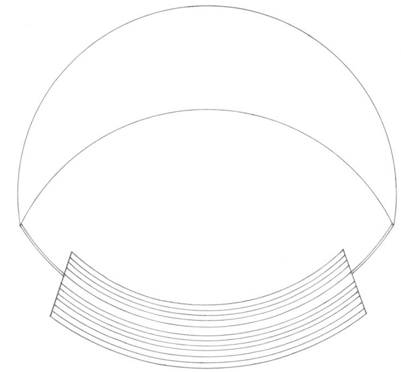


Figure 4-33. Plan.

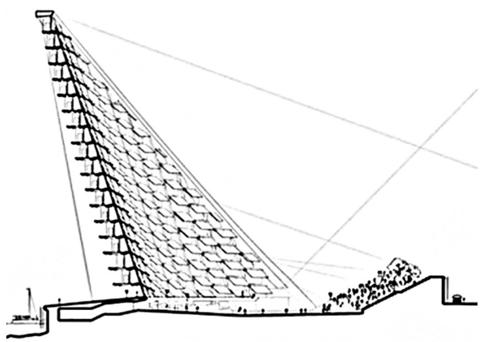


Figure 4-31. Section.

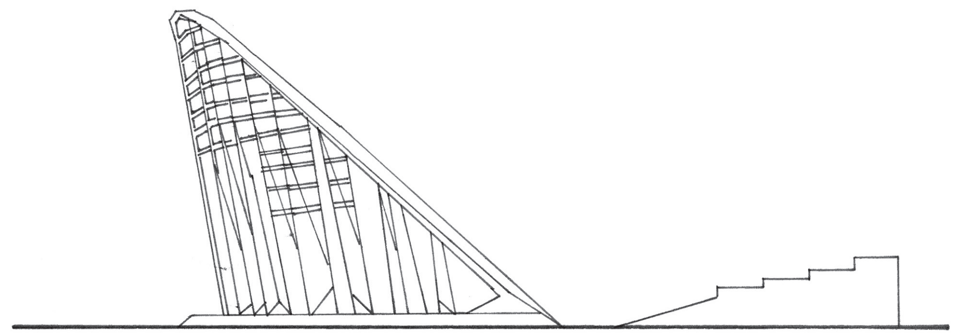


Figure 4-34. Elevation.

TEATRO DEL AGUA

GRIMSHAW ARCHITECTS

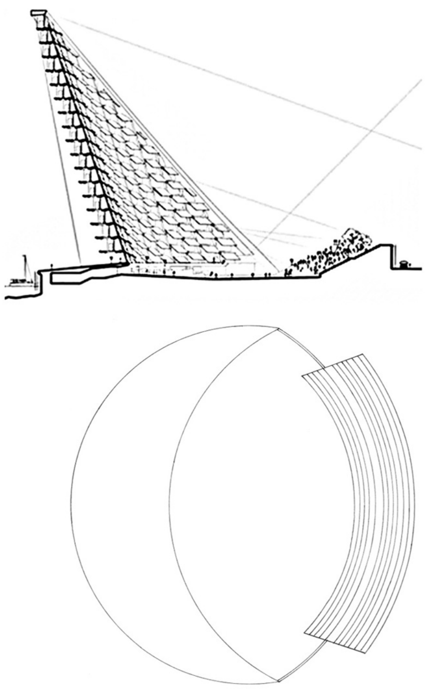


Figure 4-35. Plan to section.

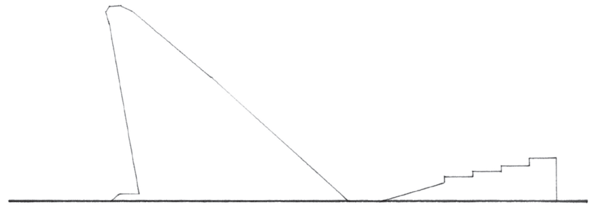


Figure 4-36. Massing.

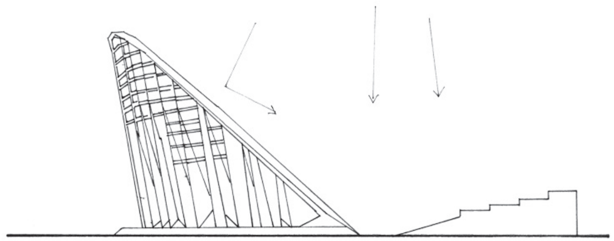


Figure 4-37. Natural light.

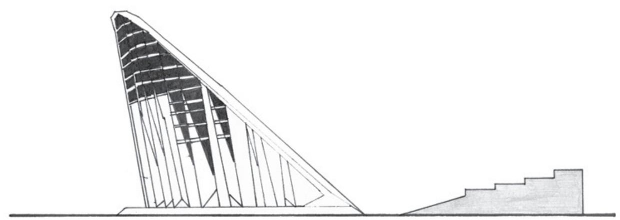


Figure 4-38. Hierarchy.

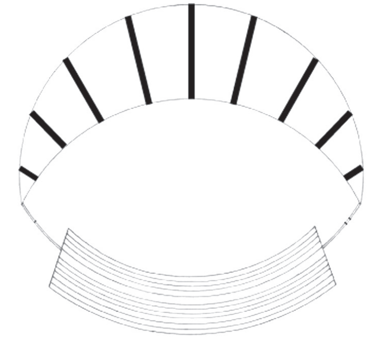


Figure 4-39. Structure.

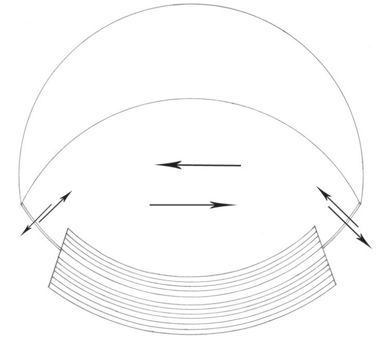


Figure 4-40. Circulation.

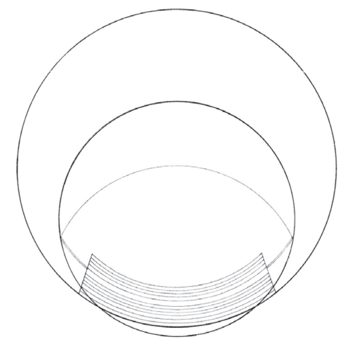


Figure 4-41. Geometry.

Throughout the history of the western civilization, architecture has taken many shapes. It has often been a reflection of events well outside the profession itself. Religion, natural events, politics, conflicts, economic power, and other social events have left a huge impact our built environment. From the medieval times of 200AD and the Gothic era of 1200AD to the Renaissance period of 1450, the architectural styles tell a vivid story about their time and place. It is well known that no century in the history of western civilization has seen more change than the 20th century, and the architectural movements of that time period are proof of that. The 20th century was a time of major scientific breakthroughs, remarkable social reforms, and great technological advancements. Music, art, and architecture saw dramatic changes and astonishing diversity during the 20th century. From 1901 to the present, architectural movements went as following: Art Moderne, Bauhaus, Deconstructivism, Formalism, Modernism, Structuralism, and Postmodernism. Contemporary architectural styles are characterized by changes that are happening at an even faster rate in the 21st century than in the 20th. The current dominant movement of Postmodern Architecture began as an international style in the 1970s. It is a style said to be heralded by the return of the "wit, ornament, and reference" to architecture.

However, 21st century technology and sustainability have arguably been the top two leading influences on contemporary architecture. 21st technology has helped a great deal in introducing new "smart" materials and techniques never before seen in the world of architecture. Defined as highly engineered materials that respond intelligently to their environment, smart materials have become the go-to answer for the 21st century's technological needs. Computer technology has also played a major role in architecture, especially in the last two decades. In the book *Smart Materials and New Technologies*, Michelle Addington and Daniel Schodek state, "Through advancements in Computer Aided Design and Computer Aided Manufacturing CAD/CAM technologies, engineering materials such as aluminum and titanium can now be efficiently and easily employed as building skins, allowing an unprecedented range of building facades and forms. Materials have progressively emerged as providing the most immediately visible and thus most appropriable manifestation of a building's representation, both interior and exterior. As a result, today's architects often think of materials as part of a design palette from which materials can be chosen and applied as compositional and visual surfaces." Today's architecture can learn a lesson from what other fields have already accomplished. In the energy sector for example, at a time when crude oil prices are sky rocketing, individuals, businesses, and governments have begun looking for new ways to produce energy. It is in times like these that people start to have a sense of how scarce some resources really are.

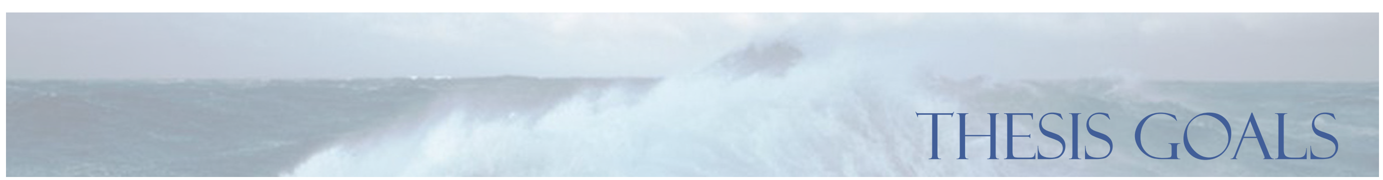
In the United States for instance, dependency on foreign fossil fuel oil has been proven to be very costly. The choice was to either continue paying the high price or innovatively find cheaper and more environmental friendly alternatives. In times like these, necessity often leads to invention. Fossil fuels will not last forever and alternative fuels led by bio-fuels, wind, solar, and other renewable energies have painted a picture of what the future will most likely hold. One great example of a positive outcome out of something destructive is in Algae Bio-fuel. Algae are a large and diverse group of autotrophic organisms that can grow up to 215 feet. They are different from most land plants because their tissues are not organized into many distinct organs. In the past, seaweed algae have been feared because of how fast they can invade bodies of water. They can threaten recreational and farming waters. But despite all the negative aspects, there are benefits associated with algae. Algae are used in applications, such as pollution control in sewage systems, fertilizer production, food production, and more recently as a source of energy. Fuel collected from algae is helping reduce the U.S. dependency on costly foreign oil, and it is helping reduce pollution caused by fossil fuel emissions.
Innovative technologies and sustainable measures can help pave the way for desalination as a source of fresh water in our communities. It is a technique that has been around for many centuries but as an industry, large-scale desalination has only been around since 1960s and mainly practiced in oil-rich middle-eastern countries, where freshwater needs outweigh energy costs.

Today, due to an unprecedented global population growth followed by rising freshwater demands and dropping costs of reverse osmosis filters, large-scale desalination is on rise. Many coastal municipalities with freshwater shortages and rising traditional water purification or groundwater tapping costs are slowly finding an alternative in desalinated seawater. But the disposal of waste brine produced by desalination can be harmful to the environment. Traditionally, desalination plants dump the highly salty waste brine back into the ocean. This is a type of pollution threatening marine life. This thesis project proposes an innovative and sustainable disposal of brine. It proposes collecting salt out of brine and using it architecturally to prevent it from being dumped back into the ocean. The goal is to build a desalination plant on Lake Mead to address the Southern Nevada water shortages, and a research laboratory dedicated on studying the qualities of salt that can be used in architectural applications to prevent pollution.

Academically, the goals of thesis project are to help me acquire and improve my research, writing, graphic, and verbal presentation skills. As a college student, this thesis will help me demonstrate a higher level of writing skills, as it is essential in the professional world, and as it is often the key to great communication. For example, a nicely written resume can be the difference maker in who gets a job and who does not. A nicely put together proposal can be the difference maker in who wins the bid and who does not. Research skills, especially in the architecture profession are a must. Different projects present different technical aspects, specifications, codes, and design challenges. Public safety, ADA requirements, and state and federal laws are all topics that must be addressed during the design process. The amount and quality of research invested in a project can often predict the outcome of the project. And, last but not least, a great project is completed with great graphic and verbal presentation skills.

Professionally, my goals are to show, how with great design, and sustainable disposal of brine, desalination can be a source for water for Las Vegas and surrounding areas. My goals are to promote sustainable design, energy conservation, and innovation in architecture. Salt collected from brine can help reduce the cost of desalination and pollution at the same time. It might not have the properties and characteristics of concrete, but it has been used structurally and architecturally in different parts of the world, and it can find a place in contemporary architecture in applications, such as light structure and non load-bearing wall. A desalination plant can prevent the state of Nevada from engaging in expensive and environment threatening groundwater tapping.

My personal goal in this thesis project is to raise awareness of what is happening to places such as Lake Mead and Las Vegas. It is to introduce new ways of thinking and new materials to address problems threatening our planet and our very existence on it. With the global population projected to grow 50% in the next 50 years, our planet is on the brink of a water crisis. This is why many nations are already turning to desalination for their growing freshwater needs. In a sustainable way, desalination and structural salt can pave the way to a better tomorrow.



The site of the Lake Mead Desalination Plant is located on the peninsula that holds the Hoover Dam on the Lake Mead about 30 miles east of the Las Vegas city center. More precisely, it is about a quarter mile west of Lake Mead Cruises boating company, and about half a mile west of the Hoover Dam. The main access to the site is from the Hoover Dam Access Road by car or bus, but pedestrians have the advantage of the Historic Railroad hiking trails on the south side of the site, which offer an amazing view of the site and the lake. There is a 25-foot drop in elevation from the south side of the site to the lake shore. Lake Mead is on the north side of the site. The north side also offers breathtaking view of the Boulder basin and its two islands. Two recreational companies on the west of the site have taken the views. The Lake Mead Resort & Marina and the Lake Mead Cruises share the flattest areas of this stretch of land and have access to the lake via the Hemenway Harbor. The two companies have enough space for 200 boats on the lake. Other than the flat stretch of land occupied by the recreational facilities, the rest of site slops from 19 to 25 feet south to north, offering a wonderful natural shade from the ever shining desert sun. The average monthly temperatures range from highs of about104 F to lows of about 19 F, meaning it can get very hot during daytime hours, but then temperatures can drop dramatically during the night.

Figure 5-1. Photograph of site facing north.

Figure 5-2. Photograph of site facing east.

Figure 5-3. Photograph of site facing west.


Figure 5-4. Desert lizard.

In state of Nevada, the prevailing winds are from the west. As the warm moist air from the Pacific Ocean ascends the western slopes of the Sierra Range Mountains, the air cools, condensation takes place and most of the moisture falls as precipitation. As the air descends the eastern slope, it is warmed by compression, and very little precipitation occurs. The effects of this mountain barrier are felt not only in the west but throughout the State, with the result that the lowlands of Nevada are largely desert or steppes.
Light cream sand, large pieces of dark maroon granite, and silt gravel river rock cover the vast majority of the land. The little vegetation present on the site is made up of desert plants, such as the mesquite, salt cedar, saltbush, and cattail. It is highly unusual, but Mojave desert animals like the bighorn sheep, mule deer, coyotes, kit foxes, bobcats, ringtail cats, desert tortoise, lizards, snakes, and numerous species of desert birds, like falcons, have been spotted in area surrounding the site. Many of these animals depend a great deal on the presence of Lake Mead for their survival in the desert.

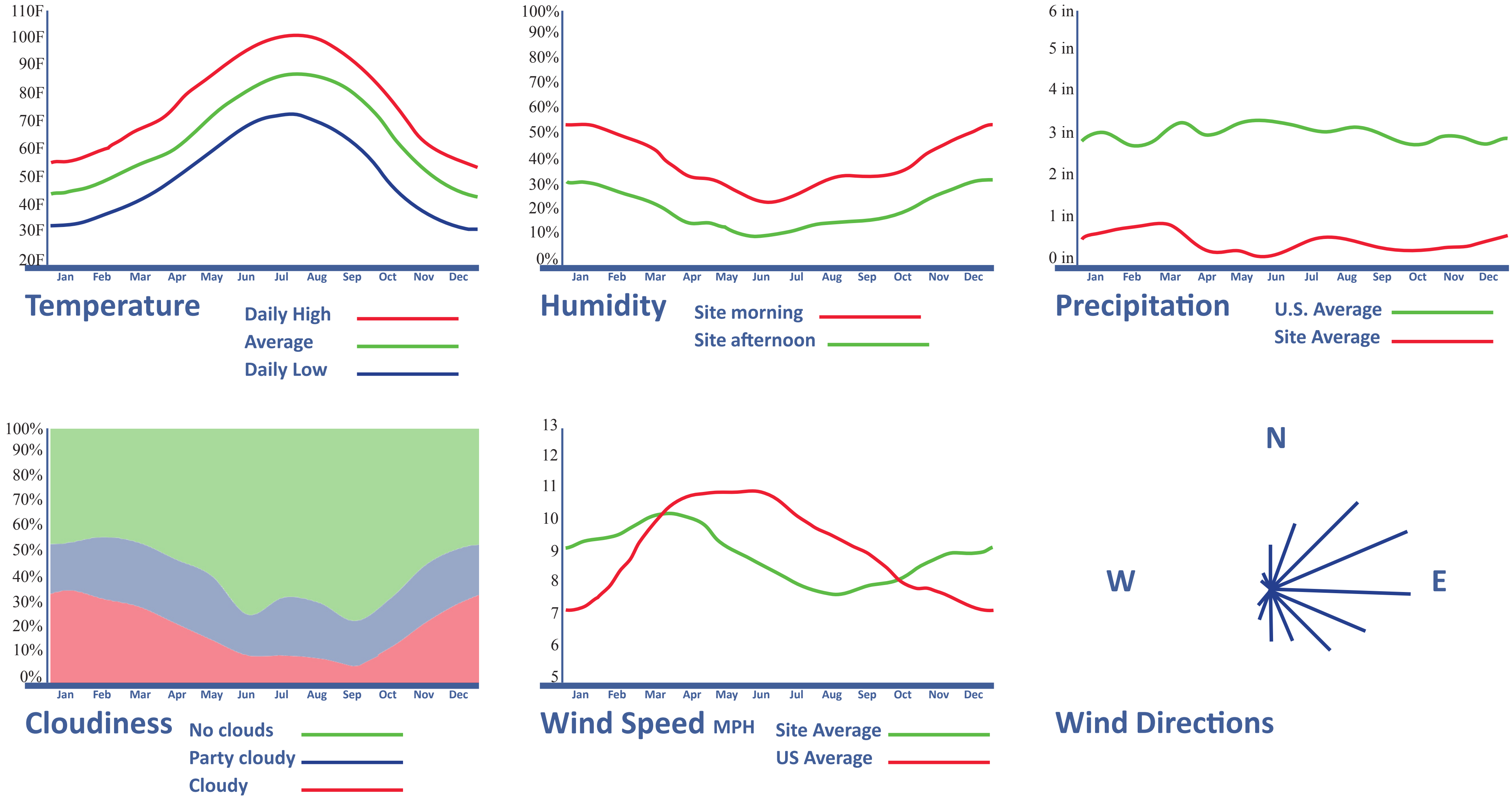
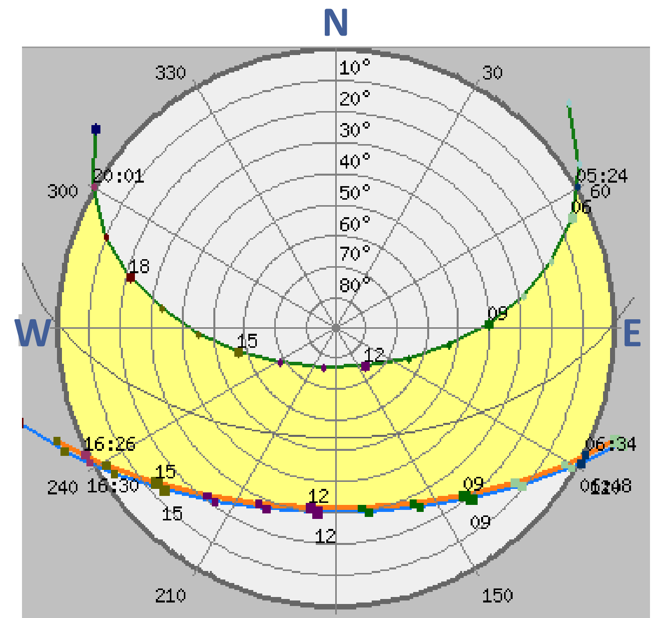


Figure 6-1. Climate data graphs.

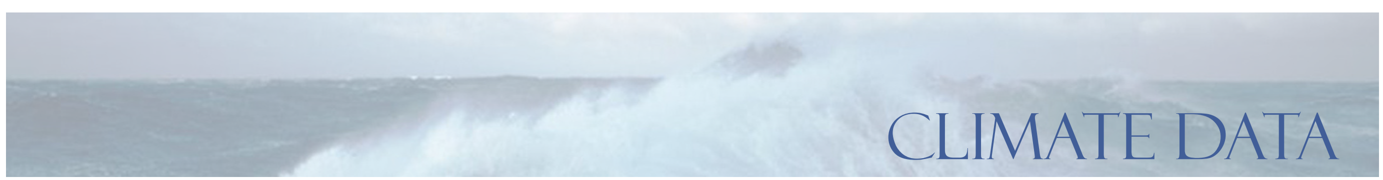
Figure 6-2. Site analysis.

Shading
Air movement
Noise



(Figure 6-3. Sun path.

Sun Path



	Public entrance	Reception and lobby	Public restrooms	Gallery space	Lounge	Viewing terrace	Main-floor offices	Storage room	Research labs	Employee entrance	Desalination area	Control room	Lower-floor offices	Break room	Mechanical room	Employee restrooms	Parking lot cars/buses	Walking paths	Salt storage
Public entrance		Essential	Desirable	Desirable	Desirable	Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Essential	Desirable	Not Needed
Reception and lobby	Essential		Essential	Essential	Essential	Desirable	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed
Public restrooms	Desirable	Essential		Essential	Desirable	Not Needed	Desirable	Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed
Gallery space	Desirable	Essential	Essential		Desirable	Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed
Lounge	Desirable	Essential	Desirable	Desirable		Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed
Viewing terrace	Not Needed	Desirable	Not Needed	Not Needed	Not Needed		Not Needed	Not Needed	Desirable	Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Desirable	Desirable
Main-floor offices	Desirable	Essential	Desirable	Desirable	Desirable	Not Needed		Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Desirable	Not Needed	Not Needed	Not Needed
Storage room	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable		Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Essential	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed
Research labs	Not Needed	Not Needed	Desirable	Not Needed	Not Needed	Desirable	Not Needed	Not Needed		Essential	Not Needed	Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Essential
Employee entrance	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Essential		Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Essential	Desirable	Not Needed
Desalination area	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Not Needed		Essential	Essential	Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Essential
Control room	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Not Needed	Essential		Essential	Not Needed	Desirable	Desirable	Not Needed	Not Needed	Not Needed
Lower-floor offices	Not Needed	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Essential	Essential		Desirable	Not Needed	Desirable	Essential	Not Needed	Not Needed
Break room	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Essential	Essential	Not Needed	Not Needed	Not Needed	Not Needed	Desirable		Not Needed	Desirable	Not Needed	Not Needed	Not Needed
Mechanical room	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Desirable	Not Needed	Not Needed		Not Needed	Not Needed	Not Needed	Not Needed
Employee restrooms	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Essential	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Desirable	Desirable	Not Needed		Not Needed	Not Needed	Not Needed
Parking lot cars/buses	Essential	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Essential	Not Needed	Not Needed	Essential	Not Needed	Not Needed	Not Needed		Not Needed	Not Needed
Walking paths	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Not Needed	Desirable	Desirable	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed		Desirable
Salt storage	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	Not Needed	Not Needed	Essential	Not Needed	Essential	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Not Needed	Desirable	

Figure 7-1. Interaction matrix.

Legend

Essential

Desirable

Not Needed

INTERACTION MATRIX

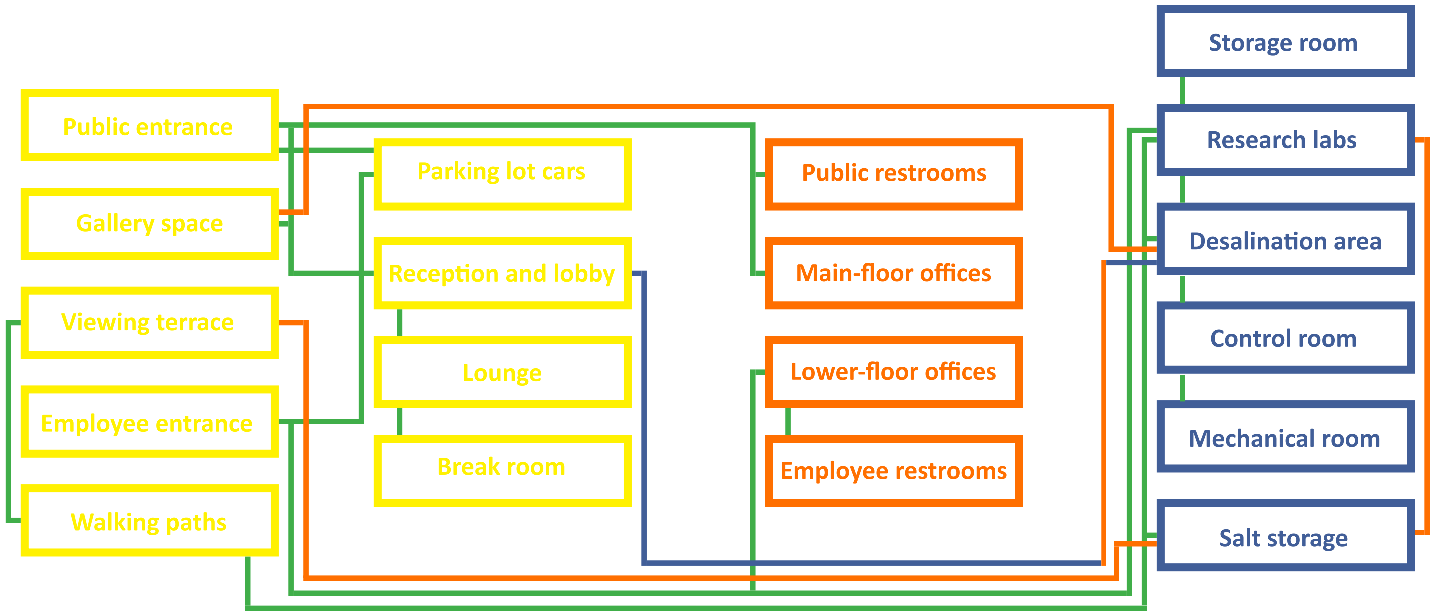


Figure 7-2. Interaction net.

Legend

Public Spaces

Private Spaces

Work Spaces

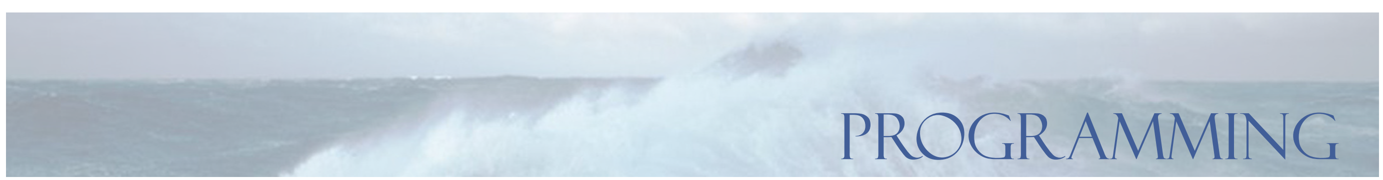
Formal Connection

Informal Connection

Casual Connection

PROGRAMMING

Reception and lobby		585 sf
Gallery space		3,000 sf
Main-floor offices	5@95 sf	475 sf
Lounge		875 sf
Conference room	2@300	600 sf
Public restrooms	2@45 sf	90 sf
Desalination area		20,000 sf
Research labs	4@915 sf	3,660 sf
Lower-floor offices	5@95 sf	475 sf
Control room		1,325 sf
Employee restrooms	4@35 sf	140 sf
Viewing terrace		1,500 sf
Break room		875 sf
Mechanical room		1,000 sf
Salt storage		10,000 sf
Storage room		100 sf
		44,700 sf



DESIGN PROCESS

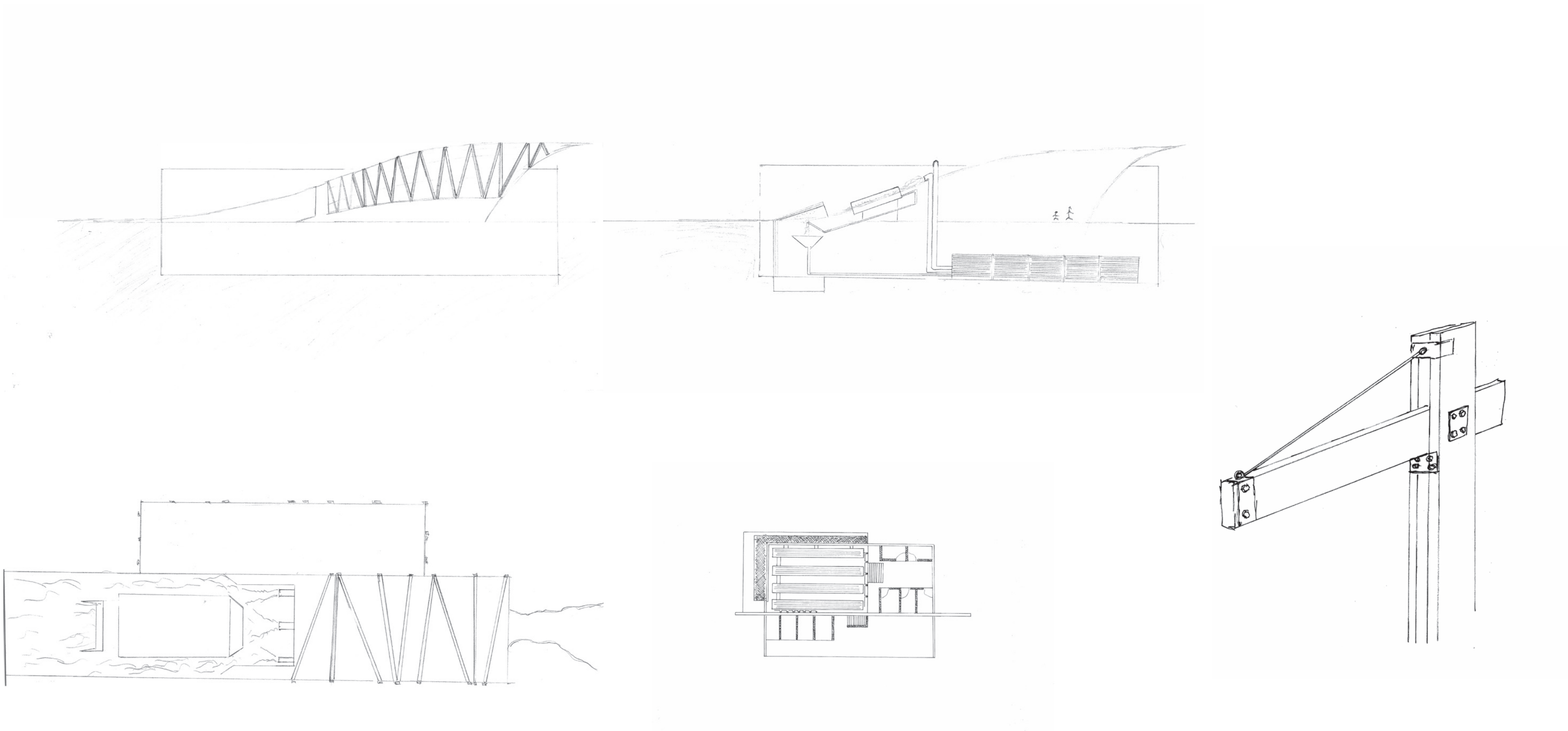
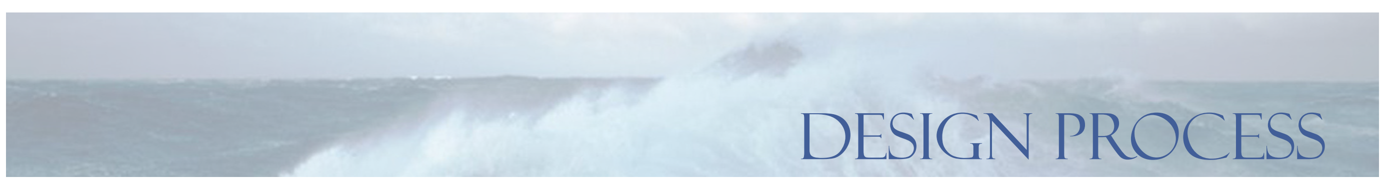


Figure 8-1. Process sketching.



FINAL DESIGN

DESALINATION & ARCHITECTURE

DESALINATION PLANT - BOULDER CITY, NEVADA

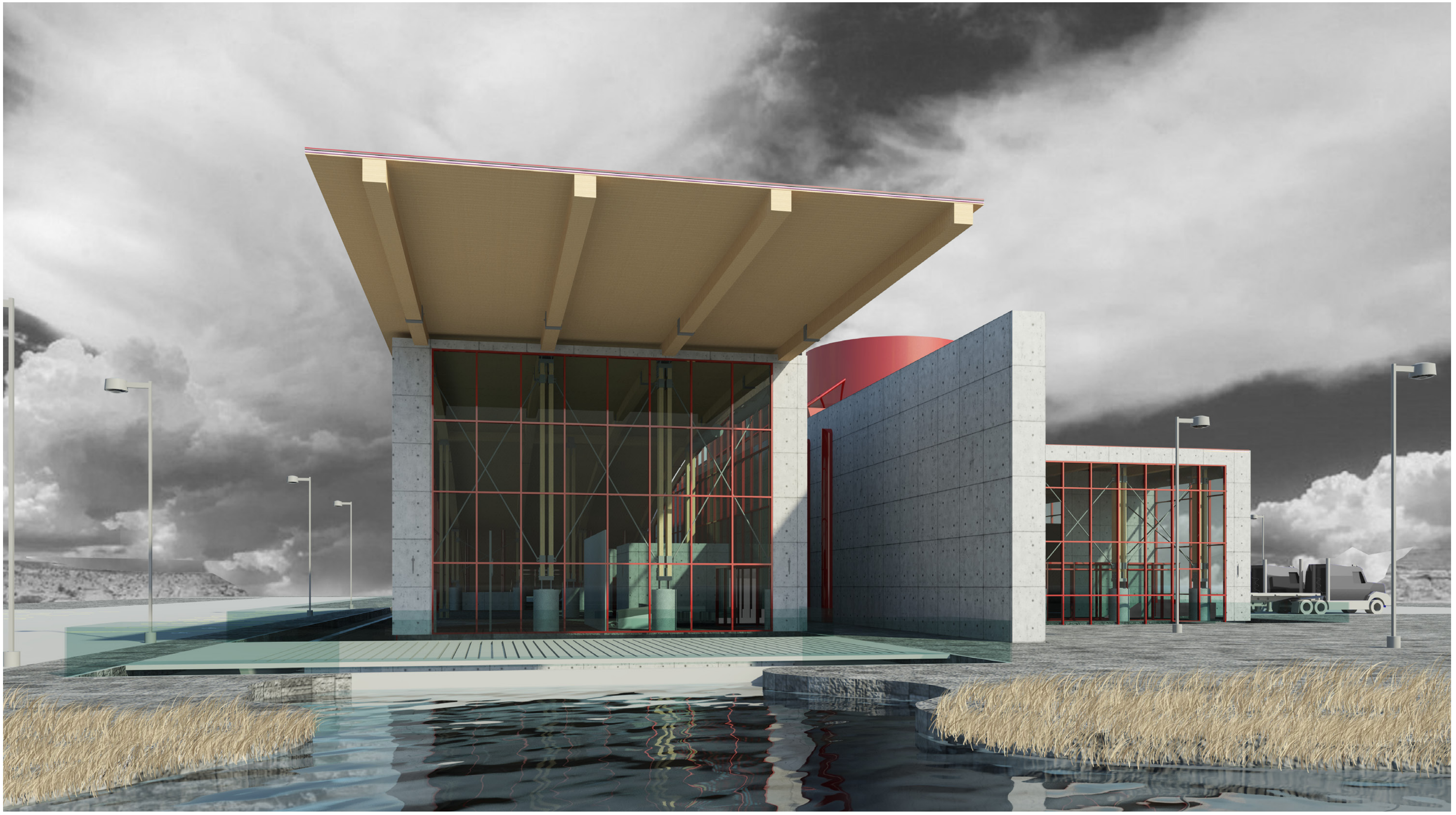


Figure 9-1. First presentation board .

FINAL DESIGN

This thesis project focuses on how a desalination plant can benefit the environment. As population grows, climate changes, and local water scarcity heighten, desalination of brackish water and seawater is increasingly considered as an option for a source of fresh water to meet anticipated demand. Desalination could also help restore water levels in places such as Lake Mead, where insufficient rain and snowfall in the Rocky Mountains have caused the lake water level to fall well below drought levels. Finding innovative ways to use the remaining salt in architectural application, such as building non-load bearing walls, could then help lower the rising salinity of seawater caused by global warming and pollution.

LAKE MEAD

Las Vegas and surrounding communities get the majority their fresh water from Lake Mead. It is the largest manmade reservoir in the US, created by Hoover Dam damming the Colorado River. More than 90 percent of its waters come from melting snow and rainfall in the Rocky Mountains of Utah, Colorado, and Wyoming. But factors such as large-scale population growth and shortfall in snow and rainfall due to ecological changes caused by global warming have led Lake Mead to lose more water than it is taking in, there depleting to near catastrophic levels. If no action is taken, Lake Mead water levels will deplete to a point where the Hoover is no longer useful, and potentially dry out by the year 2020.

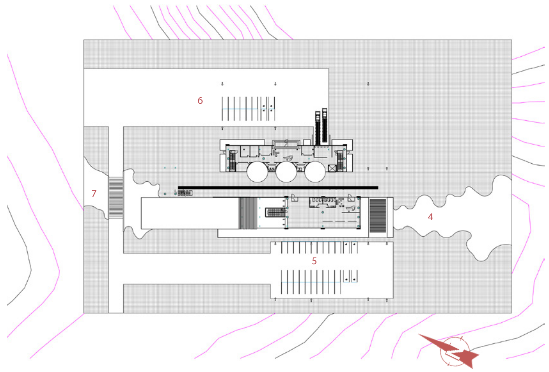
LEGEND

SITE PLAN

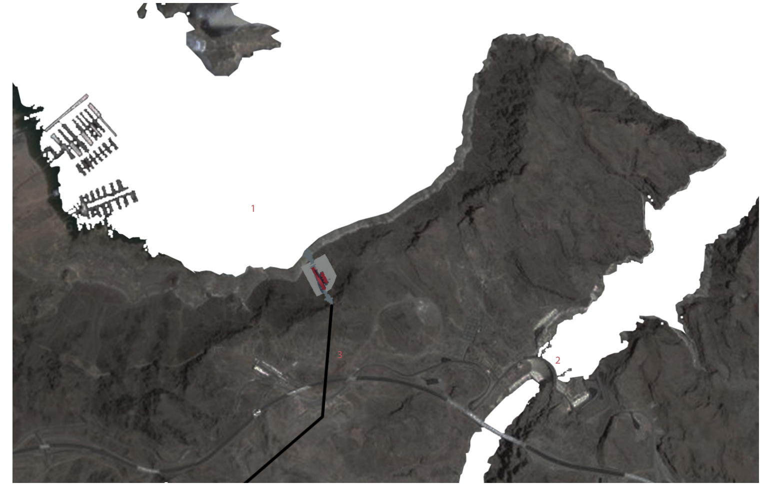
1 LAKE MEAD
2 THE HOOVER DAM
3 SEAWATER PIPE-LINE

SITE MAP

4 SEAWATER
5 VISITORS PARKING LOT
6 EMPLOYEE PARKING
7 DESALINATED FRESH WATER



SITE PLAN



SITE MAP

Figure 9-2. Second presentation board

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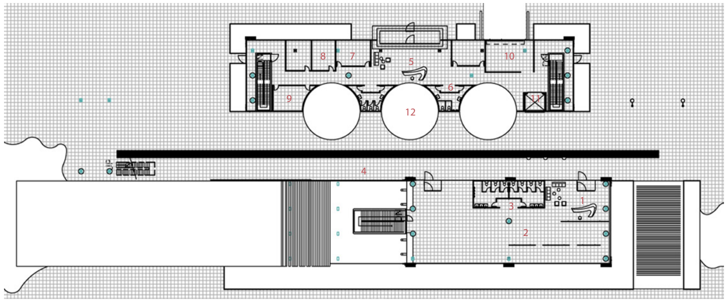
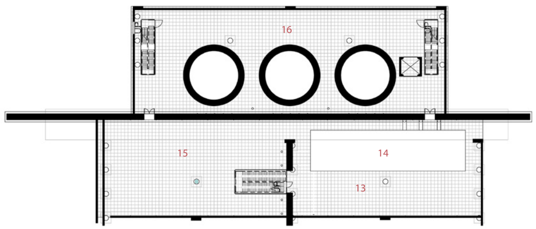


GROUND LEVEL PLAN



BASEMENT PLAN

LEGEND

GROUND LEVEL PLAN

1 PUBLIC RECEPTION
2 GALLERY SPACE
3 PUBLIC RESTROOMS
4 LONG CORRIDOR
5 EMPLOYEE RECEPTION
6 EMPLOYEE RESTROOMS
7 BREAK ROOM
8 OFFICE
9 CONFERENCE ROOM
10 SHIPPING & RECEIVING
11 FREIGHT ELEVATOR
12 WATER BOILERS

BASEMENT PLAN

13 REVERSE OSMOSIS AREA
14 REVERSE OSMOSIS FILTERS
15 CONTROL ROOM
16 RESEARCH LAB

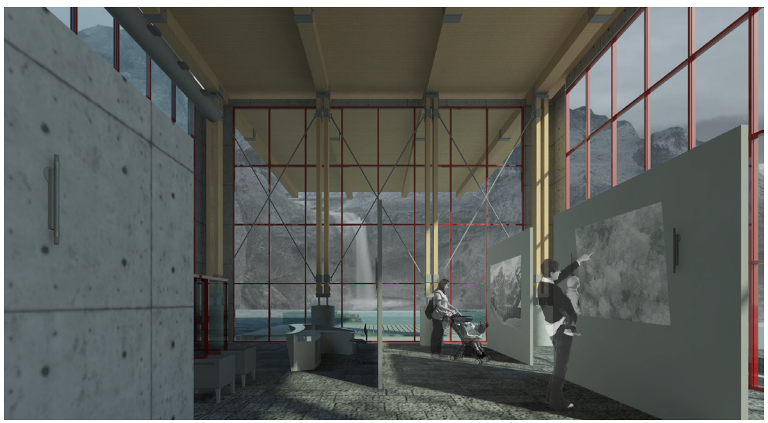
A POETIC EXPLORATION IN THE DESIGN OF A DESALINIZATION PLANT

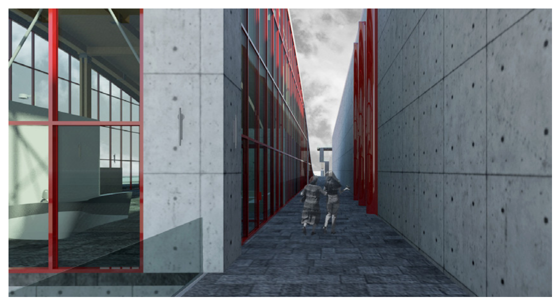
Long before the existence of Lake Mead and the Hoover Dam, the Mojave Desert was occupied by several Native American Indian cultures in a much cooler and wetter temperate climate. As early as 10,000 ago, these Indian cultures had mastered the art of hunting. Ground sloth, horses, and mountain sheep were some of the animals they hunted. These Indians also practiced early farming of corn, beans, and squash. In all of these processes, it was stone that played a major part in these cultures' daily lives. It is with a refining stone that young teenage males would sharpen wood and bone arrows, and later metal. It is also with a refining stone that women would grind corn to prepare flour tortillas. The process of refining natural resources was central to the survival of their culture.

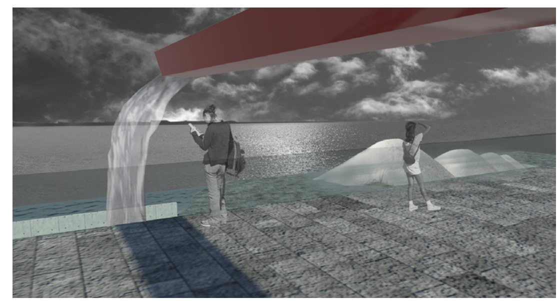
In our modern world the process of refinement is still a central concern for ongoing survival. However, today this process is based on machines which can most efficiently extract and transfer energy and resources. This is witnessed in many desalination plants. Desalination is a technique that many coastal cities have more and more turned to as a way to obtain freshwater to accommodate growing demands. The process of desalination removes salt and other minerals from seawater. Saline water is desalinated in order to produce freshwater that is suitable for human consumption and irrigation. After freshwater has been taken out of seawater, salt is the remaining product of the process.

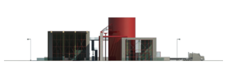
In a metaphoric and poetic way, I wanted to create artifacts that speak of both past and present forms of refinement simultaneously. I did so in order to reveal both historical precedents and a more tangible presence of the refinement process (typically concealed within modern machines). The series of artifacts I created seek to reveal resonances between the refinement of seawater in desalination, and the processes involved making stone tools. Since stone carving leaves dust and desalinization machines leave freshwater and salt at the end, the elemental nature of refinement is brought forward in the performance. Similarly, the sound of the stones connects to the machines in the desalination plant.

The challenge was then to transition from artifact creation to designing a desalination plant that that embodies the same poetic and metaphoric qualities that the artifacts have. The overall program of the plant calls for a lower level where the desalination takes place, and a main level where visiting students and the general public can learn about what is happening to Lake Mead and how a desalination plant can be beneficial. The sounds of the machines on the lower floor would give the visitors on the main floor a similar experience as that of the sounds of the refining stones. A longitudinal organization of the spaces, a long central narrow corridor, and opening views transitioning from an industrial feel to a revealing view of nature and freshwater separated from salt as visitors exit the building to access the exterior deck, tell a story of the long process of refinement much similar to the refinement of natural resources practiced by ancient Native American cultures. The obtained fresh water would then be dumped in Lake Mead to help prevent depletion, and the remaining salt would be process at a research lab and used in applications such as architecture, human consumption, lithium ion battery production and more.



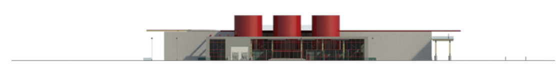




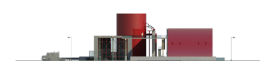


SOUTH

WEST



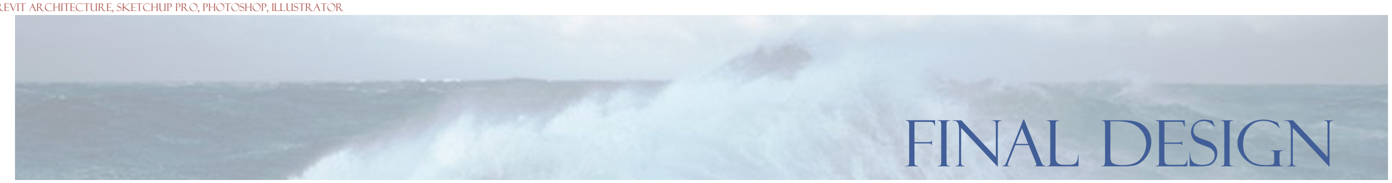
EAST

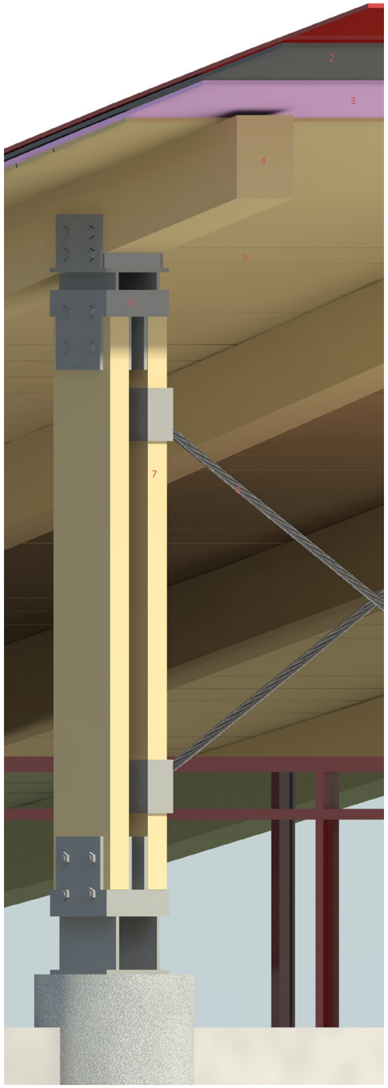


NORTH

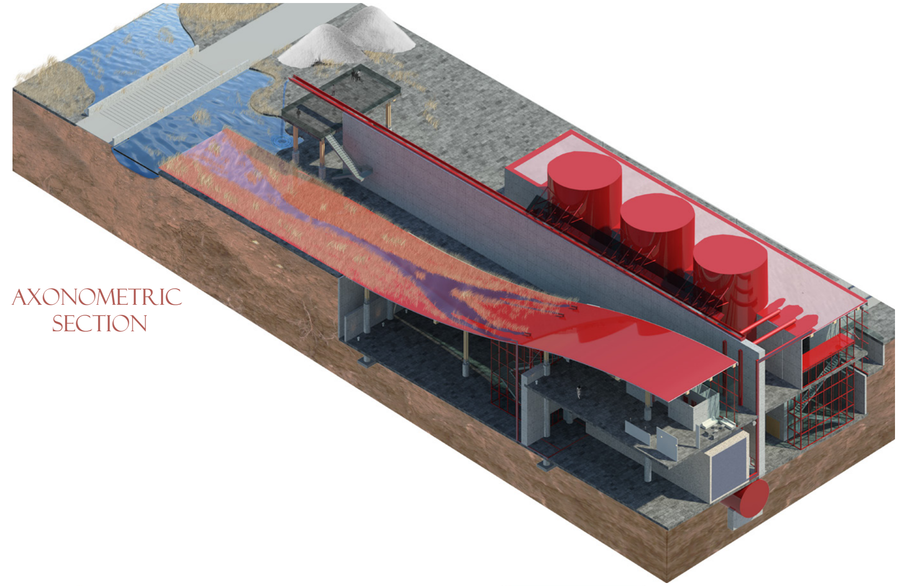
ARCH 772 DESIGN THESIS -SPRING 2012 -OLIVIER BUSAGARA -PROFESSOR REGIN SCHWAEN -REVIT ARCHITECTURE, SKETCHUP PRO, PHOTOSHOP, ILLUSTRATOR

Figure 9-3. Third presentation board .



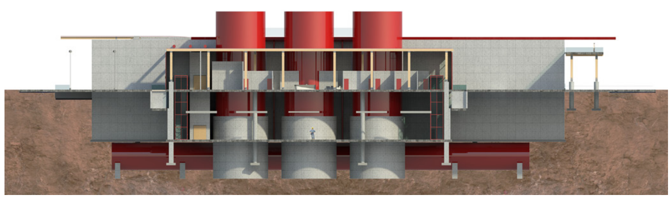


1 METAL ROOF
2 VAPOR BARRIER
3 INSULATION
4 GLULAM BEAM
5 GLULAM PLANK
6 CONNECTOR
7 COLUMN
8 STEEL CABLE



AXONOMETRIC SECTION

This facility will use two methods of desalination to produce freshwater. It will refine seawater supplied via a pipeline from the Californian coast. The first method is called Solar Thermal desalination. Using solar energy to power the process, seawater is boiled. The seawater releases a vapor that is then cooled and collected as freshwater. The second method is called Reverse Osmosis desalination. Pressure is applied to seawater, forcing water molecules through a semi-permeable membrane, leaving salt and other molecules behind.



EAST SECTION

SOUTH SECTION

Figure 9-4. Fourth presentation board.

Figure 9-5. Final model pictures.

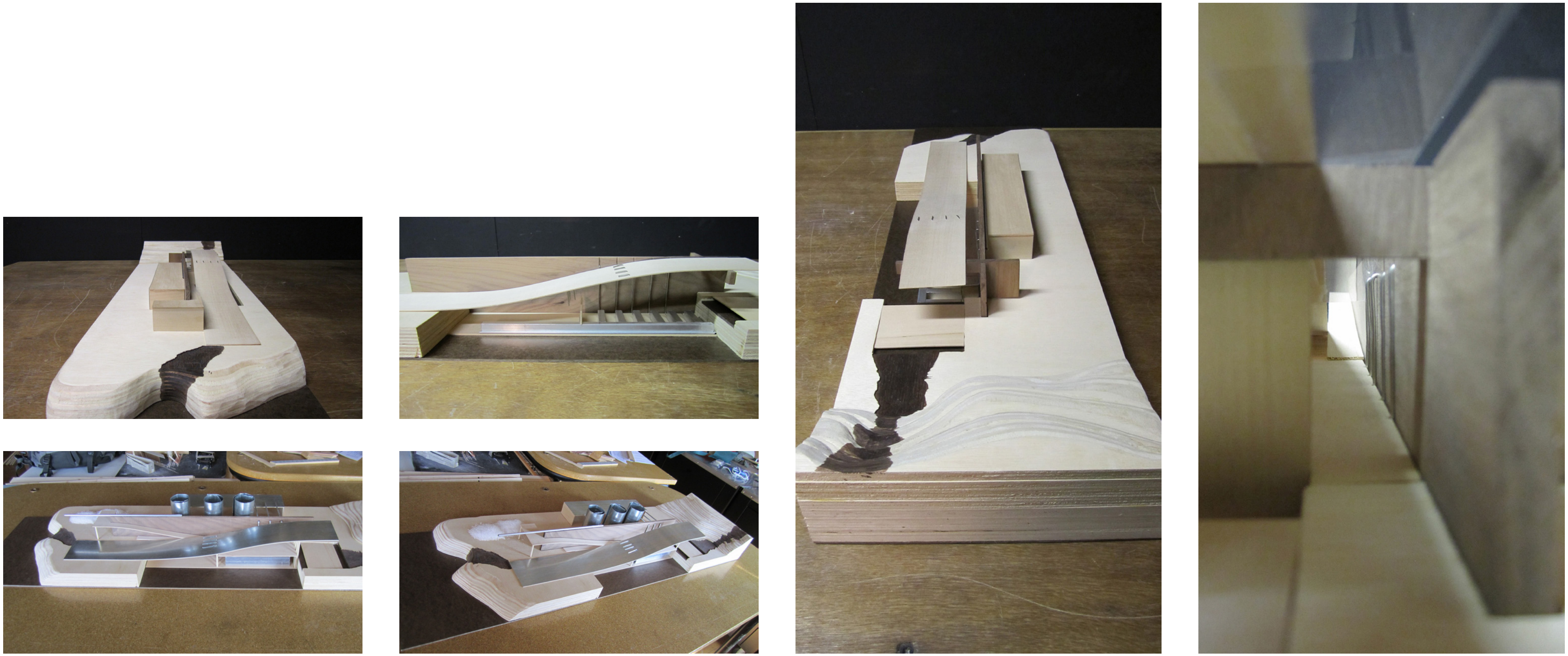


Figure 9-6. Final model pictures.

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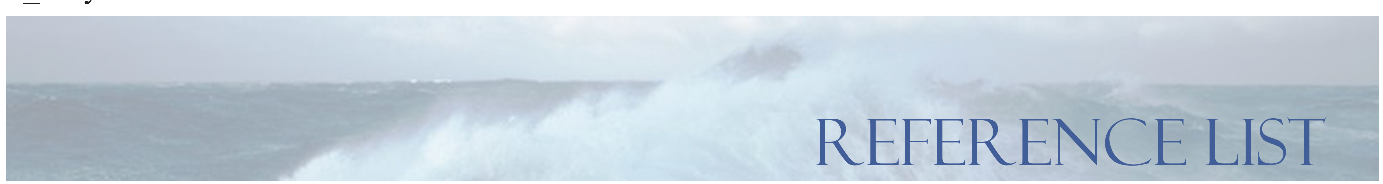

Image Credits

Figure 1-1: “Regional map”. Author’s Illustration

Figure 1-2: “Map of Lake Mead”. Author’s Illustration

Figure 2-1: “Shedule”. Author’s Illustration

Figure 3-1: “Painting of ancient sailors”. Retrieved October 7, 2011, from http://www.zmescience.com/science/archaeology/

Figure 3-2: “Diagram of the reverse osmosis desalination process”. Author’s Illustration

Figure 3-3: “Reverse osmosis filters at the Tampa Bay desalination plant”. Retrieved October 7, 2011, from http://americancityandcounty.com/weeklysnapshot/tampa-desal-02012008

Figure 3-4: “The Colorado River in the Mojave Desert”. Retrieved October 8, 2011, form http://www.zastavki.com/eng/World/USA/wallpaper-8907-2.htm

Figure 3-5: “Lake Mead in Nevada”. Author’s photograph

Figure 3-6: “The Garden of Eden seawater greenhouse”. Retrieved November 11, 2011, from http://science.howstuffworks.com/environmental/conservation/conservationists/eden2.htm

Figure 3-7: “Brine Pollution”. Author’s photograph

Figure 3-8: “Palacio del sal Hotel”. Retrieved November 18, 2011, from http://www.element-london.com/element-ideas/eco-friendly/more-than-a-pinch/

Figure 4-6: “Exterior view and football field”. Retrieved October 8, 2011, from http://openbuildings.com/buildings/evelyn-grace-academy-profile-754

Figure 4-1: “Roof access”. Retrieved October 8, 2011, from http://www10.aeccafe.com/blogs/arch-showcase/2011/03/11/faustino-winery-in-ribera-del-duero-spain-by-foster-partners/

Figure 4-2: “Exterior of the fermentation room”. Retrieved October 8, 2011, from http://www.worldbuildingsdirectory.com/project.cfm?id=3268

Figure 4-3: “Interior of the fermentation room”. Retrieved October 8, 2011, from http://www.wired.co.uk/magazine/archive/2011/02/start/a-very-wired-winery

Figure 4-4: “The gymnasium”. Retrieved October 8, 2011, from http://www.viewpictures.co.uk/Details.aspx?ID=148715&TypeID=1

Figure 4-5: “Open court-yard”. Retrieved October 8, 2011, from http://www.viewpictures.co.uk/Details.aspx?ID=148715&TypeID=1

Figure 4-7: “Rendering of the Teatro del agua”. Retrieved October 10, 2011, from http://www.futureearth.com.au/

Figure 4-8: “Birds-eye view of the Bodegas Portia winery”. Retrieved October 8, 2011, from http://www.arup.com/News/2011_05_May/27_May_11_RIBA%20Award_Bodegas_Portia/Portia%20Winery.aspx

Figure 4-9: “Plan”. GA Document 116.

Figure 4-10: “Section”. GA Document 116.

Figure 4-11: “Elevation”. GA Document 116.

Figure 4-12: “Structure”. Author’s sketch

Figure 4-13: “Circulation”. Author’s sketch

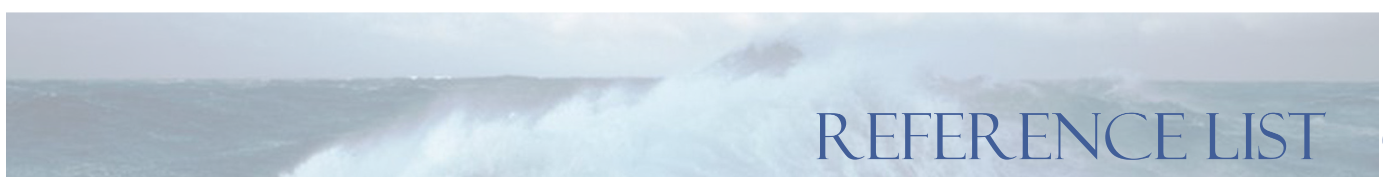

Figure 4-14: “Plan to section”. Author’s sketch

Figure 4-15: “Geometry”. Author’s sketch

Figure 4-16: “Massing”. Author’s sketch

Figure 4-17: “Natural light”. Author’s sketch

Figure 4-18: “Hierarchy”. Author’s sketch

Figure 4-19: “Exterior view of the Evelyn Grace Academy”. Retrieved October 10, 2011, from http://www.viewpictures.co.uk/Details.aspx?ID=148701&TypeID=1

Figure 4-20: “Section”. GA Document 115.

Figure 4-21: “Plan”. GA Document 115

Figure 4-22: “Elevation”. GA Document 115

Figure 4-23: “Plan to section”. Author’s sketch

Figure 4-24: “Massing”. Author’s sketch

Figure 4-25: “Natural Light”. Author’s sketch

Figure 4-26: “Hierarchy”. Author’s sketch

Figure 4-27: “Structure”. Author’s sketch

Figure 4-28: “Circulation”. Author’s sketch

Figure 4-29: “Geometry”. Author’s sketch

Figure 4-30: “Exterior rendering of the Teatro del Agua”. Retrieved October 10, 2011, from
http://inhabitat.com/charles-patons-teatro-del-agua/

Figure 4-31: “Section”. Author’s sketch

Figure 4-32: “Perspective”. Retrieved October 10, 2011, from
http://globedia.com/teatro-agua-proveeria-fresca-entretenimiento

Figure 4-33: “Plan”. Author’s sketch

Figure 4-34: “Elevation”. Author’s sketch

Figure 4-35: “Plan to section”. Author’s sketch

Figure 4-36: “Massing”. Author’s sketch

Figure 4-37: “Natural light”. Author’s sketch

Figure 4-38: “Hierarchy”. Author’s sketch

Figure 4-39: “Structure”. Author’s sketch

Figure 4-40: “Circulation”. Author’s sketch

Figure 4-41: “Geometry”. Author’s sketch

Figure 5-1: “Photograph of site facing north”. Author’s photograph

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"Till now man has been up against Nature; from now on he will be up against his own nature." Dennis Gabor