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BioHarvest: Energy Efficient Design for the Standardization of Biomimetic Technologies at Stanford University in Palo Alto, CA, USA

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BIO HARVEST

ENERGY EFFICIENT DESIGN FOR THE
STANDARDIZATION OF BIOMIMETIC TECHNOLOGIES
AT STANFORD UNIVERSITY IN PALO ALTO, CA, USA

GABRIELLA SANTOSTEFANO

B I O **H A R V E S T**

Submitted in fulfillment of the requirements for the Master of Architecture degree:

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MASTER OF ARCHITECTURE FALL 2017
ROGER WILLIAMS UNIVERSITY
SCHOOL OF ARCHITECTURE, ART, AND HISTORIC PRESERVATION
PROFESSOR HASAN-UDDIN KHAN

A B S T R A C T

The thesis serves as an investigation of the possibilities of biomimicry as well as an exploration of harvesting energy from the sun, the wind, the rain., and the earth.

Biomimicry, derived from the Greek words **bios** meaning “life” and **mimesis** meaning “imitate,” is the examination of nature in order to create systems that are derived from the natural world and provide sophisticated solutions to human problems.

Biomimicry asks the question. “What in nature has already solved what I am trying to solve?” In the case of this project, nature will inspire the creation of a new building typology, **Bio-Inspired Solutions Laboratory**, which intends to expand the scope of environmentally responsible architecture.

"For the development and improvement of humankind, it is imperative to renew a commitment to living as part of the earth by understanding development and growth as processes which can be sustained."

-The Hannover Principles, 1992

CHAPTER 1

INTRODUCTION

M A N I F E S T O

Nature is an invaluable resource for discovering new ways to approach design issues, and I firmly believe that architects have much to learn from the natural world. It is important that **designers remain innovative and, like nature, find new ways to adapt to and to sustain an ever-changing world.**

I believe that designers should imitate what nature has already discovered and learn to apply it to design. For instance, fiber manufacturers are currently studying spiderwebs to understand how their silk strands are five times stronger than steel.

I believe that **architecture is based on context - the user, the culture, the climate, and the environment**. I believe that "cookie cutter architecture," that which is placed all over the world without adjusting to its site, has no value or integrity.

I believe that the most successful architecture integrates with its site and provides a deep connection and understanding of its environment. Architecture is not about standing out or having an interesting form. Rather, I believe that the success of a design is measured by how it is used and how it sustains its environment.

I believe that architecture can play a role in society as an agent of social change. Architects should not only be aware of, but responsive to the cultural and social context.

I believe that we, not just as architects but as members of the human race, have a responsibility to the environment and to the earth. I truly believe that **architecture must lead with consideration, integration, and the betterment of the environment**.

The investigations that i wish to explore include the creation of a building typology that derives itself from the natural world. The conceptual investigations that I intend to undertake focus on biomimetic architecture as a means of integrating nature with building design.

T H E S I S   S T A T E M E N T

"The truth is, natural organisms have managed to do everything we want to do without guzzling fossil fuels, polluting the planet or mortgaging the future.

Life solves its problems with well-adapted designs, life-friendly chemistry and smart material and energy use."

- **Janine Benyus**

Humankind has been looking to nature for inspiration since our early beginnings. Still today, we have much to learn from evolution and natural selection. The natural world is constantly working to outperform itself, by perfecting its processes and evolving to adapt to an ever-changing environment.

Biomimicry is about bringing a new discipline - biology - to the design table. From aesthetics and form to function and purpose, biomimicry gives us the opportunity to emulate nature's well-adapted designs to solve human problems.

In my thesis, I wish to explore how architecture can do the same. There is a world of beauty and efficiency to be explored through biomimicry, and **designers should draw inspiration from and learn from nature in order to better contribute to the environment**.

Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies. It is the most powerful solution to making our built environment better adapted to life on earth. Biomimetic design is a means of producing buildings that imitate natural processes for the betterment of the environment and the human condition.

Biomimicry is a powerful science and tool for designers and environmentalists alike. Today, biomimicry is often applied to innovative designs of varying capacities, including prototypes for products such as Fontus, a self-filling water bottle that collects humidity from the air and transforms it into a potable water source.

In designing the high-speed bullet train, an issue arose when the train passed through tunnels. When this occurred, a loud booming sound would result from the high speed impact. The original design for the front of the train was reconsidered, and a new solution was modeled after the beak of the kingfisher, a bird able to dive into water without making a splash, which ultimately resolved the issue of sound.

Unfortunately, since it is such a new concept, there are few precedents and architects willing to discover how this idea can be formally applied to building design.

As I begin this exploration into my thesis project, I will investigate ideas from nature which I believe apply to architecture to find an architectural solution.

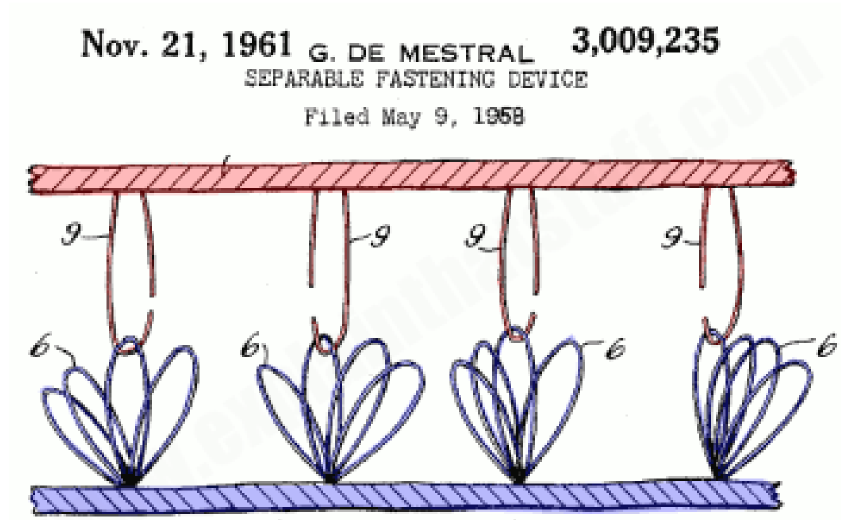
Conceptually, I wish to understand the process of examining nature to create models and systems to solve human problems. Through my thesis project, I hope to speculate about what biomimicry means for the future of design and to **inspire the continual study of nature to achieve a more sustainable built environment**.

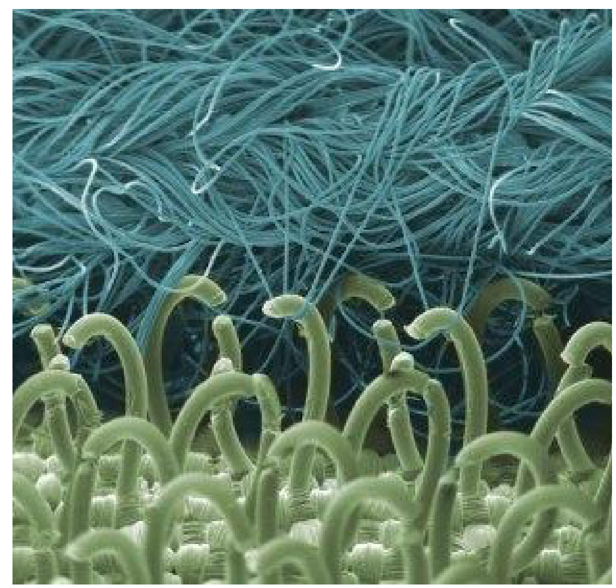
CHAPTER 2

B I O M I M I C R Y

ORIGINS

One of the earliest known forms of biomimicry is an invention from the 1940s in Switzerland by an engineer named George de Mestral. While hunting in the Jura Mountains, the needles of **cockle-burs** got caught on his clothing and in his dog's fur. Having wondered how the needles attached themselves, de Mestral studied their composition, which inspired his invention, Velcro®.





BASIC PRINCIPLES

Most biomimicry points to a specific organism for inspiration. However, the concept can be more broadly applicable when design strategies and principles are identified by other scientists, designers, and engineers. The excerpt below outlines the principles of biomimicry:

1. Nature runs on sunlight.
2. Nature uses only the energy it needs.
3. Nature fits form to function.
4. Nature recycles everything.
5. Nature rewards cooperation.
6. Nature banks on diversity.
7. Nature demands local expertise.
8. Nature curbs excesses from within.
9. Nature taps the power of limits.

-Janine M. Benyus, 9 Basic Principles of Biomimicry

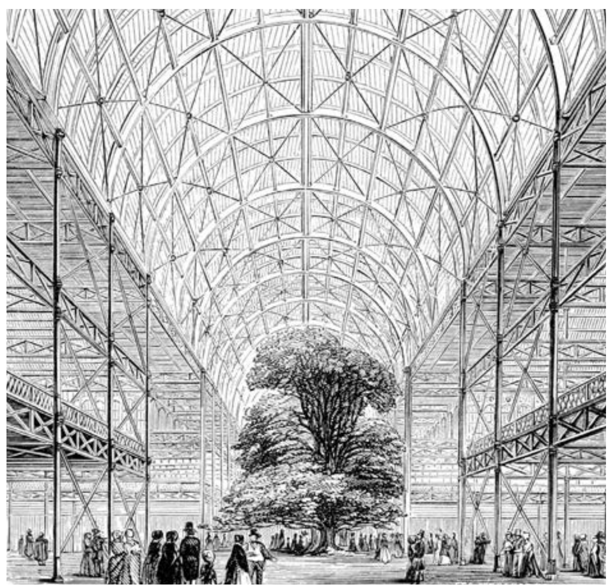
The following chapter provides examples of biomimicry as applied to architecture.

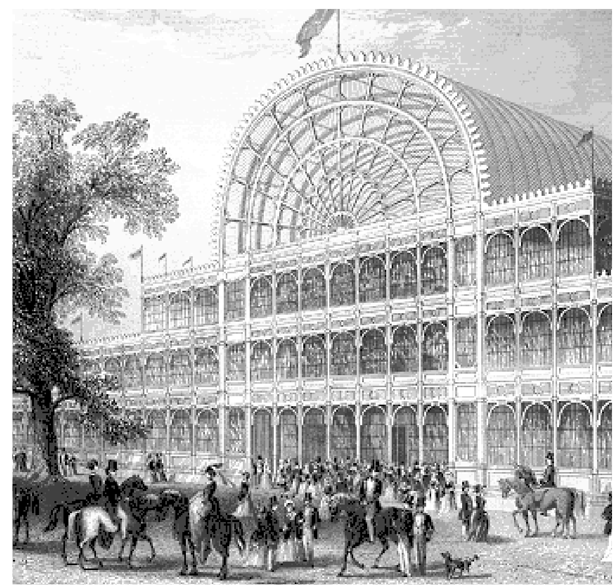
CRYSTAL PALACE

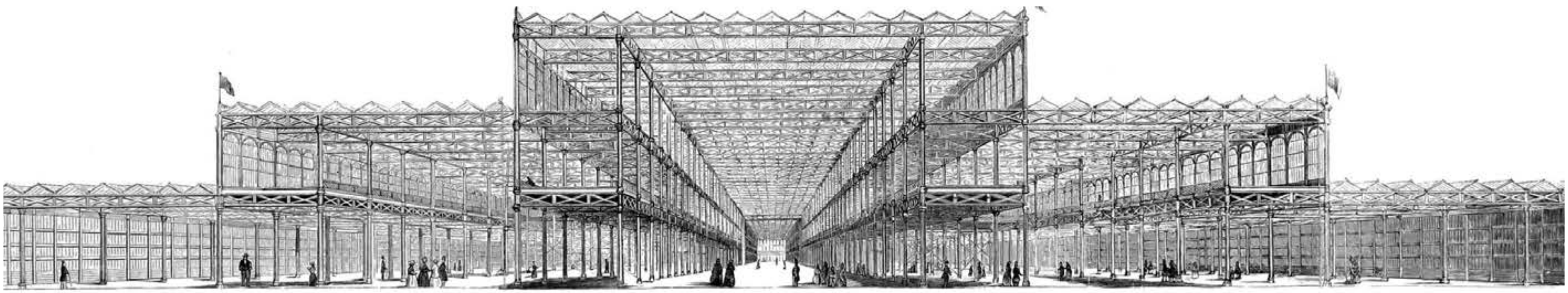
LOCATION: LONDON, UK
ARCHITECT: JOSEPH PAXTON
AREA: 990,000 SQ FT
YEAR: 1851

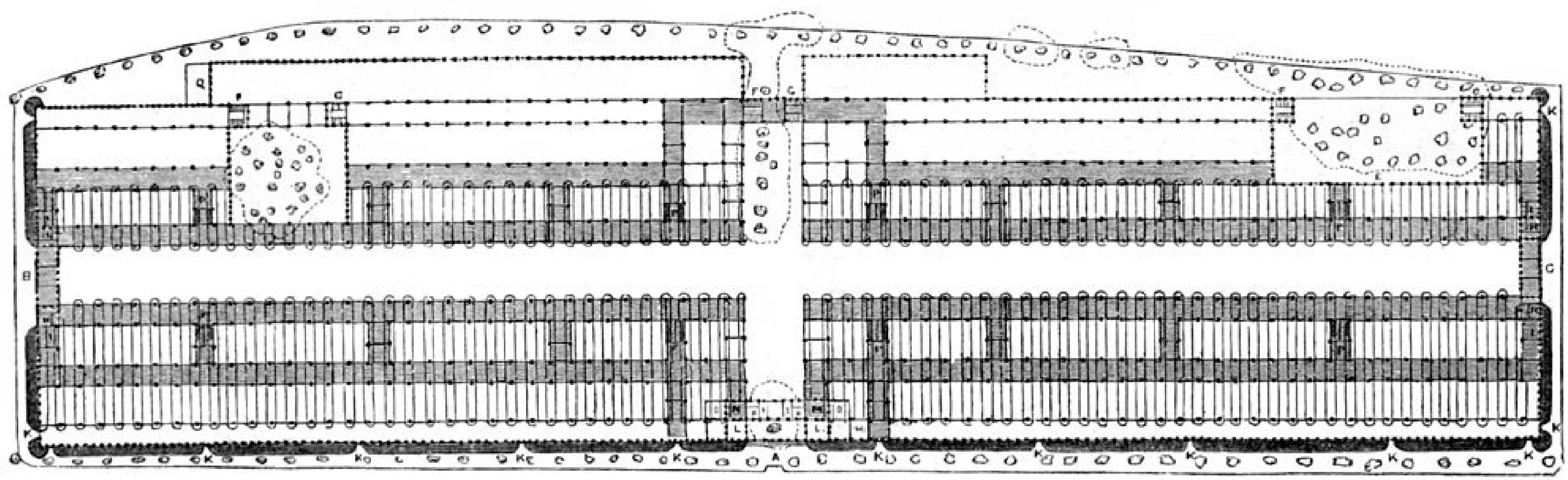
The Crystal Palace, designed by Joseph Paxton in London in 1851, is widely known for having been modeled after the giant weight-bearing water lily pads.

Built in the mid-19th century and almost entirely of plate-glass and iron, its light structure was a revolutionary concept of its time.. The design intended to demonstrate how thin structures, just like lily pads, can support great amounts of load.



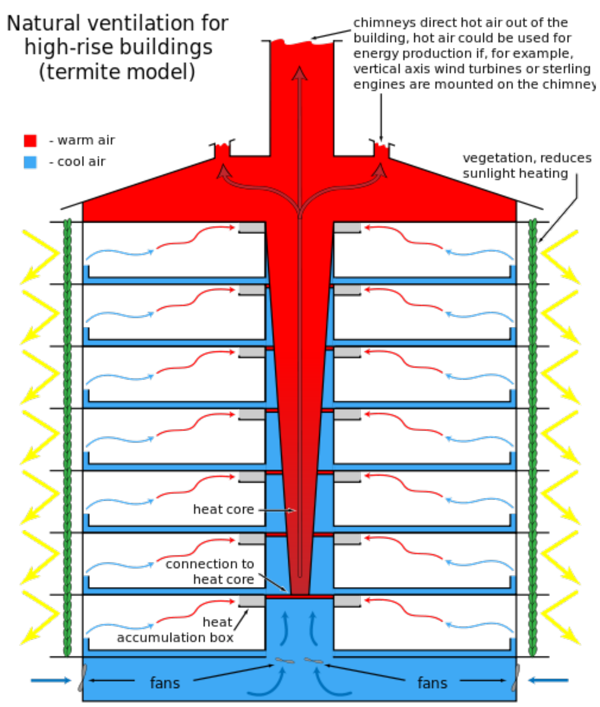






EASTGATE CENTER

LOCATION: ZIMBABWE, AFRICA
ARCHITECT: MICK PEARCE
AREA: 333,000 SQ FT
YEAR: 1996



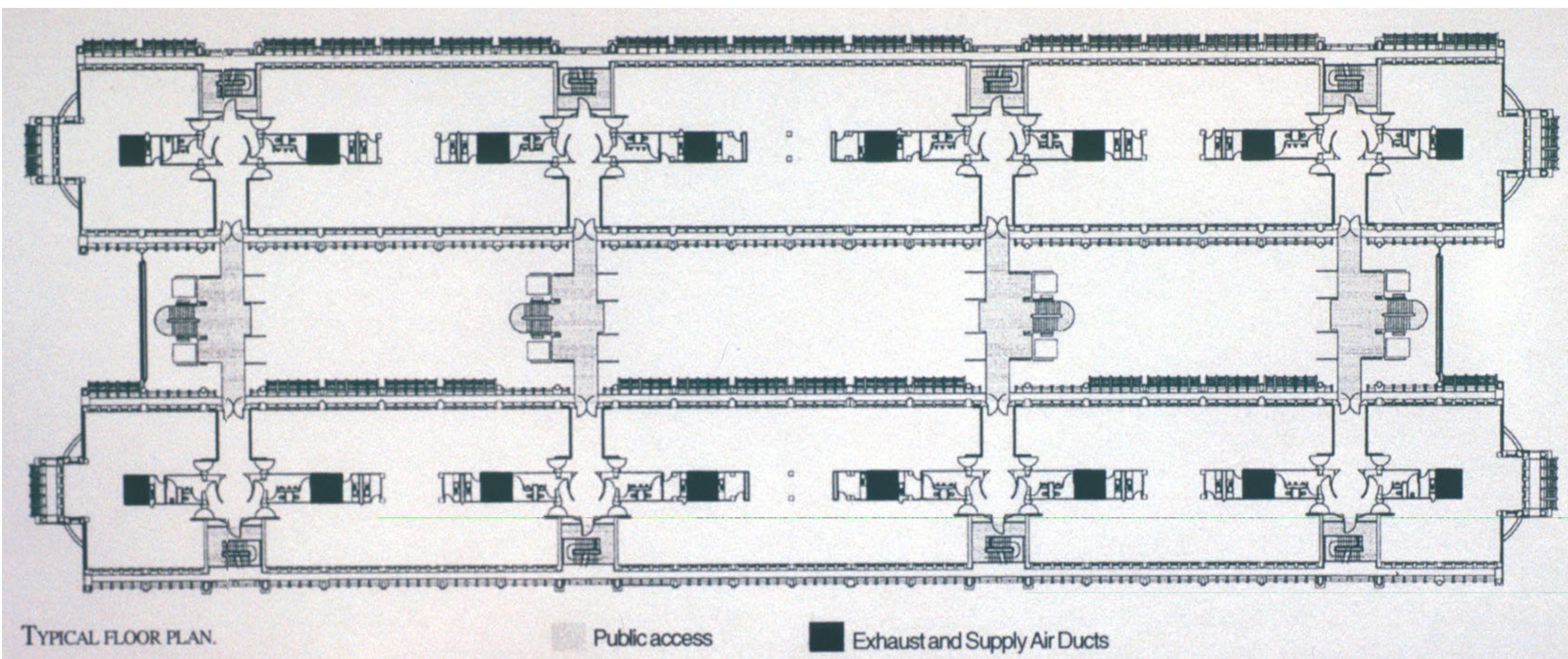
The Eastgate Centre is a shopping centre and office block designed to be ventilated and cooled by entirely natural means. It provides retail space, office space, as well as parking for 450 cars.

The building performs at low cost, low maintenance, and low environmental impact and uses only 10% of the energy needed by similar conventionally cooled buildings. .

The building is quite possibly the first in the world to use natural cooling to this level of sophistication. An example of biomimicry, it achieves passive cooling and ventilation by replicating local African termite mounds.

Passive cooling systems are particularly appropriate for this part of Africa because, long before humans thought of it, passive cooling was being used by the local termites.

Termite mounds include flues which vent through the top and sides, and the mound itself is designed to catch the breeze. As the wind blows, hot air from the main chambers below ground is drawn out of the structure, helped by termites opening or blocking tunnels to control air flow.


TYPICAL FLOOR PLAN.
Public access
Exhaust and Supply Air Ducts

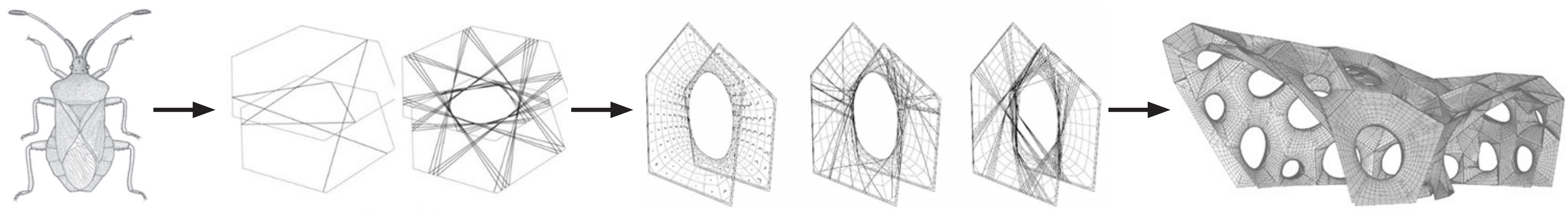
ICD/ITKE RESEARCH PAVILION

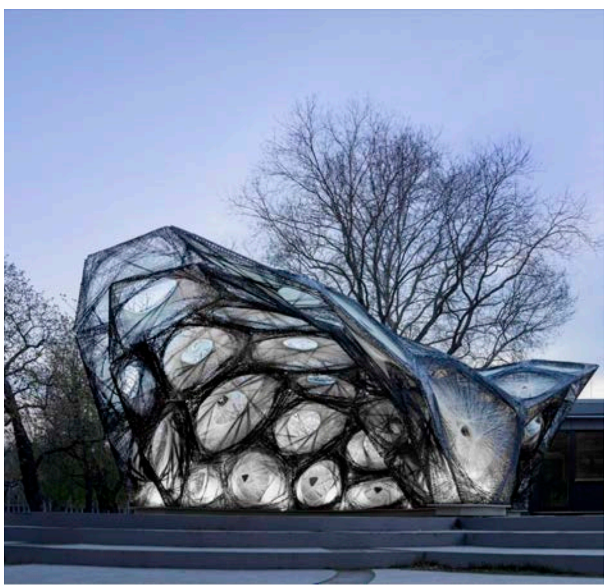
LOCATION: STUTTGART, GERMANY
ARCHITECT: ICD/ITKE
AREA: -
YEAR: 2013

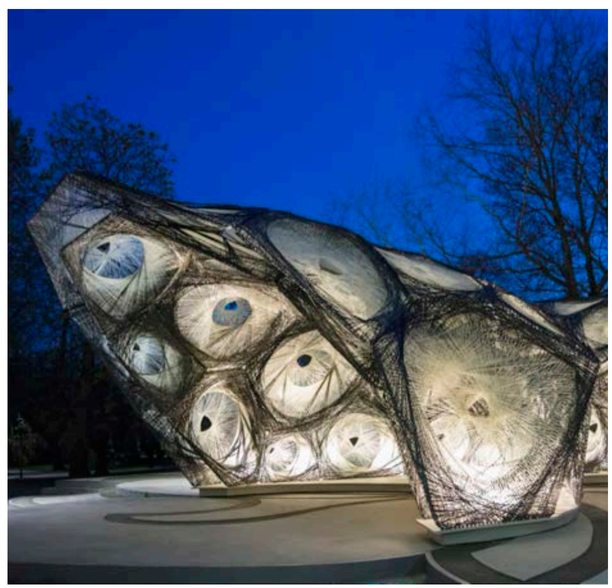
The structure, made of woven fibers, investigates the structural performance of protective beetle shells.

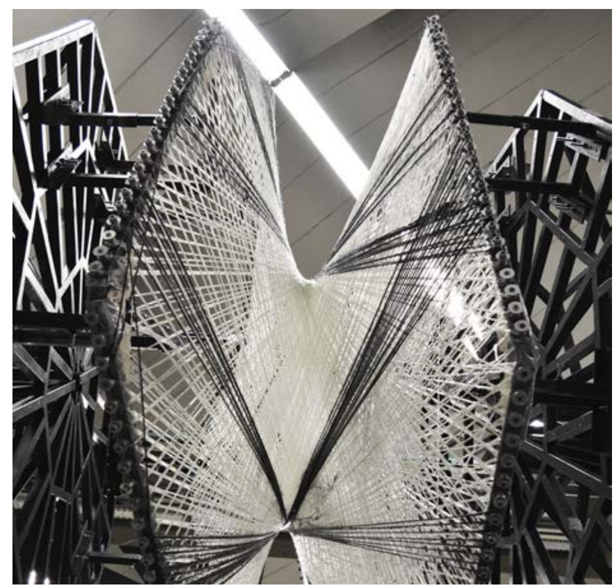
According to the team of researchers and students that studied the beetles, their shells "have proven to be a model for highly efficient construction based on the geometric morphology of the double-layered system and the mechanical properties of natural fiber composites (glass and carbon fiber reinforced polymers).

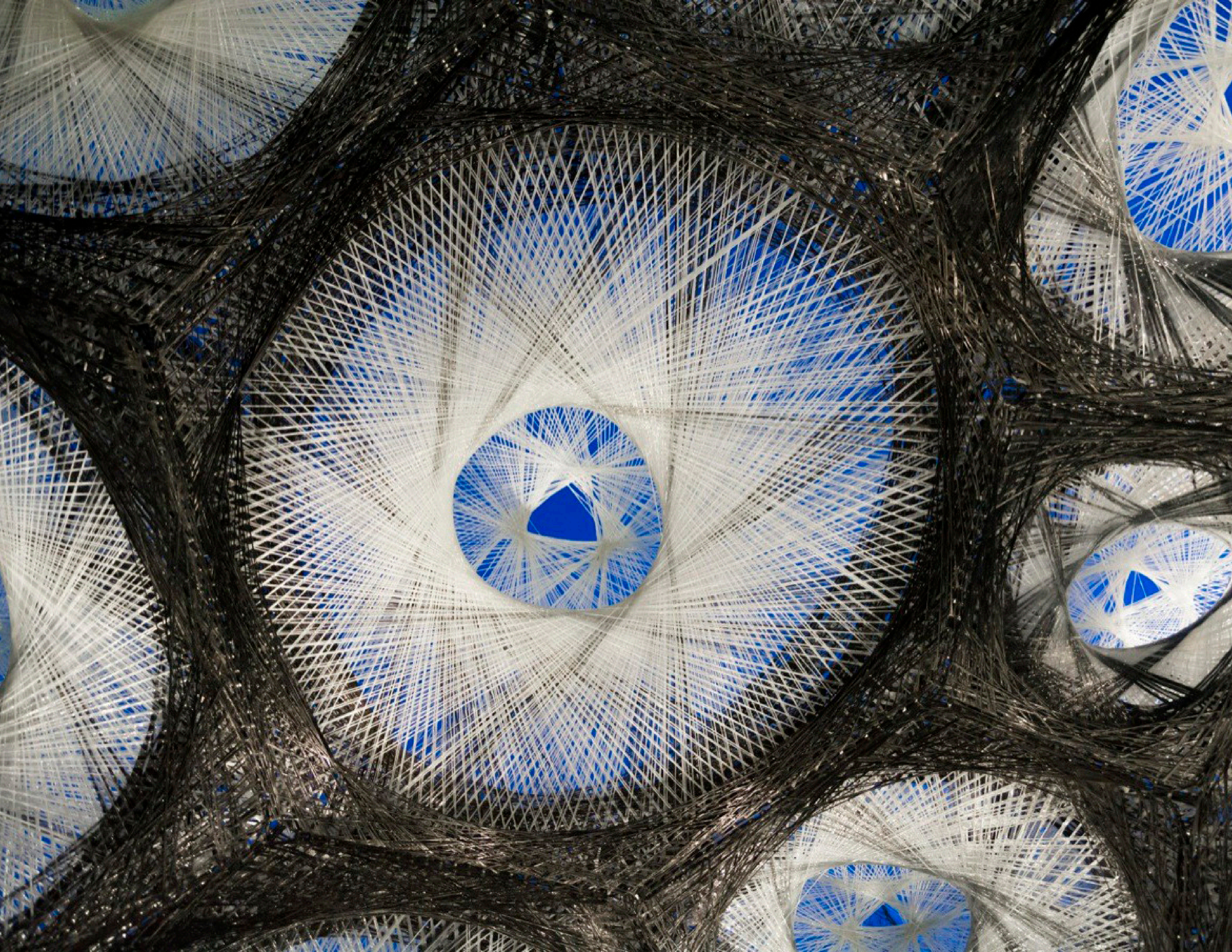
The shells contain a high strength-to-weight ratio and the potential to generate differentiated material properties through fiber placement variation."











STRAWSCRAPER

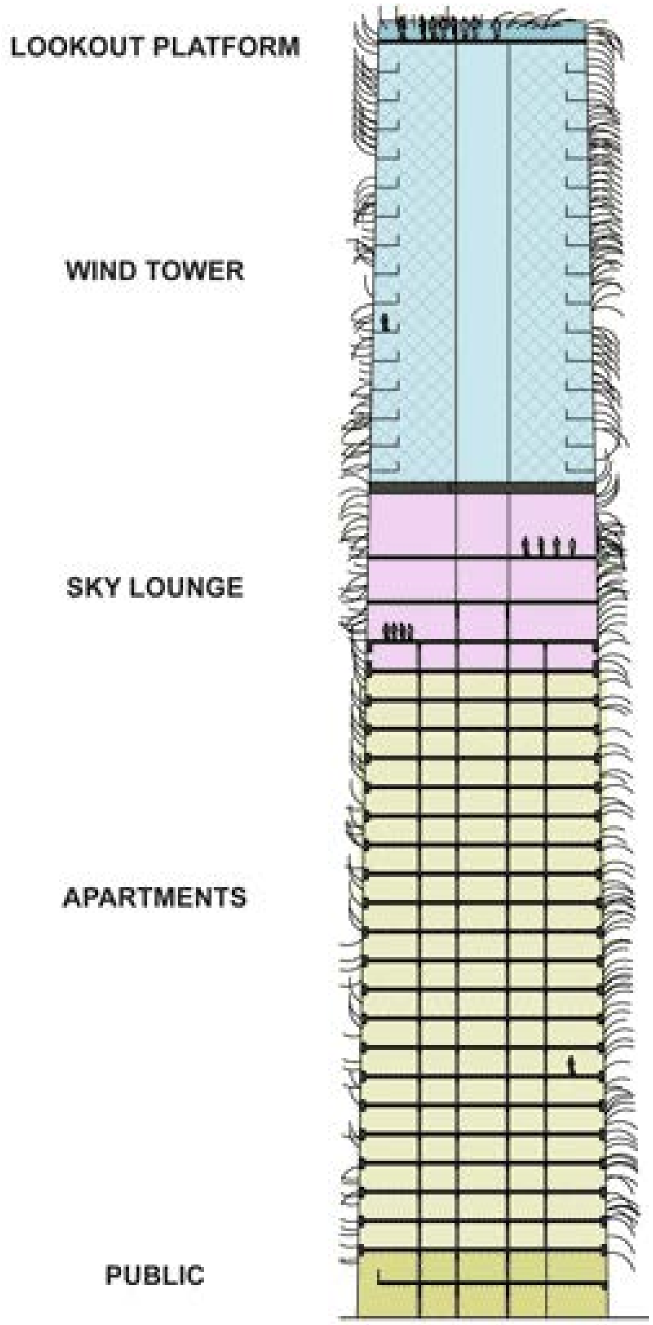
LOCATION: STOCKHOLM, SWEDEN
ARCHITECT: BELATCHEW LAB ARCHITECTURE
AREA: -
YEAR: -

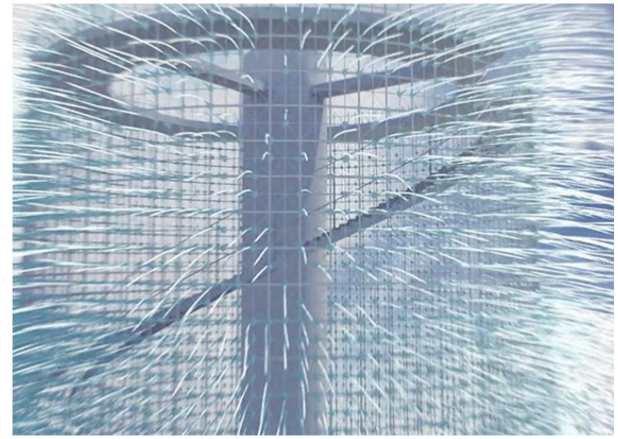
The Strawscraper is a conceptual skyscraper covered in a hair-like shell that can harness energy from the wind. The skyscraper is an extension of an existing tower in Stockholm, Sweden, which was completed in 1997. The original architect stepped off of the project mid-construction, leaving it 14 stories short of its intended height.

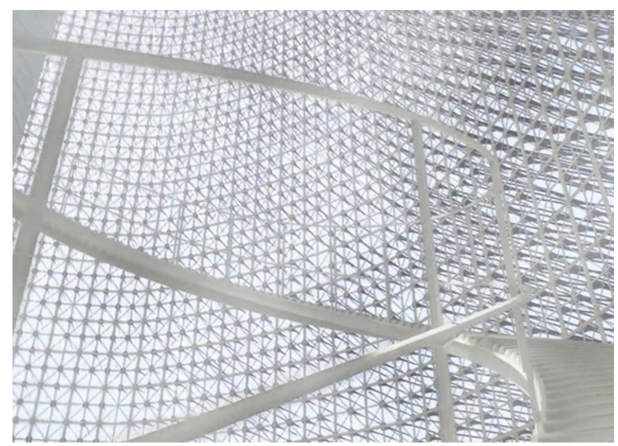
Belatchew Labs stepped in to give new life to the old project with a new look and technology that intends to influence the future of the skyscraper. Urban wind farming is a challenge that can often seem impossible. Finding a location for traditional wind turbines that doesn't take up too much room or isn't dangerous in an urban setting is another issue.

Strawscraper solves this problem by using a hair covered shell that harvests the power of the wind without the traditional turbine. The system utilizes Piezoelectric technology, which turns movement into electricity that can be stored for later use. The hair's tiny movement is safe for birds and humans and isn't noisy like traditional turbines.

The hair covering the building creates the illusion of movement, giving the normally static city skyline the illusion of motion.


LOOKOUT PLATFORM
WIND TOWER
SKY LOUNGE
APARTMENTS
PUBLIC





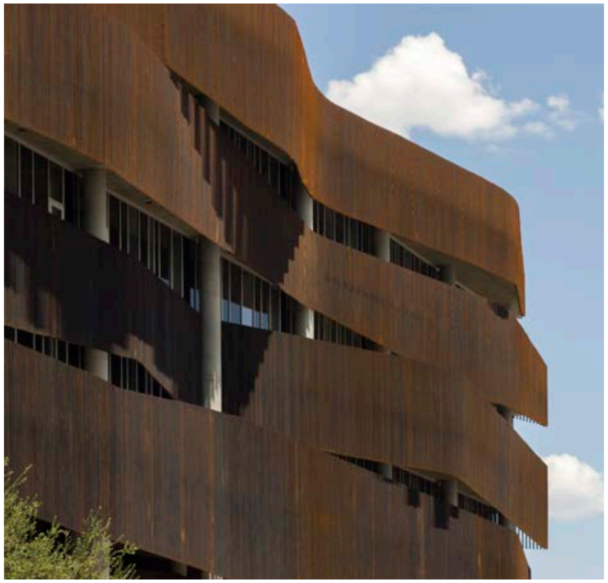
ENR2 (ENVIRONMENT + NATURAL RESOURCES 2)

LOCATION: UNIVERSITY OF AZ, USA
ARCHITECT: RICHÄRD+BAUER
AREA: 150,954 SQ FT
YEAR: 2015

ENR2 is a university building which contains offices, classrooms, auditoriums and gathering rooms.

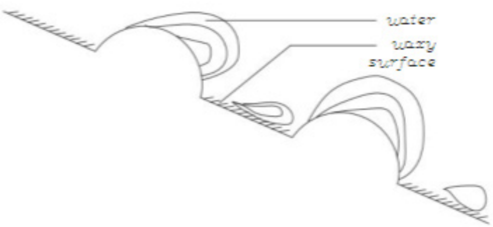
Designed to emulate a slot canyon, the building incorporates energy efficient heating and cooling systems, rainwater harvesting and low-flow faucets, and other innovative architectural solutions in a desert landscape.

A central courtyard harvests rainwater runoff which is continually reused to irrigate the native trees and plants that populate the desert ecosystem within the building.



SEAWATER GREENHOUSE LTD.

LOCATION: TENERIFE
DESIGNER: LIGHT WORKS LTD
YEAR: 1991



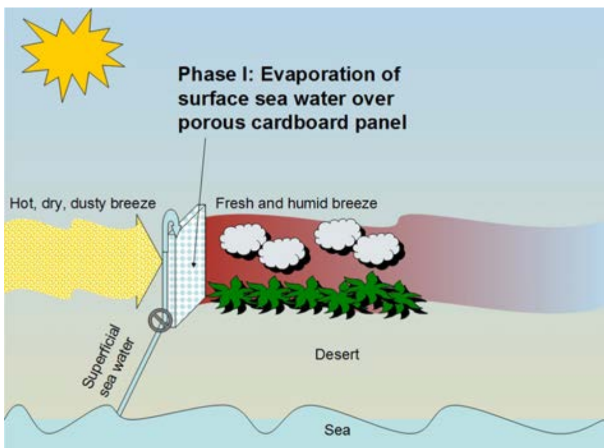
A seawater greenhouse uses the sun, the sea and the atmosphere to produce fresh water and cool air. The structure enables the growth of crops in arid regions, using seawater and solar energy.

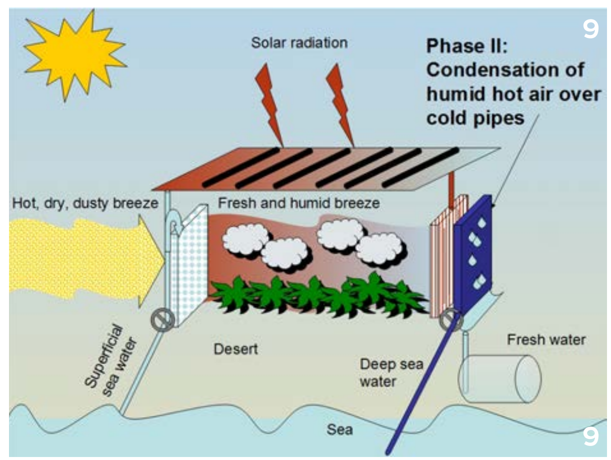
First introduced by British inventor Charlie Paton in the early 1990s, its technology is a response to the global water crisis and peak water.

The technique imitates the Namibian fog basking beetle, which collects water droplets on its back from the moisture in the foggy air. The greenhouse pumps seawater to an arid location and then subjects it to the two processes shown below.

The front wall of the building is a seawater evaporator. It consists of a honeycomb lattice which faces the prevailing wind. As seawater trickles down the lattice, the air cools and humidifies before passing through into the planting area.

Sunlight is filtered through a specially constructed roof. The roof traps infrared heat, while allowing visible light through to promote photosynthesis. This creates optimum growing conditions- cool and humid with high light intensity.





CHAPTER 3

ENERGY HARVESTING

ENERGY HARVESTING

The thesis advocates for an architecture which **adapts to its environment, by imitating nature and abiding by the principles of biomimicry**.

Biomimicry is not currently utilized to its maximum potential in architecture. Still today, there are very few examples of biomimicry being applied to building design.

However, it is evident from each of the projects in the previous chapter that **the study of nature yields unique results and innovations that likely would not have been achieved without its influence**.

The project intends to serve as an opportunity to define and advance the role of biomimicry in the realm of energy-responsible architecture. The project will apply the principles of biomimicry to develop a unique new response to energy harvesting inspired by processes in nature.

The project will explore energy harvesting in the pursuit of an architecture which contributes to and positively impacts its environment.

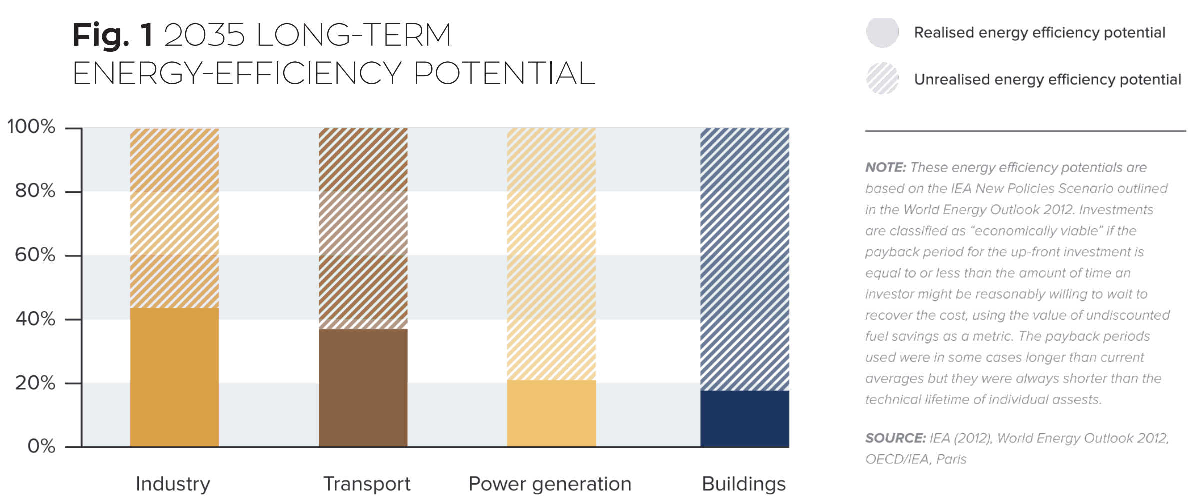
In order **to innovate a future standardization of biomimicry and renewable energy-based design**, the project will focus on the future development of biomimetic products, such as building skins that harvest renewable energy.

The following chapter illustrates the current systems and technologies used to harvest wind, rainwater, and solar energy.

For many decades, people have searched for ways to store renewable energy. The history of energy harvesting dates back to the windmill and the waterwheel. T**oday, energy harvesting is motivated by a desire to address the issues of climate change and global warming**.

The project will address the potentials of future energy-efficiency (Fig. 1) in industry, transport, power generation, and buildings..

Fig. 1 2035 LONG-TERM ENERGY-EFFICIENCY POTENTIAL



NOTE: *These energy efficiency potentials are based on the IEA New Policies Scenario outlined in the World Energy Outlook 2012. Investments are classified as "economically viable" if the payback period for the up-front investment is equal to or less than the amount of time an investor might be reasonably willing to wait to recover the cost, using the value of undiscounted fuel savings as a metric. The payback periods used were in some cases longer than current averages but they were always shorter than the technical lifetime of individual assests.*

SOURCE: *IEA (2012), World Energy Outlook 2012, OECD/IEA, Paris*

W I N D   H A R V E S T I N G

Wind is a type of renewable energy that creates electricity using the air flows that occur naturally in the earth's atmosphere.

Types of Wind Power

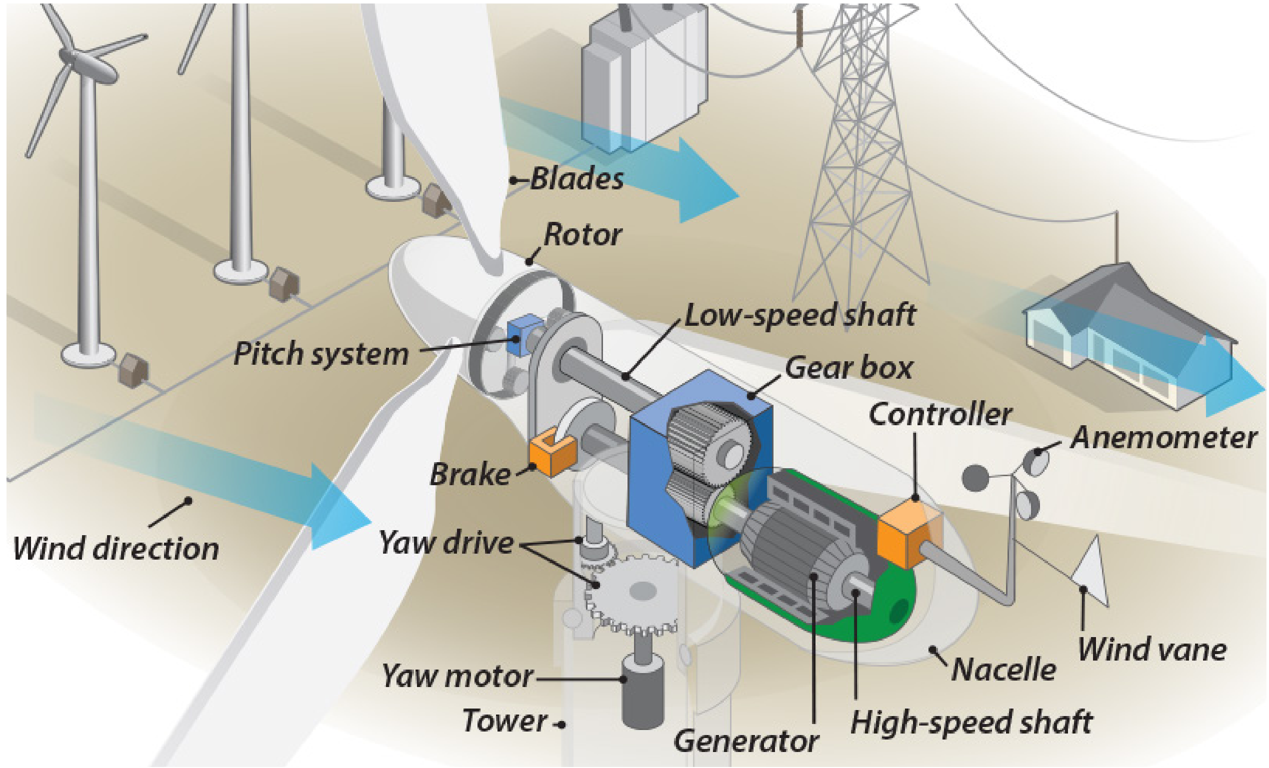
Wind power can be divided into three categories:

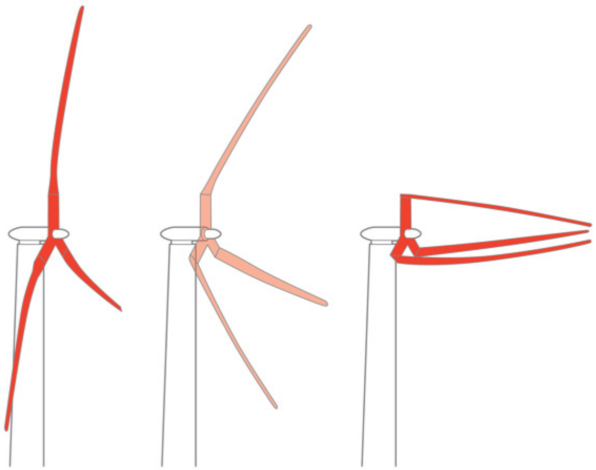
1. Utility-scale wind
2. Distributed or "small" wind
3. Offshore wind

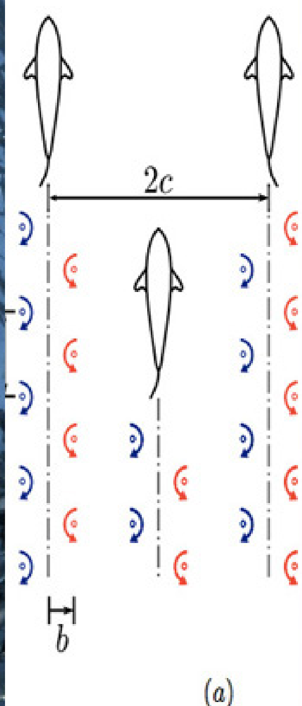
Utility-scale wind consists of wind turbines larger than 100 kilowatts that are developed with electricity, delivered to the power grid, and distributed to the end user by electric utilities or power system operators.

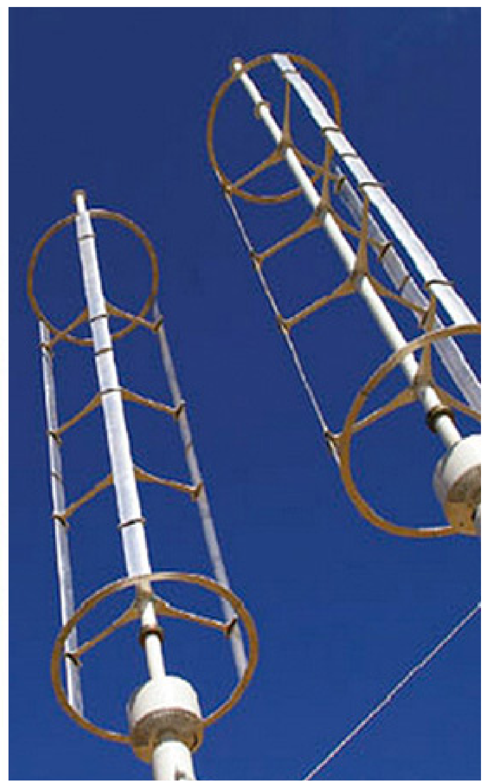
Distributed wind uses turbines of 100 kilowatts or smaller to directly power a home, farm or small business as its primary use.

Offshore wind farms are wind turbines erected in bodies of water.









Wind Turbines

Wind turbine blades capture kinetic energy from the wind and convert it into mechanical energy, spinning a generator that creates electricity. This rotation turns an internal shaft connected to a gearbox, which increases the speed of rotation by a factor of 100. This mechanical power can be used for specific tasks or a generator can convert this mechanical power into electricity.

A typical modern turbine generates usable amounts of power over 90 percent of the time. It will start to generate electricity when wind speeds reach 6 -9 miles per hour and cut off at about 45 miles an hour to prevent equipment damage. Over the course of a year, modern turbines can reach more than 40 percent of their rated maximum capacity; better than most other forms of electric generation such as natural gas plants.

Modern examples of biomimicry in wind energy harvesting:

(Top Left) Wind turbines with blades longer than two football fields that curve and fold in the wind like a palm tree's fronds.

(Bottom Left) Flowe by John Dabiri, professor at Stanford University. Inexpensive and efficient vertical-axis wind turbines inspired by schools of fish that can outperform traditional wind farms.

H Y D R O   H A R V E S T I N G

Harvested rainwater is the precipitation captured and used for indoor needs, irrigation, or both from surface catchments. The collection of rainwater is beneficial for potable purposes in areas lacking alternative sources or minimum rainfall with very little number of rainy days.

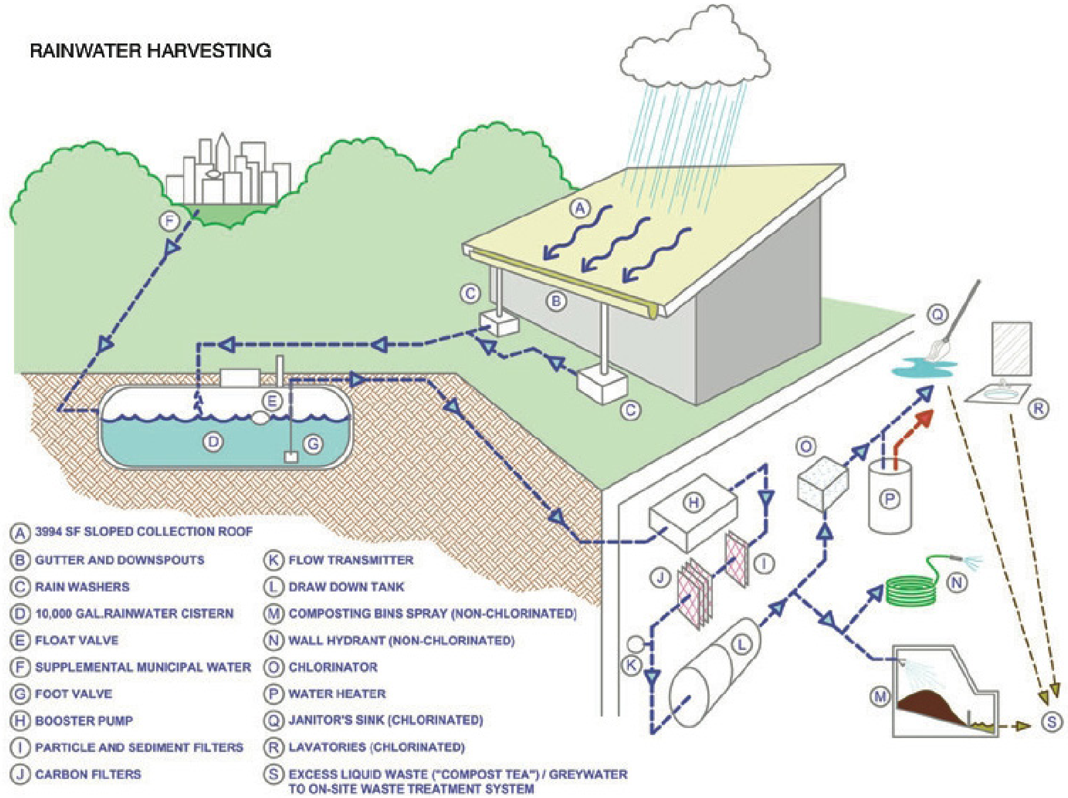
Rainwater Collection

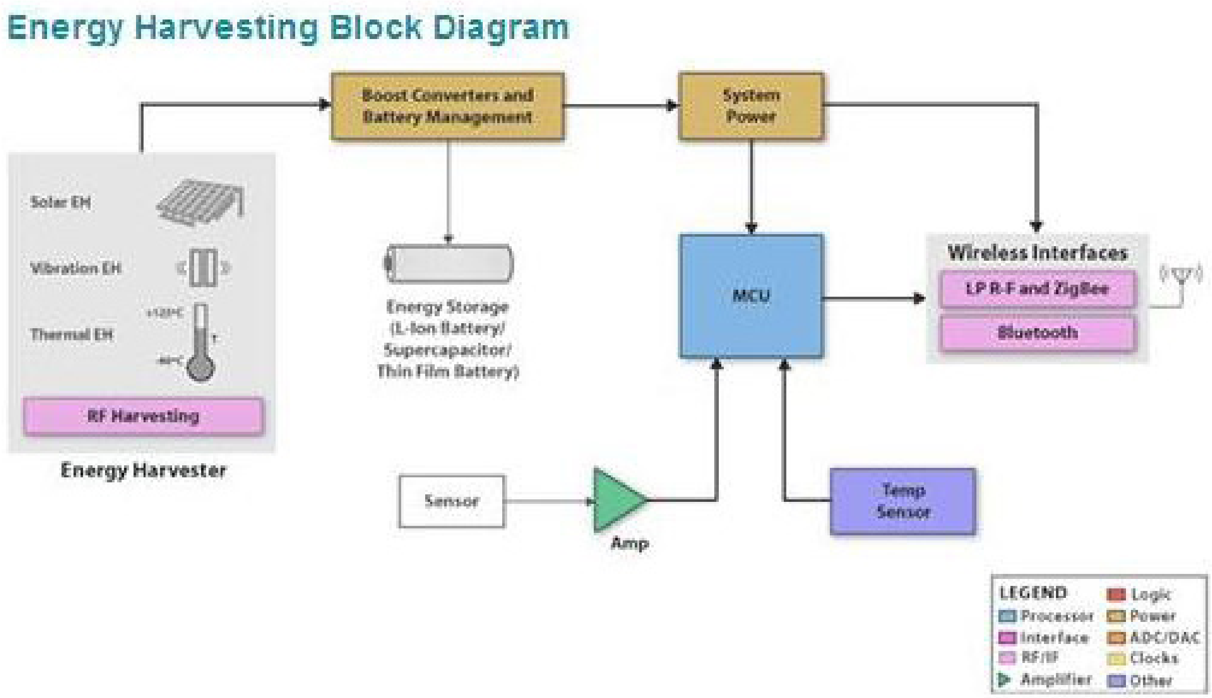
Approximately 40% of water used in summer is used outdoors, which is when most areas face water shortages and have water restrictions. This water shortage period is when plants and trees require water the most. As population grow, water shortages occur.

In order to minimize and to reduce the utilization of water, various water conservation techniques can help monitor and restrict fresh water wastage.

The more rainwater is used, the less the need to use chlorinated or other chemically treated tap water. The more we use rainwater, the less that will go into storm sewers where it is mixed with oil and other toxic residues from streets and parking lots, allowing for more use of settling ponds to remove these toxins

The following steps are often followed in rainwater harvesting from roofs:
1. Collection of rainwater
2. Separation of first rain flush
3. Filtration of rain water
4. Storage of rain water
5. Distribution of rain water

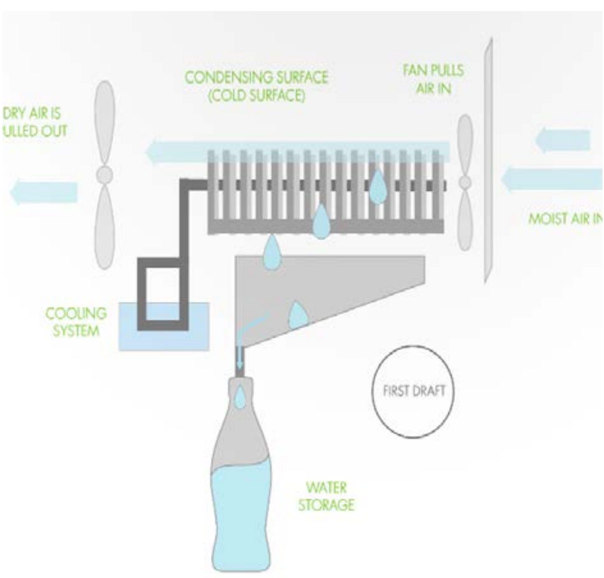




Harvesting Techniques

The process of rainwater collection includes augmenting the natural infiltration of rainwater or surface run off into the underground formation by some artificial methods. There are many methods for harvesting rainwater, all of which are site-specific. Each technique can either be combined or used individually depending upon hydrogeological and agroclimatic conditions.

The methods suggested are:
1. Water spreading
2. Recharge through pits, wells, chambers, trenches, borewells
3. Open used wells, shafts
4. Directly diverting run off water into the existing wells
5. Irrigation or drinking water wells



Modern example of biomimicry in hydro energy harvesting:

(Left) Fontus, a self-filling water bottle, captures moisture contented in the air, condenses it and stores it as drinking water.

A small fan draws the air from the surrounding environment, runs it through a filter and presses it into the condensation chambers. A series of small coolers bring the moisture contained in the air to condense on special surfaces. The resultant liquid water then drops into the bottle´s main body and is stored.

S O L A R   H A R V E S T I N G

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV), or indirectly using concentrated solar power.

Types of Solar Energy Technologies:

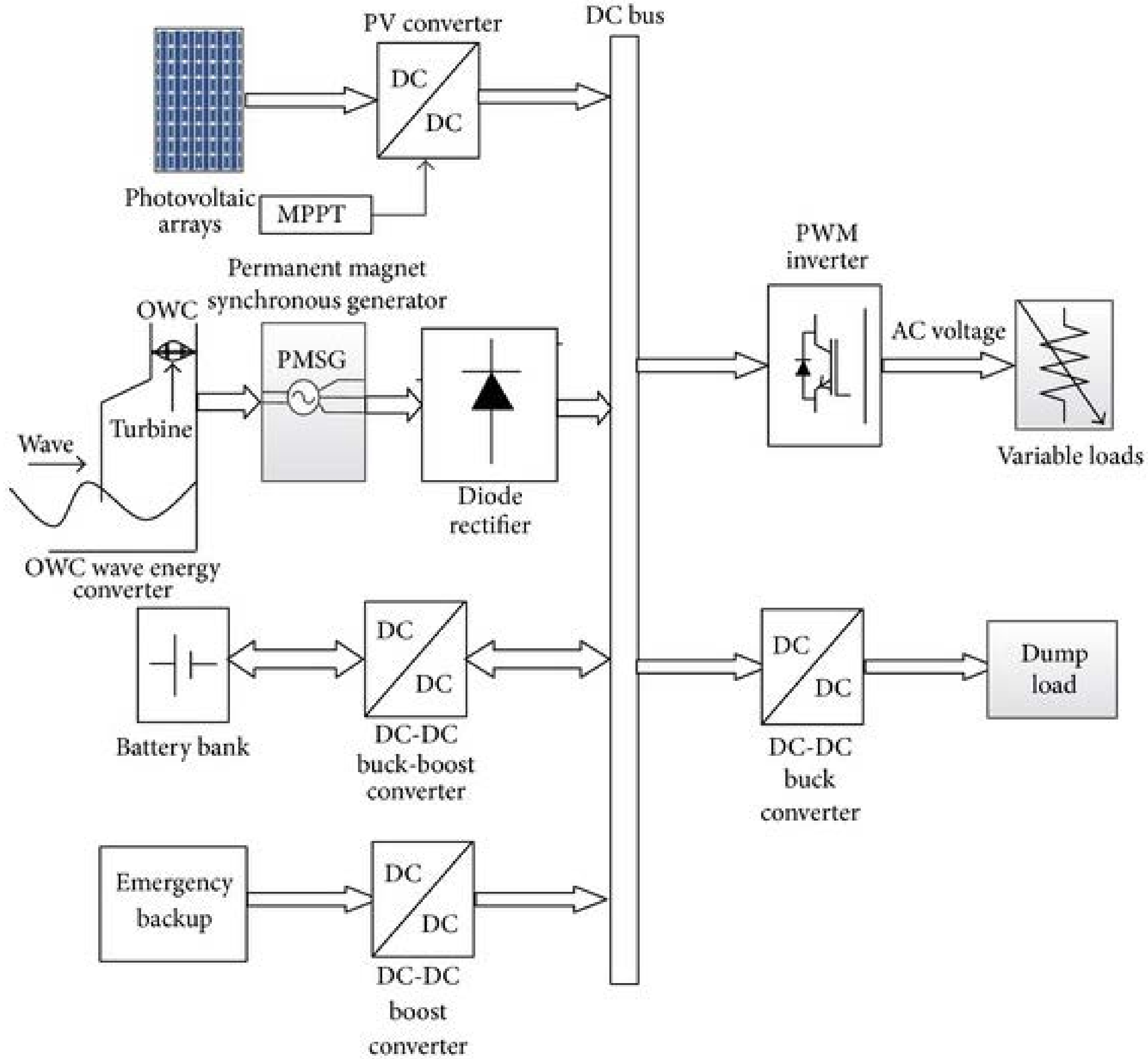
There are two main types of solar energy technologies:
1. Photovoltaic (PV)
2. Concentrating solar power (CSP)

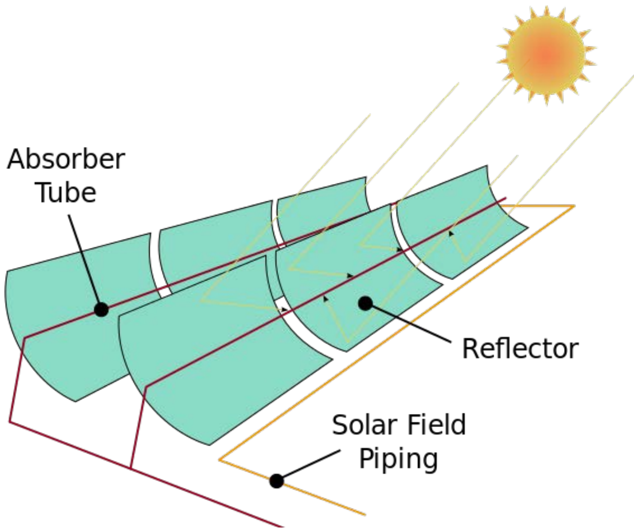
Photovoltaic (PV):

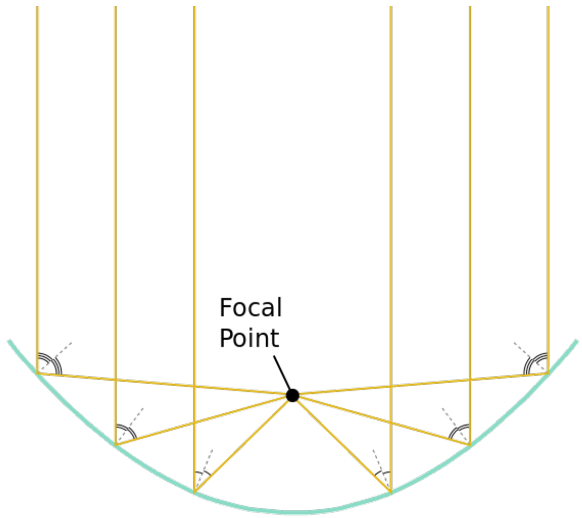
PV is utilized in panels. When the sun shines onto a solar panel, photons from the sunlight are absorbed by the cells in the panel, which creates an electric field across the layers and causes electricity to flow.

Photovoltaic materials and devices convert sunlight into electrical energy. A single PV device is known as a cell. An individual PV cell is usually small, typically producing about 1 or 2 watts of power. To boost the power output of PV cells, they are connected together in chains to form larger units known as modules or panels. Modules can be used individually, or several can be connected to form arrays. One or more arrays is then connected to the electrical grid as part of a complete PV system. Because of this modular structure, PV systems can be built to meet almost any electric power need, small or large.

The largest PV systems in the country are located in California and produce power for utilities to distribute to their customers.





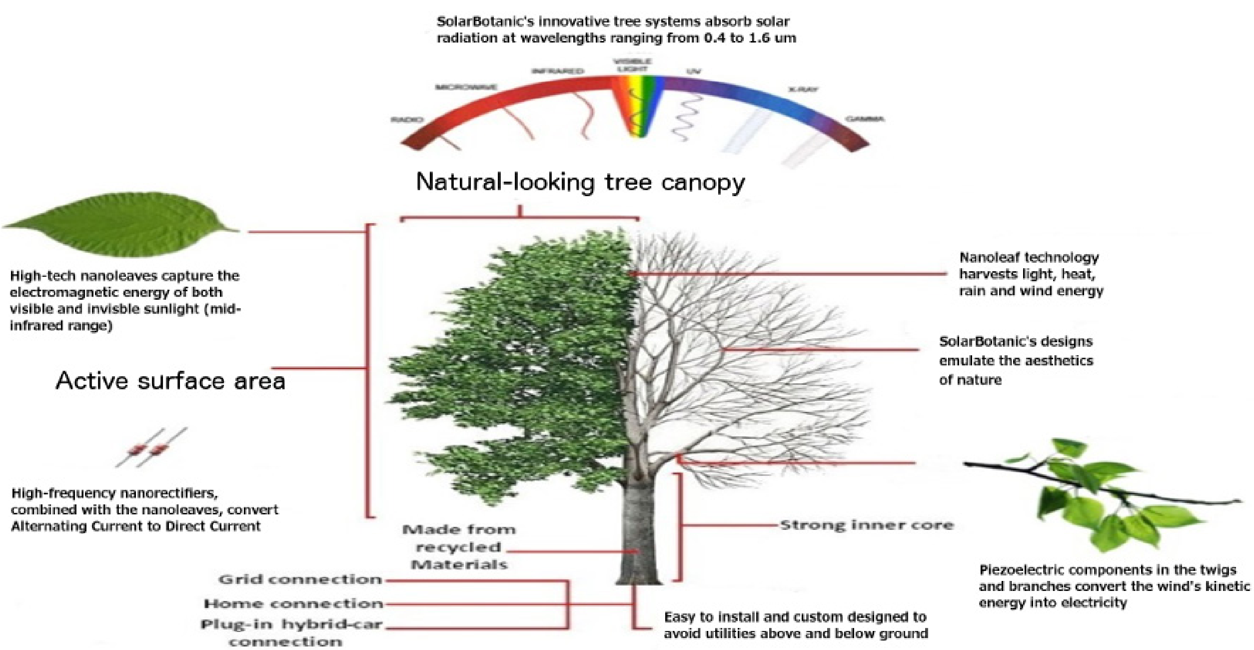


Concentrating Solar Power (CSP):

The second technology is concentrating solar power, or CSP. Photovoltaic cells convert light into an electric current using the photovoltaic effect.

Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam where it is collected and converted into heat. The mirrors in CSP plants focus sunlight onto a receiver that heats a high-temperature fluid, which is used to spin a turbine or power an engine that drives a generator. This thermal energy can then be used to produce electricity.

Concentrating solar power systems are generally used for utility-scale projects and are not appropriate for residential use. Smaller CSP systems can be located directly where power is needed.



Modern examples of biomimicry in solar energy harvesting:

(Left) Solar Botanic's artificial trees mimic the architectural design of trees and shrubs, and use knowledge about the roles trees play in photosynthesis. Clean, carbon-free and renewable, solar power is a resource that can energize the future.

CHAPTER 4

P R O G R A M

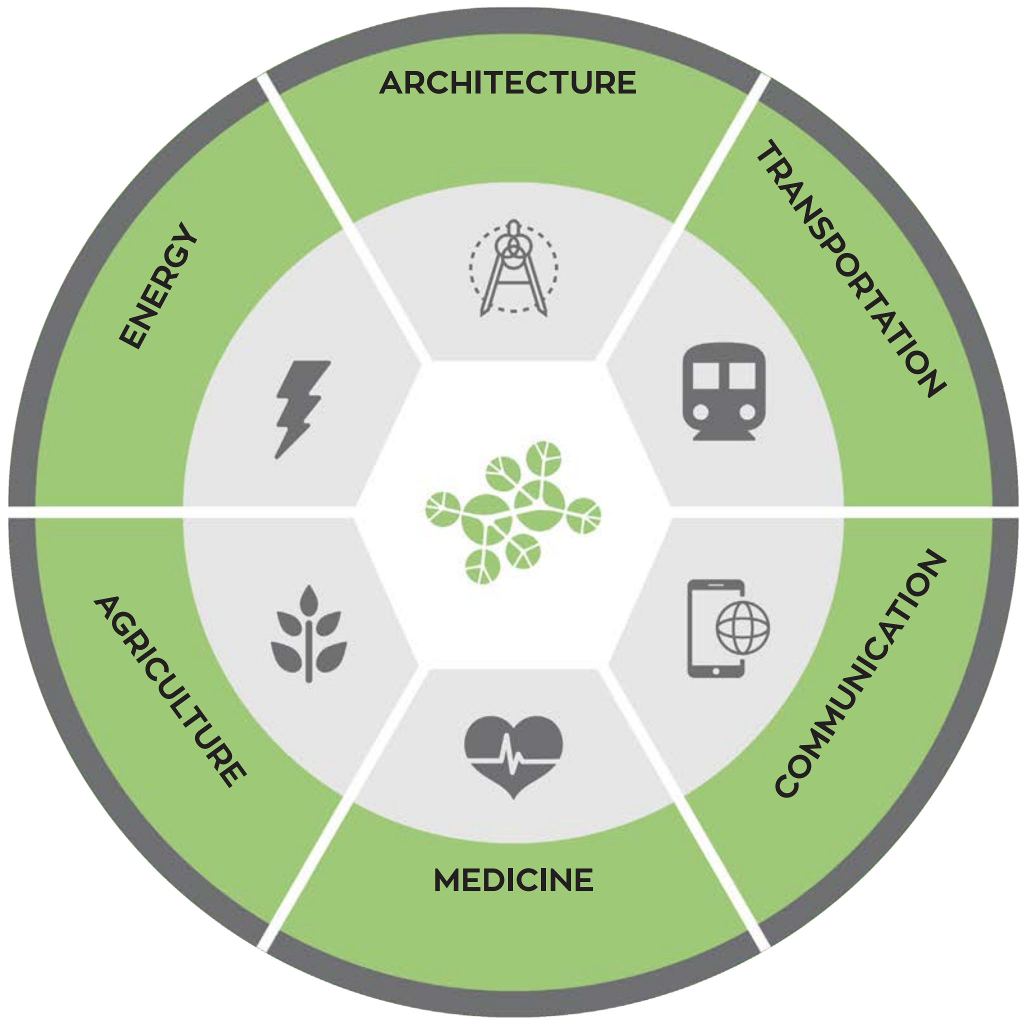
BIOMIMICRY IN PRACTICE

Given the need for a standardization of biomimicry in design and energy harvesting, the program is an innovation and testing facility for biomimicry, or a Bio-Inspired Solutions Laboratory. The new typology would be a first-of-its-kind institution, allowing its users to produce groundbreaking research in an emerging practice.

A study was performed of the professions which currently utilize biomimetic research to varying capacities. (Fig. 2) This includes Energy, Architecture, Transportation, Agriculture, Medicine, and Communication.

The program which evolved out of this study generally meets the requirements of each profession. This would include research greenhouses, laboratories, classrooms, conference and meeting spaces, a library, and workspaces, among other program.

Fig. 2 PROFESSIONS WHICH UTILIZE BIOMIMICRY



BIO-INSPIRED SOLUTIONS LABORATORY

The following program components promote an exploratory process for the creation of **biomimetic prototypes, in an effort to innovate and develop new technologies for a more sustainable built environment**.

EDUCATION:

-Classrooms should provide a thriving environment for students, making it the ideal location-The laboratories should be open and face the outdoors to indicate a seamless connection to the outdoors.
-A lecture hall will serve as a unique space for meetings, seminars, and workshops.

ADMINISTRATION:

-The faculty offices should be separate from but located near the educational spaces.
-The staff support areas should be adjacent to the offices, and serve as a retreat for faculty and staff.

SUPPORT:

-There shall be multiple conference rooms throughout the facility to promote an environment of collaboration and ongoing discussion.
-The mechanical equipment used to harvest and convert energy into power should be clearly displayed so that it may be used for educational purposes.

OUTDOOR:

-The outdoor areas should allow a hands-on approach, and inspire users to draw inspiration from the surrounding environment.
-A courtyard should be utilized as a growing area for plant species that can be studied in laboratories.
-An immersive education area should be used by faculty as an outdoor classroom and an opportunity for observation and teaching.

SOCIAL + ARCHITECTURAL INTENTIONS

EDUCATION:

Classrooms	10,000 asf
Research Laboratories	30,000 asf
Research Lab Support	4,000 asf
Conference Rooms	5,000 asf
Exhibition Space	2,000 asf
Lecture Hall	3,000 asf

ADMINISTRATION:

Offices	12,000 asf
Staff Support Areas	4,000 asf

SUPPORT:

Lobby	500 asf
Storage	600 asf
Mechanical Space	800 asf
Security/Camera Rooms	100 asf
Lavatories	TBD

TOTAL 72,000 asf

OUTDOOR:

Entry Courtyard
Immersive Education Area
Parking

Determining Supply Air Needed

Three drivers determine the required volume of supply air in a laboratory: temperature, exhaust, and ventilation.

Temperature-driven laboratories hold a lot of equipment to perform chemical analysis or ovens and heating elements to speed up chemical processes. Without an adequate supply of cool air, the laboratory housing this equipment will become uncomfortably warm. Lights, laboratory personnel, and even heat transmitted through the building also contribute to the cooling load of a laboratory. Determining the necessary supply air volume for cooling involves summing up all of these loads. However, loads other than the building envelope should be determined according to expected usage. For example, engineers revise supply air volume downward if all of a laboratory's equipment will not be used simultaneously.

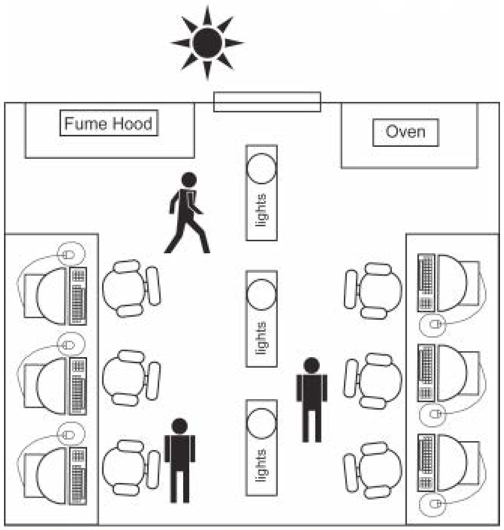


Figure 2. Supply air volume in laboratories with high heat loads, such as computers, ovens and other electrical equipment, is driven by cooling requirements.

Maximizing a laboratory's functionality requires the design team, building owners and laboratory users to determine the usage and goals of the facility. Building design, laboratory design and laboratory equipment all can affect functionality.

Laboratory HVAC controls also have significant impact on building functionality. No single type of system is appropriate for all laboratories. Each control system has its own usages and limitations. An overall comparison of control strategies is listed below.

Let TSI help you evaluate the goals for your laboratory in order to develop an optimal control strategy.

	Energy Efficiency	First Cost	Future Flexibility	Safety
Constant Volume	☆	☆☆☆	☆	☆☆
2-Position	☆☆	☆☆	☆	☆☆
Variable Air Volume				
Direct Pressure	☆☆☆	☆☆	☆☆☆	☆☆☆
Flow Tracking	☆☆☆	☆☆	☆☆☆	☆☆
Flow Tracking with Pressure Feedback	☆☆☆	☆☆	☆☆☆	☆☆☆

Figure 21. Comparison of Room Control Types.

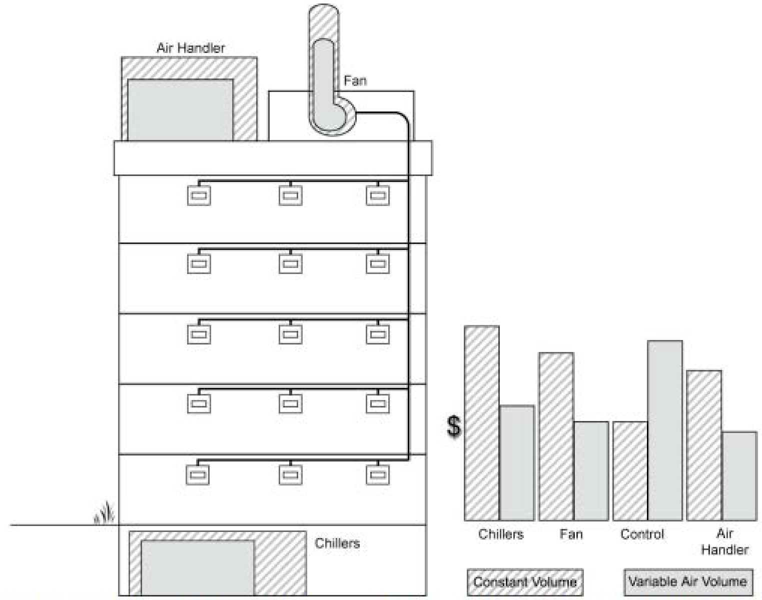


Figure 9. Applying diversity reduces maximum airflows, shrinking capital equipment and offsetting the additional cost of controls.

The savings from diversity result from the assumption that not all laboratories will require full airflow at the same time. These savings take the form of downsizing capital equipment. Much of the cost of a buildings HVAC system is in the chillers, fans, air handlers, and other large equipment. Sizing this equipment for expected loads instead of maximum possible loads can cover much of the cost premium of VAV controls. Operating expenses may also decrease, because HVAC equipment is most efficient at full-flow operation—equipment sized for expected airflows will run at close to peak capacity instead of part-load.

CHAPTER 5

PRECEDENT ANALYSIS

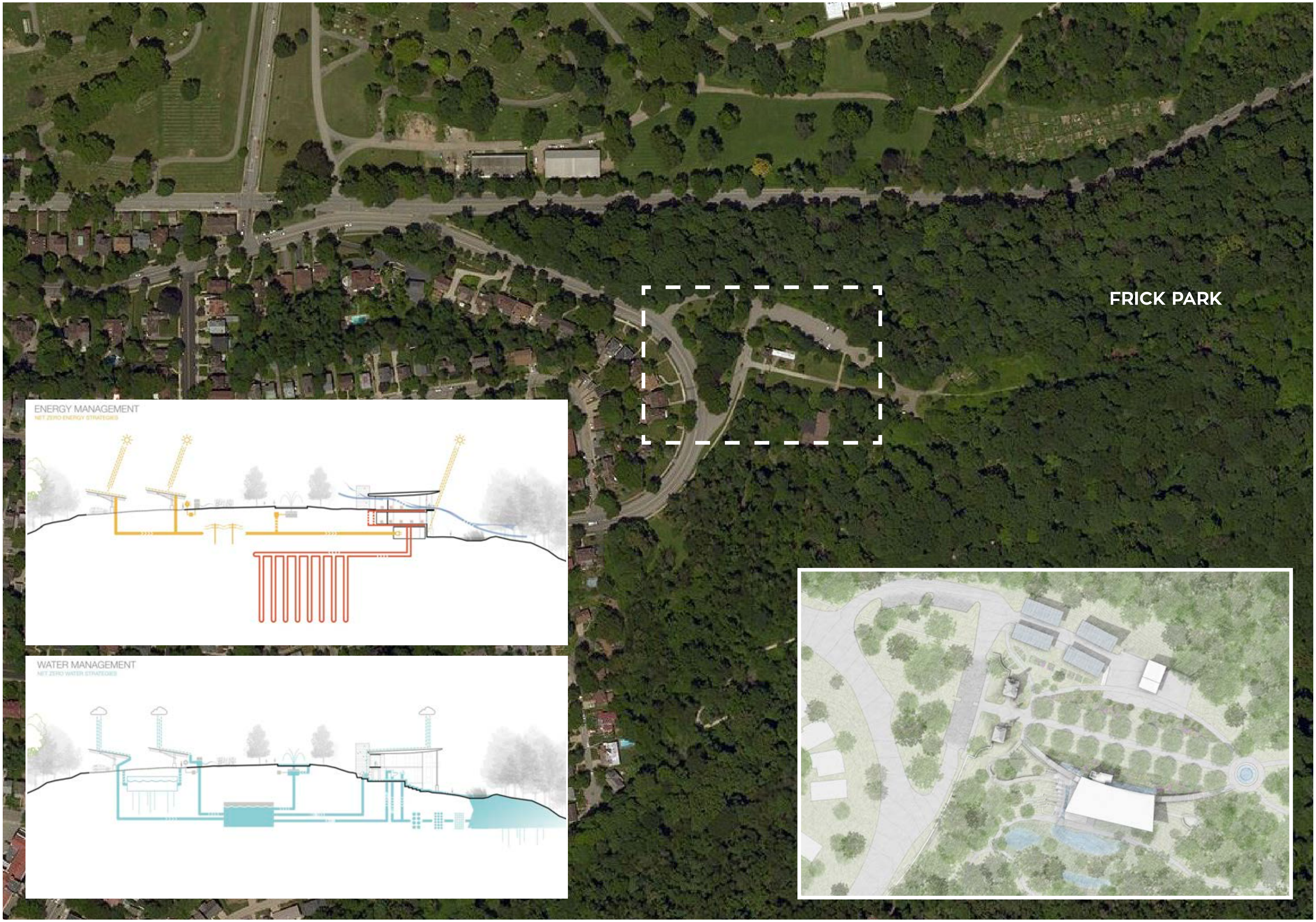
FRICK ENVIRONMENTAL CENTER

LOCATION: PITTSBURGH, PA, USA
ARCHITECT: BOHLIN CYWINSKI JACKSON
AREA: 15,570 SQ FT
YEAR: 2016

The Frick Environmental Center (FEC) is the world's first publicly accessible, free admission Living Building Challenge-targeted project. The building will be a world-class center for environmental education. A joint venture between the City of Pittsburgh and Pittsburgh Parks Conservancy, the FEC will act as a gateway to the 644-acre Frick Park.

The building will be a living laboratory, designed and engineered to achieve Living Building Challenge and LEED Platinum standards, and providing experiential learning to a projected 20,000 K-12 students and hundreds of thousands of people who visit Frick Park each year. The Conservancy now has a home base for its growing environmental education programs, which are offered to students in Pittsburgh's public schools. Fully equipped classrooms, offices, and support spaces provide the much-needed amenities for the Conservancy's award-winning programs, while a public 'living room' and gallery space welcome park visitors to stop in to learn more about the park's history and extensive trails, and the sustainability of the building."

The design and construction team collaborated with the City and Parks Conservancy throughout the design process. The project continues a long history of design excellence by engaging with and restoring many of the site's original historic features including the John Russell Pope-designed gatehouses, as well as the allée and fountain, which were part of the original Innocenti and Webel 1935 Masterplan.


FRICK PARK
ENERGY MANAGEMENT
WATER MANAGEMENT

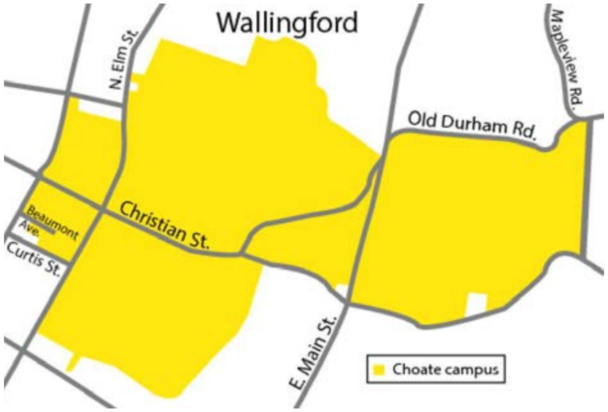
KOHLER ENVIRONMENTAL CENTER

LOCATION: CHOATE ROSEMARY HALL
WALLINGFORD, CT, USA
ARCHITECT: ROBERT A.M. STERN
ARCHITECTS
AREA: 32,000 SQ FT
COST: $8.8 M
YEAR: 2012

SERVICES:
ENVIRONMENTAL DESIGN CONSULTING
ENERGY ANALYSIS
BENCHMARKING: LEED
LIGHTING DESIGN
LEED PLATINUM
NET ZERO ENERGY

"The Kohler Environmental Center is the first teaching, research and residential environmental center in U.S. secondary education. By achieving net zero energy use it reinforces the school's mission to promote environmental understanding, land stewardship, and social responsibility."

The Kohler Environmental Center (KEC) is a LEED Platinum Certified / Net Zero Energy Building



SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER

LOCATION: MATHIS LAB
EDGEWATER, MD, USA
ARCHITECT: EWINGCOLE
AREA: 94,000 SQ FT
LOT SIZE: 2,650 ACRES
COST: $29 M
YEAR: 2014

SERVICES:
ADJUSTABLE LAB SPACE
OFFICE SPACE
FIELD PREPARATION AREA
WET/DRY SAMPLE STORAGE
ENVIRONMENTAL CONTROL ROOM

"This project includes a new laboratory addition to the existing Mathias Lab building. EwingCole performed a facilities assessment of the existing Mathias Lab building, which confirmed the need for expansion to accommodate increased and more efficient research activities in keeping with their mission.

The existing building required select renovation including the relocation or "rezoning" of numerous labs and offices, and the creation of storage facilities. Designers used Laboratories for the 21st Century (Labs21) design guidelines for project development.

The overall project design includes features and systems to earn a minimum certification of LEED Gold."

"The Charles McC. Mathias Laboratory houses 92,000 ft2 of laboratory and office space. The building houses a field prep and storage area, wet and dry sample storage, chemical sample prep area, shop area and environmental control rooms.

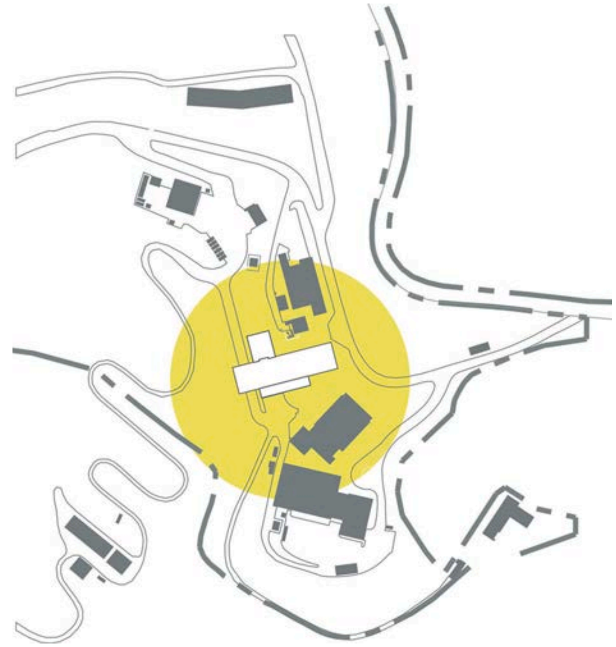
Lab spaces are open concept with computer stations, adjustable lab benches, snorkel-style bench hoods, chemical fume hoods and DI water system."

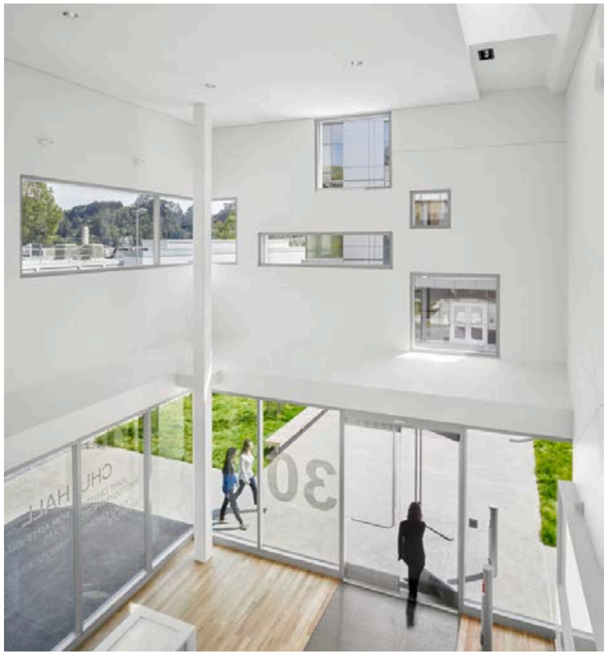
CHU HALL/SOLAR ENERGY RESEARCH CENTER

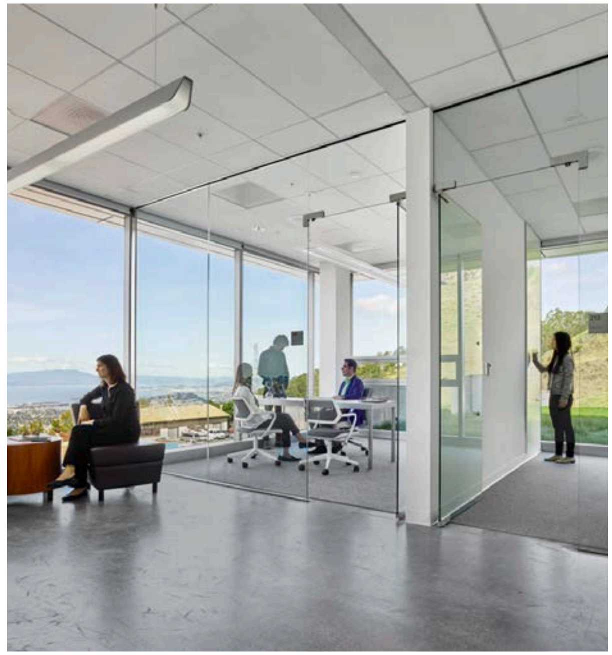
LOCATION: LAWRENCE BERKELEY NATIONAL LABORATORY, BERKELEY, CA, USA
ARCHITECT: SMITHGROUPJJR
AREA: 39,000 SQ FT
YEAR: 2015

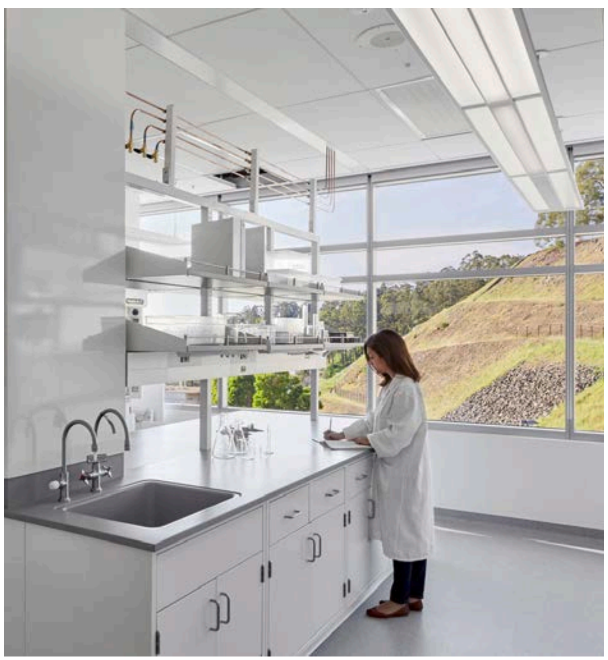
The recently completed $59 million Solar Energy Research Center has opened at the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab). Chu Hall is Berkeley Lab's latest addition to a collection of buildings that create a hub of interactive and collaborative research.

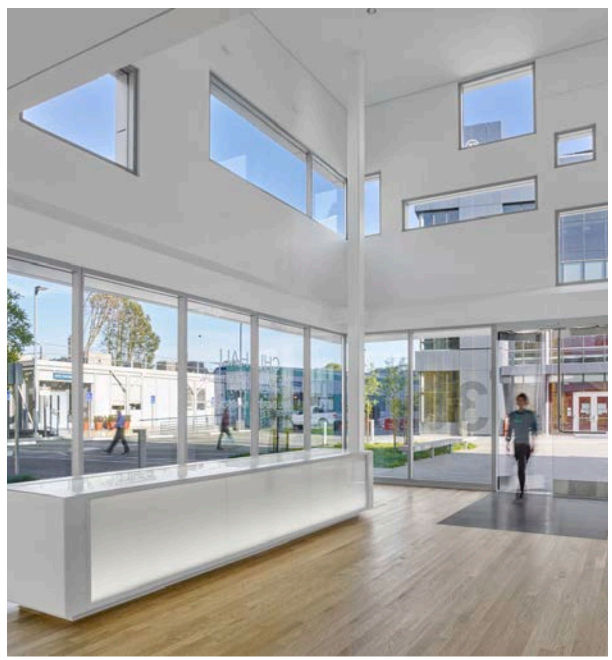
The new 39,000-square-foot, three-story building is the new home for 100 researchers, most from the Department of Energy-funded Joint Center for Artificial Photosynthesis (JCAP), the nation's largest research program dedicated to the development of an artificial solar-fuel generation technology.











Chu Hall has three architectural components, each situated on one of the building's three levels.

Level 1 is the subsurface "Plinth,"which takes up more than 50 percent of the overall square footage and designed to be an ultra-low vibration space to house laboratories sensitive to light and vibration.

Level 2, located on the ground level, is the "Breezeway." Designed to foster interdisciplinary interaction, it is the location for the main door and entrance lobby, shared office space for principal investigators, cubicles for Theory researchers and small and large conference rooms.

Level 3 is the "Corona," a simple rectangular form that houses wet lab spaces as well as research to develop technology needed to assemble nanoscale components into active systems.

Outside, a new courtyard space serves as a central meeting point used by Chu Hall researchers as well as those from nearby labs in the Old Town neighborhood.

MONTREAL BIOSPHERE

LOCATION: QUEBEC, CANADA
ARCHITECT: BUCKMINSTER FULLER
AREA: 65,000 SQ FT
COST: $175 M
YEAR: 1967

SERVICES:
ENVIRONMENT MUSEUM

The only environment museum in North America. The Biosphere is devoted to educating visitors on major environmental issues relating to water and air quality, sustainable development, and ecotechnologies.

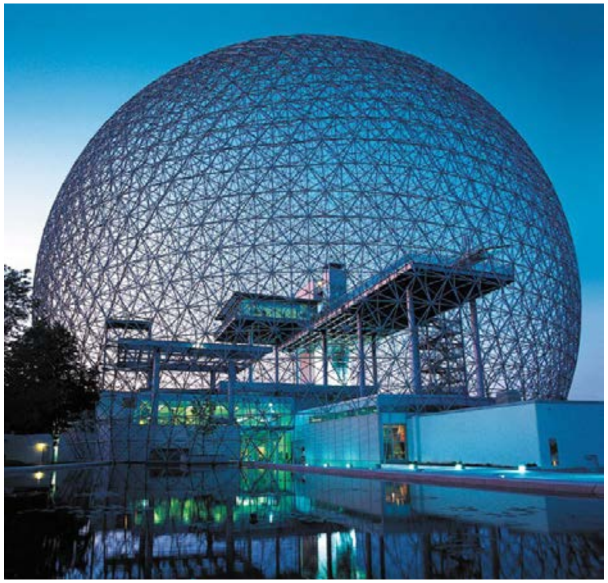
A complex system of shades was used to control its internal temperature. The sun-shading system was an attempt by the architect to reflect the same biological processes that the human body relies on to maintain its internal temperature.

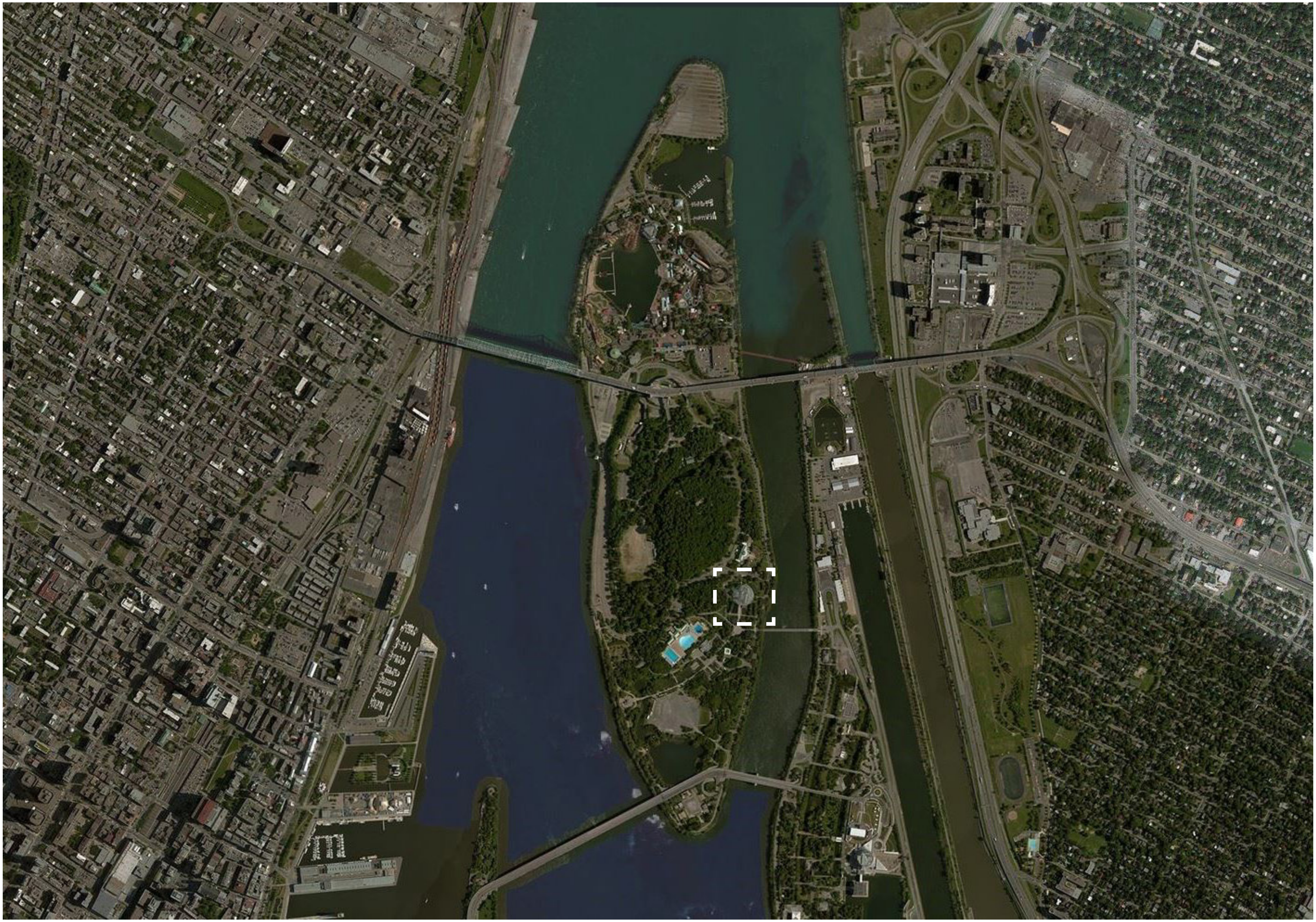
Even more ambitious, Fuller's original idea for the geodesic dome was to incorporate "pores" into the enclosed system, further likening it to the sensitivity of human skin.

Sadly, the shading system failed to work properly and was eventually disabled.

In August, 1990, Environment Canada purchased the site to turn it into an interactive museum showcasing and exploring the water ecosystems of the Great Lakes-Saint Lawrence River regions.

The museum was inaugurated in 1995 as a water museum, and is a set of enclosed buildings designed by Éric Gauthier, inside the original steel skeleton.





CHAPTER 6

C L I E N T

CLIENT SELECTION

In selecting a client for the Bio-Inspired Solutions Laboratory, the objective was to connect the project to a university, in order to allow students to undertake groundbreaking research in the field of biomimicry.

A study was conducted in search of leading institutions in environmental research. The top three universities were considered based on the requirements listed at right.

An in-depth study of these schools followed in order to select the university with the greatest need, potential use, and available space for the proposed research facility.

REQUIREMENTS:

1. Shared principles and values on sustainability.
2. Committed to conservation of the environment.
3. Promote interest in study of nature.
4. Ideal location for energy harvesting.
5. Contain site suitable for proposed facility.

POTENTIAL CLIENTS (UNIVERSITIES):

The following list outlines the universities with the highest rated environmental and biological science programs. as of 2014:

Harvard University	Boston, MA
Massachusetts Institute of Technology (MIT)	Cambridge, MA
Stanford University	Stanford, CA
University of California-Berkeley	Berkeley, CA
California Institute of Technology	Pasadena, CA
Johns Hopkins University	Baltimore, MD
University of California-San Francisco	San Francisco, CA
Yale University	New Haven, CT
Princeton University	Princeton, NJ
Scripps Research Institute	La Jolla, CA
Cornell University	Ithaca, NY
Duke University	Durham, NC
Washington University in St. Louis	St. Louis, MO
Columbia University	New York, NY
Rockefeller University	New York, NY
University of California-San Diego	La Jolla, CA
University of Chicago	Chicago, IL
University of Wisconsin-Madison	Madison, WI
University of California-Davis	Davis, CA
University of California-Los Angeles	Los Angeles, CA

#1 HARVARD UNIVERSITY

Biomedical Engineering

Chemical and Physical Biology

Earth and Planetary Sciences

Engineering Sciences

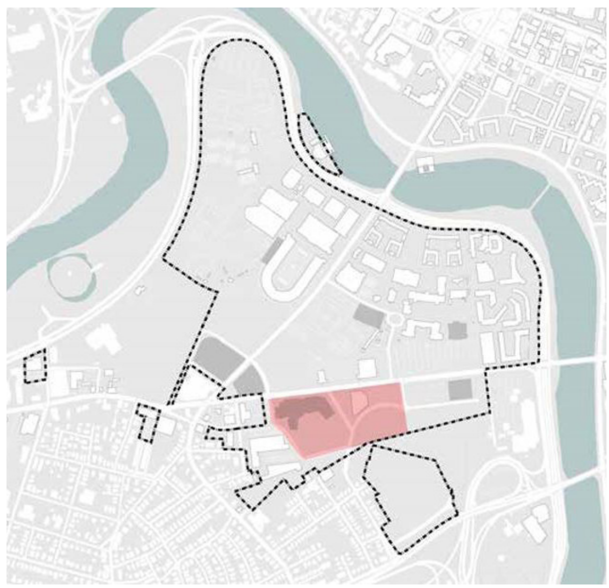
Environmental Science and Public Policy

Integrative Biology

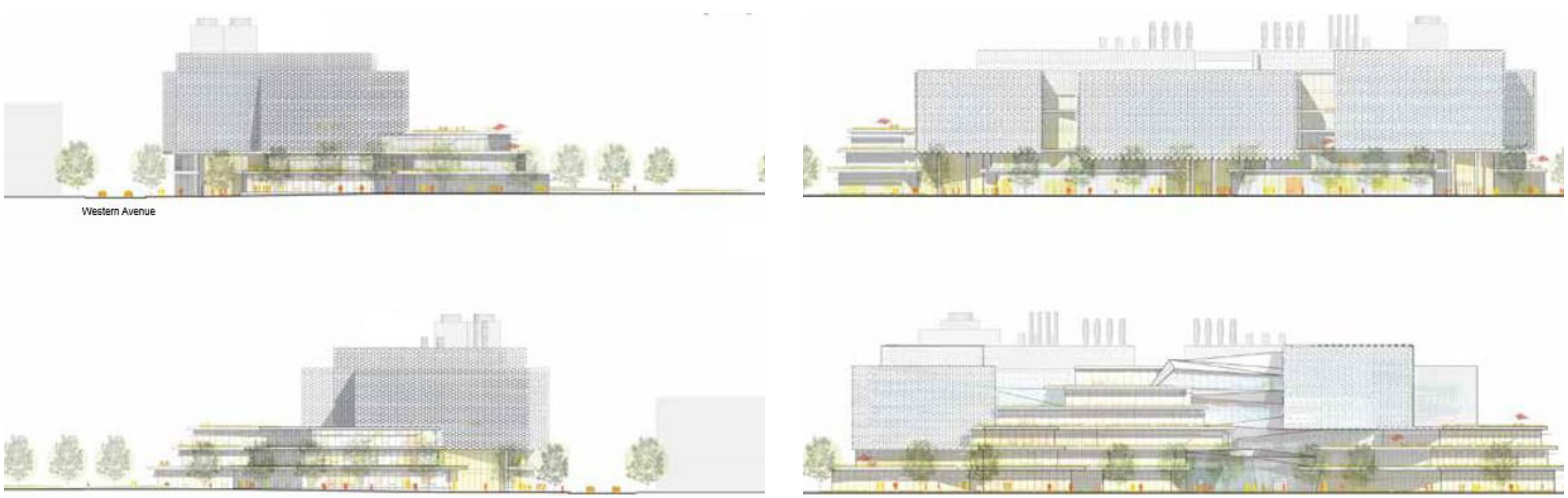
Visual and Environmental Studies

Harvard University is a private Ivy League research university in Cambridge, Massachusetts, established in 1636. However, the university has recently approved the Allston Campus, a complex for the study of science and engineering. **The proposed complex contains program not dissimilar to that of the thesis project**, such as laboratories and teaching environments, with a focus on natural sciences and renewable energy products.

	SEC	114 Western	TOTAL
Dedicated Laboratory	209,000	0	**209,000**
Admin	8,400	12,200	**20,600**
Amenities / Retail	31,000	1,700	**32,700**
Atrium / Circulation	122,250	20,800	**143,050**
Teaching Environments	58,200	14,300	**72,500**
Core Layout	16,500	2,500	**19,000**
TOTAL	**445,350**	**51,500**	**496,850**



Allston Campus - Science and Engineering Complex
(Proposed 2015)


Western Avenue

#2 MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

Biological Engineering

Biology

Biomedical Engineering

Civil and Environmental Engineering

Civil and Environmental Systems

Earth, Atmospheric and Planetary Sciences

Energy Studies

Environmental Engineering Science

Toxicology and Environmental Health

MIT campus in Cambridge, MA currently has three buildings which serve the majority of the biological science majors.

The Koch Building, named for David H. Koch (SB & SM '62), is a leading-edge research and teaching facility and the administrative headquarters of MIT Biology. Home to more than 30 members of the faculty, the building, which opened in 1994, was designed to provide a dynamic forum for interaction and collaboration.

The Administrative Offices for the Department of Biology are located on the first floor of the Koch Building. These offices support the overall needs of the Biology faculty and the educational program for the department. In addition, the offices are in charge of the administrative, financial, human resources, and operations & safety functions of the Koch Building.

Koch Biology Building (1994)
Goody Clancy & Associates

Dreyfus Building (1970) - Dept. of Chemistry
I. M. Pei & Partners

Dept. of Earth, Atmosphere, and Planetary Sciences (1964)
I. M. Pei & Partners

MIT 2030 PLAN

The long-term plan for the campus illustrates the potential future uses of the university's campus. The campus is highly concentrated with different building types, such as the academic, residential, athletic, and administrative program.

MIT campus' location in such a highly developed city does not seem to have enough open space to accommodate the proposed facility.

The proposed square footage for the environmental research facility does not seem suitable for any of the available sites within a reasonable distance from the campus center.

#3 STANFORD UNIVERSITY (SU)

Bioengineering

Biology

Biomedical Engineering

Chemical Engineering

Chemistry

Earth System Science

Energy Resources Engineering

Environmental Engineering

Geological Sciences

Geology and Earth Science

Geophysics

Materials Engineering

Physics

Stanford University is one of the world's leading research and teaching institutions in biological and environmental studies. Located in Stanford, California, the university's sustainable efforts are ingrained in the philosophy of student education. **The university's goals clearly align with the principles and goals of the thesis**.

The university exhibits an inherent drive to preserve and study nature. This is apparent from clubs, organizations, classes, and published research journals from students and faculty members. The open space preserves that surround the campus act as sites for scientific field research and are integral in classroom studies.

Institutional Goal #1: Maintain land use flexibility.

Institutional Goal #2: Maintain and enhance biological resources (i.e., native biodiversity) on University lands so that these resources can be utilized by future generations of students and faculty researchers.

Institutional Goal #3: Prepare a conservation program that incorporates sustainable land use planning policies and practices.

Institutional Goal #4: Implement cost effective conservation measures that efficiently invest the University's assets.

Institutional Goal #5: Define the University's legal responsibilities toward biological resources so that the University can develop its lands and operate in an environmentally and fiscally responsible manner during the next 50 years.

Institutional Goal #6: Utilize Stanford's water resources for the benefit of the University's research, educational, and operational activities, to the full extent of its water rights.

Biological Goal #1: Maintain and enhance natural communities so that they benefit the Covered Species.

Biological Goal #2: Stabilize the local California tiger salamander population and increase its chance of long-term persistence at Stanford.

Biological Goal #3: Maintain ponds to promote California tiger salamander reproduction in the Foothills.

Biological Goal #4: Increase the local California red-legged frog population and increase its chance of long-term persistence at Stanford.

Biological Goal #5: Maintain or improve hydrologic and terrestrial conditions that presently support steelhead and increase the chance of long-term persistence for the local steelhead population.

Biological Goal #6: Maintain and improve habitat for western pond turtle to increase its chance of long-term persistence at Stanford.

Biological Goal #7: Maintain or improve habitat that could support the San Francisco garter snake and continue to contribute to the body of information about garter snakes at Stanford.

CHAPTER 7

CONTEXTUAL INFORMATION

HISTORICAL TIMELINE: PALO ALTO, CA

18th century	19th century	Early 20th century	1940s	1950s
-1769 - Earliest recorded history -City named after El Palo Alto, a coastal redwood tree	-1855 - The township of Mayfield was formed (now southern Palo Alto) -1862 - Flood, severe damage -1868 - “Great San Francisco earthquake” -1875 - Jean Baptiste Paulin Caperon purchased over 1,000 acres in Mayfield -1882 - Leland Stanford bought Ayshire Farm -1891 - Jane and Leland Stanford founded Stanford University -1894 - Palo Alto incorporated in Santa Clara County	-1902 - The Carpenter Gothic Victorian St. Thomas Aquinas Church is completed in Palo Alto -1906 - The California earthquake on April 18th caused over 3,000 fatalities and severe damage in the San Francisco Bay area -1910’s: - Northern EPA becomes a military training ground (WWI) -1911 - Flood, severe damage -1925 - Palo Alto voters approved annexation of Mayfield -1936 - The Hanna–Honeycomb House by Frank Lloyd Wright is completed	-1940 - Palo Alto Airport of Santa Clara County begins operations	-1951 - Stanford Industrial Park in Palo Alto is completed -1955 - The Christmas Flood, severe damage. More than 650 Palo Alto homes were flooded, totaling $1.1 million in damage

1960s

-1961 - The Frontier Village amusement park in San Jose opens

-1965 - The Grateful Dead forms in Palo Alto

-1969 - Violent protest; demonstrators brought traffic to a standstill at a Stanford Research Institute office on Page Mill Road, resulting in $20,000 in damage and 93 people arrested

1970s

-1970s - University Ave stores declare bankruptcy

-1971 - Palo Alto Art Center is founded, under a previous name Palo Alto Community Cultural Center

-1977 - Largest display of civil disobedience at SU; 294 arrested

1980s

-1980 - Palo Alto Yacht Harbor closes after political campaign

-1983 - The San Jose School District declares bankruptcy

1990s

-1995 - The San Jose Earthquakes soccer team is established

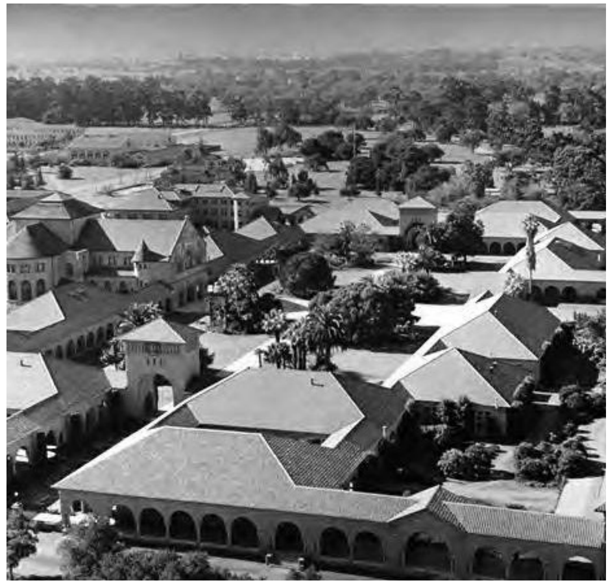
Early 21st century

-2003 - Tesla Motors is founded in Palo Alto

-2011 - Steve Jobs dies at his home in Palo Alto

HISTORICAL PHOTOGRAPHS

1983 Foothills Park



1950 Stanford University

1941 University Ave

1983 Boronda Lake

1888 Inner Quad Construction

1906 Memorial Church After Earthquake

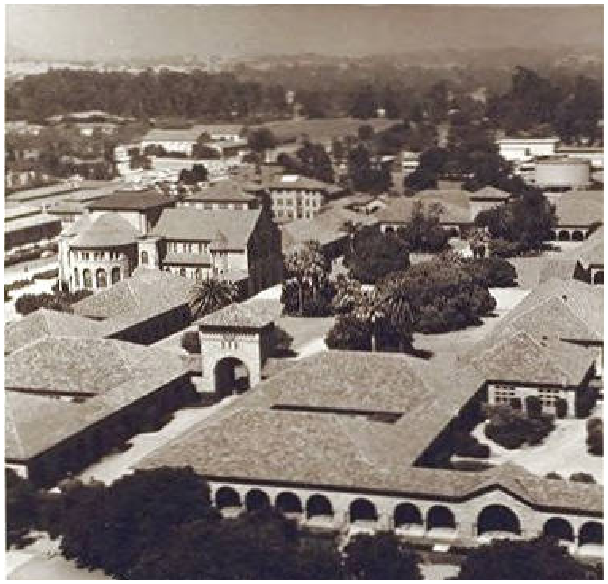
1950s Palo Alto

1955 Christmas Flood

1965 Palo Alto

Felt Lake

Palo Alto



Birds-eye Stanford

DEMOGRAPHICS

Palo Alto Demographic Profile (2010)	
Total Population	64,403 - 100.0%
One Race	61,706 - 95.8%
Not Hispanic or Latino	60,429 - 93.8%
White alone	39,052 - 60.6%
Black or African American alone	1,131 - 1.8%
American Indian and Alaskan Native alone	65 - 0.1%
Asian alone	17,404 - 27.0%
Native Hawaiian and Other Pacific Islander alone	135 - 0.2%
Some other race alone	254 - 0.4%
Two or more races alone	2,388 - 3.7%
Hispanic or Latino (of any race)	3,974 - 6.2%

Palo Alto Historical Population		
Census	Population	% (+/-)
1900	1,658	-
1910	4,486	170.6%
1920	5,900	31.5%
1930	13,652	131.4%
1940	16,774	22.9%
1950	25,475	51.9%
1960	52,287	105.2%
1970	56,040	7.2%
1980	55,225	-1.5%
1990	55,900	1.2%
2000	58,598	4.8%
2010	64,403	9.9%
Est. 2016	67,024	4.1%

*Information provided by the 2010 United States Census ("Census 2010").

FLORA

The hilly landscape of Palo Alto contains an abundance of plant and animal life. The city is **committed to properly documenting, protecting, and managing its natural resources**.

The open prairies give way to dense thickets of mesquite, acacia, and thorny undergrowth. These thickets are believed to have **inspired the name Palo Alto (Tall Trees)**.

This assortment of habitats also supports a variety of animal life. Coyotes, jackrabbits, and bobcats roam the open plain. Javelina, opossums, tortoises and many other animals find refuge in the brush. Rattlesnakes, scorpions, and fiddler crabs can be found in burrows under the ground. Dozens of different kinds of birds, including raptors and tropical species can be spotted perched on tree branches.

Palo Alto continues to display dedication to the management and restoration of natural habitats and wildlife. The following pages illustrate some of the animal and plant life found in the city.

Coast Live Oak

California Laurel

California Buckeye

Madrone

Valley Oak

Arroyo Willow

California Black Oak

Blue Oak

Big Leaf Maple

Canyon Live Oak

FLORA

Fuller's Teasel

Farewell-to-Spring

Wild Rose

Western Verbena

Purple Starthistle

Chaparral Pea

Indian Pink

Poison Hemlock

Blue Elderberry

Soap Plant

Fairy Bells

Hartweg's Tauschia

FAUNA

Broad-Footed Mole

Black-tailed Jackrabbit

Brush Rabbit

Pocket Gopher

Shrew

Black-tailed Deer

Striped Skunk

Long-tailed Weasel

Gray Fox

Bobcat

Channel Catfish

Red-Ear Sunfish

FAUNA


California Ground Squirrel


Eastern Fox Squirrel


Virginia Opossum


American Beaver


North American River Otter


American Badger

Mountain Lion

Tule Elk

North American Porcupine

Common Muskrat

Coyote

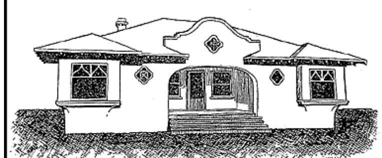
Northern Raccoon

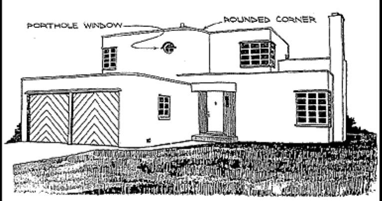
ARCHITECTURE IN PALO ALTO

Palo Alto is adorned wih richly varied architecture of many styles, including Queen Anne, Craftsman, Mission Revival, Streamline Moderne, Classical Revival, Prairie Style, Tudor Revival, Medieval Revival, Colonial Revival, Bay Area Tradition, and Spanish Colonial Revival. University Avenue (pictured at right) is particularly characterized by its variety of cafes, restaurants, shops, and businesses lining either side of the street.

WAVERLEY ~ QUEEN ANNE

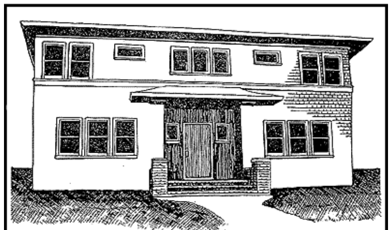
FULTON ~ CRAFTSMAN


FULTON ~ MISSION REVIVAL

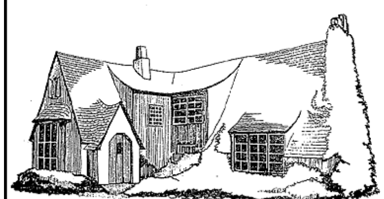


N. CALIFORNIA ~ STREAMLINE MODERNE

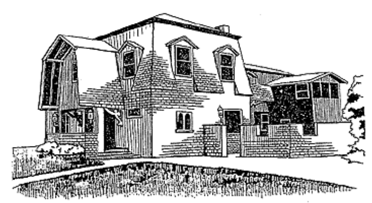

UNIVERSITY AVE. ~ CLASSICAL REVIVAL


EMERSON ~ PRAIRIE


CHURCHILL ~ TUDOR REVIVAL


COWPER ~ MEDIEVAL REVIVAL


UNIVERSITY AVE. ~ COLONIAL REVIVAL


BRYANT ~ BAY AREA TRADITION


RAMONA ~ SPANISH COLONIAL REVIVAL

TOBACCONIST
HEMINGWAY
CIGARS TOBACCO
480
CIGARS
OPEN
VARSI
BORDE
BOOKS MUSIC

ARCHITECTURE IN PALO ALTO

Commercial Building on Ramona Street

Cardinal Hotel

261 Hamilton Street

Palo Alto High School

Post Office

City Hall

Hanna-Honeycomb House

Apple Store

The Eco Center

Stanford Shopping Center

Stanford Shopping Center

Blue Bottle Cafe

ARCHITECTURE ON CAMPUS

Similar to that of Palo Alto, the architecture of Stanford's campus ranges in style from Classical Revival to modern and contemporary styles.

Stanford University attracts many tourists each year, some visiting scholars and others potential students. Of the many attractions, Stanford's unique architecture captures the interest of visitors the moment they step off the tour bus. Our architecture represents many themes, each building adhering to the styles of the time as well as the economic situation of the times. What results is a campus that represents a mixing pot of styles, while still keeping a theme of tan walls and red roofs that define Stanford architecture.

The most historic section of the Stanford campus is the original sandstone quadrangle with its thick Romanesque features and Memorial Church. Distinctive in the university architecture are the enclosed courtyard, archways, red tile roofs, thick walls, and buff sandstone from which the buildings are constructed.

The modern architecture of buildings carried over to Hoover Tower—a tall, minimalist bell tower with hints of Art Deco (zigzag designs and four minor towers on the corners).

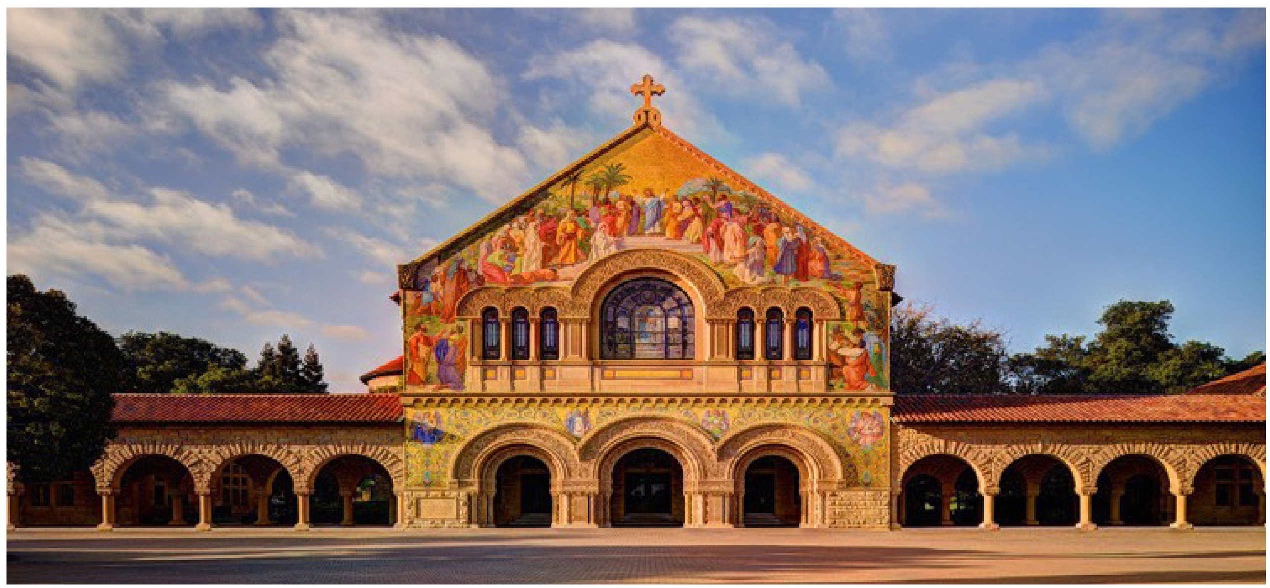
ARCHITECTURE ON CAMPUS


Hoover Tower


Wallenberg Hall


Stanford Knight Management Center


Cantor Arts Center


Stanford Memorial Church

Lokey Building

Bing Concert Hall

Shiram Center

The Gates Computer Science Building

Stanford Sun

Stanford Medical Center

SITE VISIT PHOTOGRAPHS (JULY-29-2017 THROUGH AUGUST-01-2017)

CHAPTER 8

SITE SELECTION + ANALYSIS

SITE SELECTION REQUIREMENTS

Stanford University was selected as the client in light of the state of California's recent advancements in renewable energy products and the university's efforts in establishing a basis for energy responsible design. Stanford University has already begun to introduce its students to biomimicry through the Biomimetics and Dexterous Manipulation Lab (BDML). The BDML is a student-led organization dedicated to biomimetic research as applied to robotics.

The intervention will provide a 72,000 square foot environmental research facility for Stanford University in cooperation with the School of Earth, Energy, and Environmental Sciences. **The facility will provide students with an ideal location for environmental research and study**.

The following requirements served as guidelines for the site selection::

1. Located near or within reasonable distance from campus.
2. Large enough to accommodate a building and outdoor research.
3. Within or directly adjacent to a biological preserve for the study and examination of wildlife species.

STANFORD FOOTHILLS PARK

The city bought the land for Foothills Park in 1958 and dedicated it as a park in 1965. Part of the reason Mr. Lee (the previous owner) sold the land to the city was to have it maintained as open space and to remain undeveloped; this property has been operated as open space ever since. Prior to the Lee family owning the land, the earliest occupants were Native-American peoples (at least 3,000 years ago).

In 1833, the governor of Alta California granted 4,400 acres to Domingo Peralta and Don Maximo Martinez, one of the Martinez daughters married in to the Boronda family and the land became known as Boronda Farm, the Dougherty family leased land from the Borondas until the Lee family purchased it.

The Stanford Dish is a special area to the surrounding communities, and it serves many purposes, including:

Academic Programs – The Dish itself is a radiotelescope that is still in use. Other research and teaching programs also use the dish area.

Environmental Restoration – Stanford's Conservation Biology Program is directing a program of environmental restoration in the dish area, which includes use of native grasses and other plants.

Habitat Conservation – Portions of the dish area will be devoted to special efforts to enhance habitat for the California tiger salamander, including the development of new breeding ponds.

Recreation – The Dish is a popular recreational area for hiking and jogging and is open to the public from approximately sunrise to sunset throughout the year.

FOOTHILLS PARK PHOTOGRAPHS

SITE VISIT PHOTOGRAPHS (JULY-29-2017 THROUGH AUGUST-01-2017)

FELT LAKE

The 400-acre site is located within a ten minute drive from Stanford University. It is currently undeveloped land owned by the university, home to a 150 year old reservoir called Felt Lake.

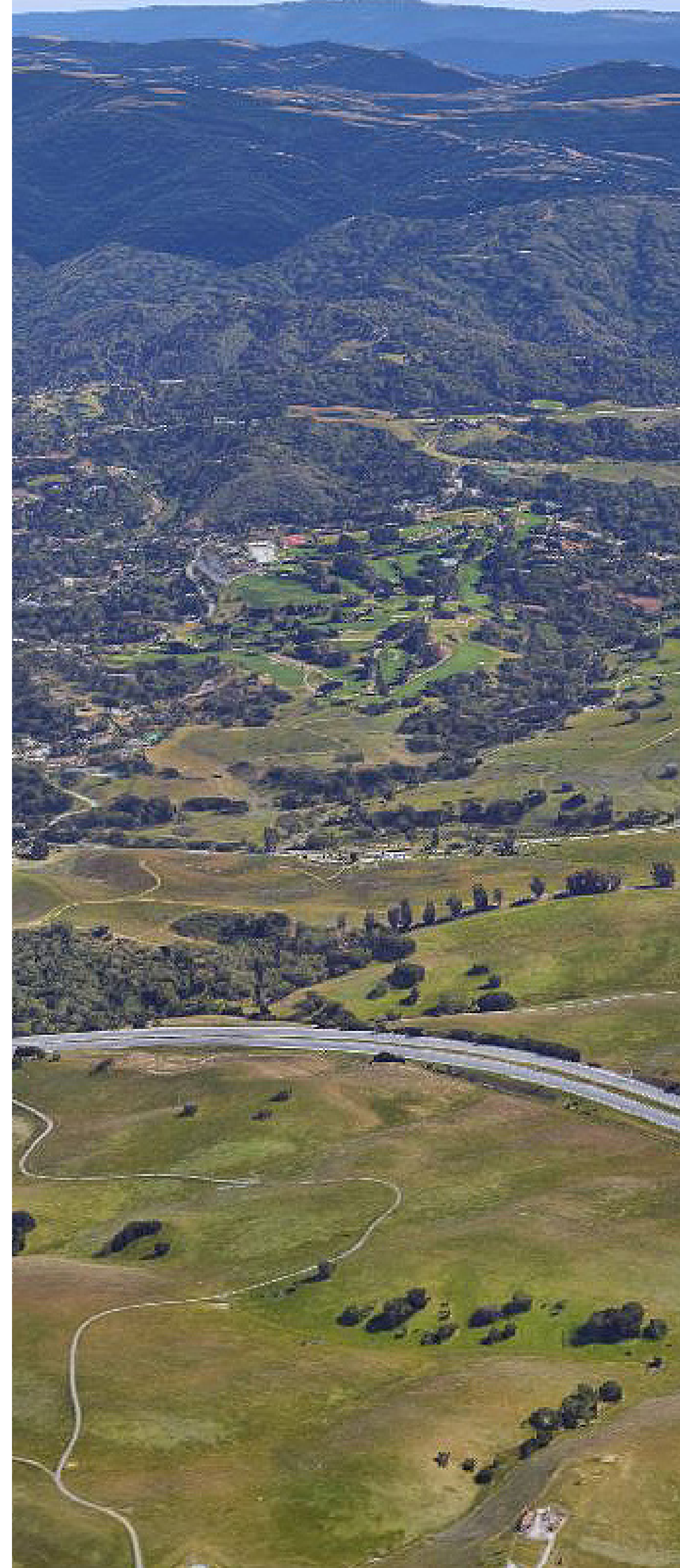
Felt Lake was constructed by gold miner and lumber dealer Job Johnston Felt, who bought 700 acres in northern Santa Clara County to farm. It was his dream to build two water companies, San Francisquito and Los Trancos, so he diverted thousands of gallons of water from Los Trancos Creek and then constructed a large earthen dam to hold them.

But by the mid-1880s, facing much opposition to his plans, the elderly Felt abandoned the water company idea. He sold the farm to Timothy Paige, who quickly sold it to Leland Stanford Sr. in 1887. The university later added a larger dam to hold irrigation water for the growing campus.

Local lore holds that Felt Lake was partially drained once before, back in 1907, to look for the double-barreled shotgun of 22-year-old Stanford law graduate Chester Silent. Silent, a member of a prominent Los Angeles family, was found dead in a boat at Felt Lake. After the sheriff found the muddy gun and saw that it had misfired, he ruled that Silent's death was a duck hunting accident.

But in decades since, the lake has filled with vast amounts of silt. According to campus biologist Alan Launer, who snorkels there regularly, it has also become home to nonnative creatures such as large-mouthed bass, bluegill, sunfish and catfish — as well as bullfrogs, large Asian snails and the cute red-eared turtles found in local pet stores.

Constructed in 1876, then expanded in 1929, Felt Lake had accumulated so much silt that it was no longer able to hold the water necessary for campus irrigation. Palo Alto is currently making an effort to restore the lake to its original size and purpose.



FELT LAKE PHOTOGRAPHS

View Facing West

View Facing South-West

View Facing North

View Facing North-West

View Facing West

SITE EVOLUTION

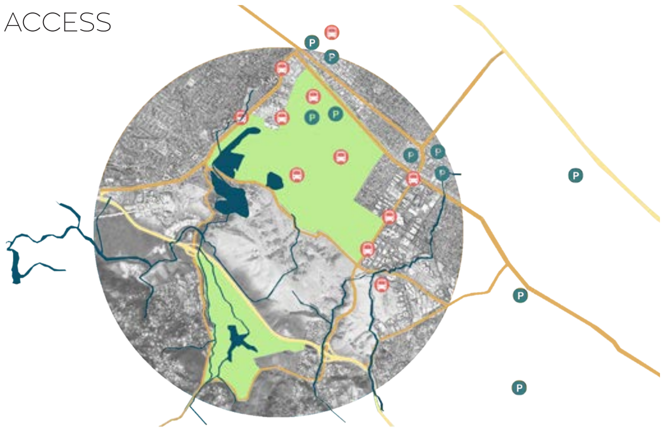
The Felt Lake site displays a palimpsest of its evolving history over the past century, including a distinct edge of 60' tall eucalyptus trees which once marked the southern edge of the old Stanford farm. Today, a line of housing development crowds up to the property line.

Interestingly, the memories of streams persist in the landscape, as well. The aerial image clearly shows sinuous lines of trees edging Matadero Creek.

The straight line running almost vertically is a railroad track, and the lines of trees that follow the creek stop at a major highway (El Camino Real), an old road that has been in that location for hundreds of years.

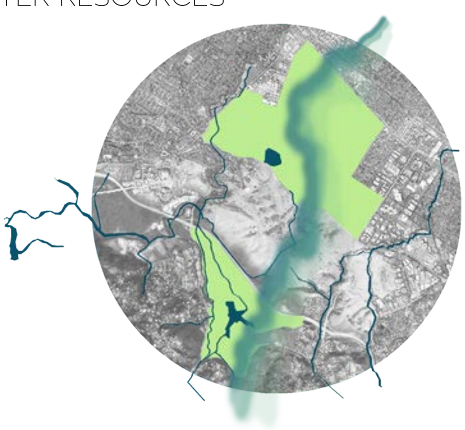
Felt Lake, aerial view, 1948

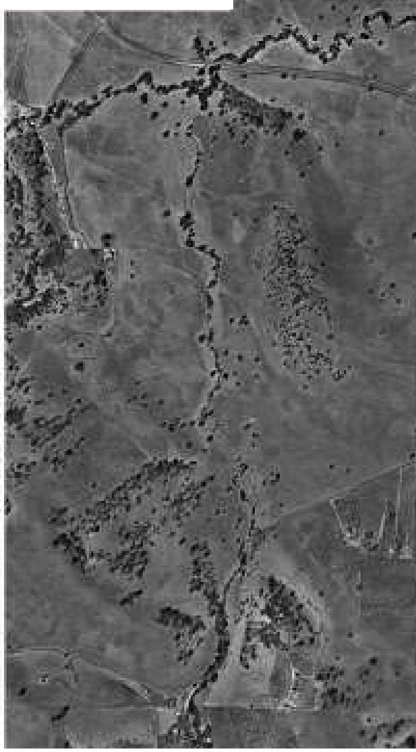
ACCESS



LAND-USES

WATER RESOURCES





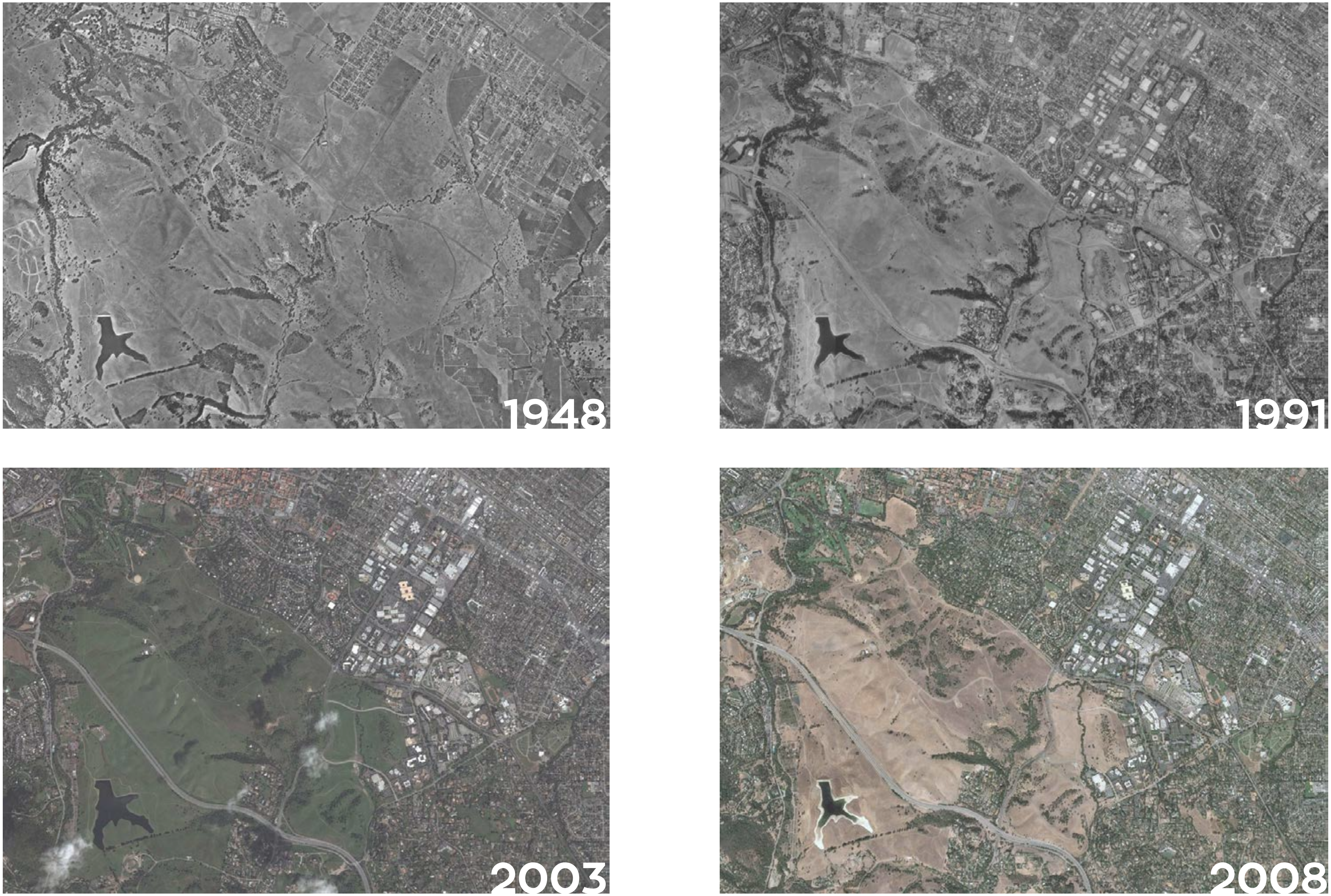
The historical, collaged aerial maps indicate that the tree lines have persisted for a long time, even through 50 years of intense development. The lines of trees along the creekbed have survived for about half a century.

The creek is in a different setting now than it had first been. Once it enters the industrial park, the stream is completely driven by runoff from acres of asphalt, and no longer fed by surrounding grassy fields.

This recent image highlights the creek in red once it leaves the Felt Lake site and enters the Stanford industrial park, eventually flowing into suburbia.

The creek is visibly broken in two places- first when it crosses Foothill Blvd, and then just after when channelized beneath the Tibco building (the straight segment in the middle of the industrial park).

SITE EVOLUTION



1876 - dam built; creation of JJ Felt Water Co.
1887 - 700 acre land sold to L. Stanford
1929 - Felt Lake expanded, water tower added

-Felt Reservoir currently holds 278,000,000 gallons of water.

-Used to irrigate athletic fields and golf course.

-60' tall eucalyptus trees mark the southern edge of old Stanford farm

INTERVIEW

An interview was conducted on Fri, Sep 15, 2017 with Alan Eugene Launer <aelauner@stanford.edu> in regard to the Felt Lake site. As a result of the interview, the native species around Felt Lake were discovered, as well as the existing conditions of the site, and the past condition of the site prior to the man-made reservoir, which would have been seasonal wetlands.

1. What types of native species are thriving in and around the reservoir? Are any in particular suffering?

Water fowl are often found in abundance at Felt (Audubon does a Christmas count there). Osprey were formerly common there, but a couple years ago a pair of bald eagles moved in, and the ospreys seem to have departed. There are few native fishes in Felt – which is not surprising since the reservoir is only marginally connected to a natural creek system. Western toads are often found in exceptionally high abundances at Felt, and Sierran treefrogs also reproduce there. There are no California red-legged frogs or California tiger salamanders at Felt....too warm and exposed for these protected species (but we have them elsewhere on Stanford lands). There are some western pond turtles living in Felt. The surrounding grasslands and oak woodlands are full of the usual California grassland species....deer, coyotes, bobcats, mountain lions, ground squirrels, voles, mice, jack rabbits, gopher snakes, western racers, fence lizards, tarantulas....and many raptors (red-tailed hawks and golden eagles frequently forage near Felt).

2. Does the dam cause any ecological challenges? Or prevent any challenges (such as flooding)?

Well, since Felt is not an in-channel reservoir/dam, the difficulties/challenges associated with many reservoirs/dams are minimized. It is an off-channel reservoir and its presence is not in any way impacting an active creek channel. A reservoir in the middle of what was originally a dry grassland obviously does change some things (by providing a year-round water source for one), but these changes are fairly localized. As for flooding....that is a Tom (Tom W Zigterman <twz@stanford.edu>) question, but as far as I know, the reservoir does not have a significant impact on flooding (+ or -).

3. Are there/have there ever been plans to remove the dam? (I have looked into Searsville Dam as a precedent).

Felt and Searsville reservoirs are very different. Searsville dam spans a creek, Corte Madera. Felt dam spans what was basically a dry canyon (which did have some seasonal run-off, but no prolonged flow). Water enters Searsville Reservoir directly from several creeks and flows over its dam and into the creek system downstream. Water is conveyed to Felt Reservoir via a flume from a somewhat distant point of diversion, and no water flows over the dam (there is an overflow channel....but given the inflow is managed, the overflow/outflow is minimal). There is no creek downstream of Felt Reservoir. Currently Felt Reservoir is a very important water storage facility. I don't know of any proposal to remove the Felt dam.

4. Does a fish ladder currently exist or are there plans in effect?

Since Felt is an off-channel reservoir, with no upstream and downstream creeks directly connecting to it, there is no reason to put a fish ladder at the Felt dam – there is no downstream connection with a creek. There is a fish ladder at the Los Trancos Creek diversion, but that keeps fishes in the creek and out of the flume (which does lead to Felt).

5. What is keeping Felt Reservoir from being a potable water source?

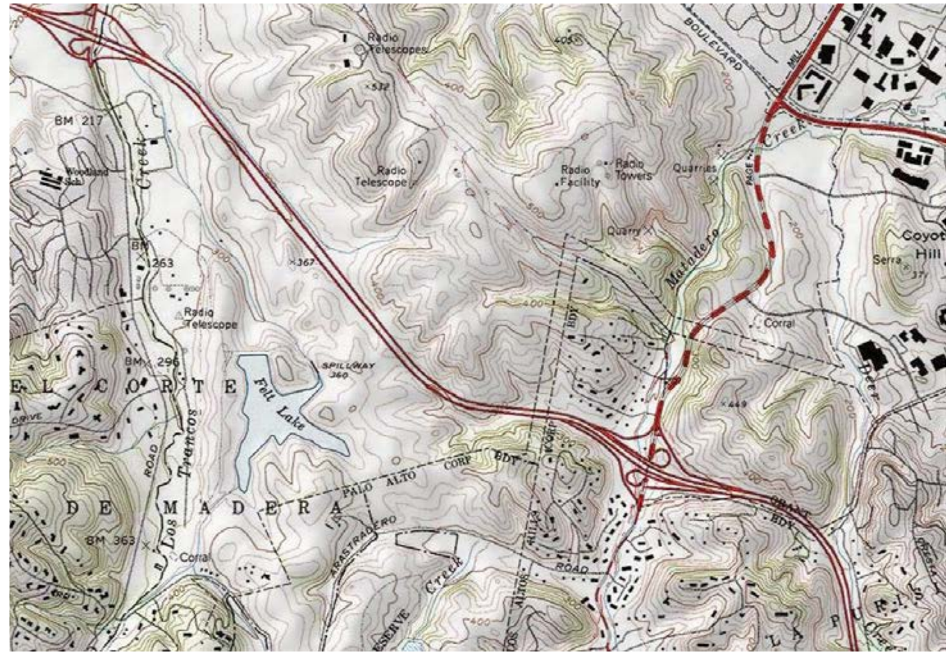
This is a question for Tom...but from what I can tell, the water in Felt is generally of good quality....add some treatment/filtering and it probably would be potable. But I don't know how practical or economically feasible it would be to install the required infrastructure. I've certainly waded and snorkeled in Felt many times.

6. Was Felt Reservoir completely man-made, or did a lake exist in its place beforehand?

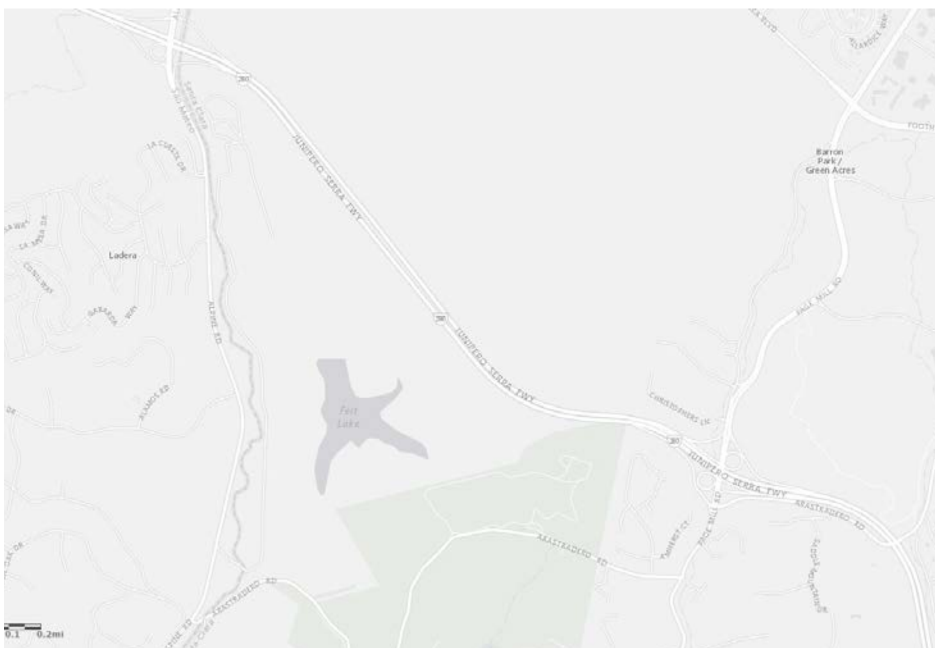
As far as I know there was no standing body of water located where Felt Reservoir is located prior to construction of the reservoir. The area would have had some seasonal "creeks" running through the rolling grasslands and the valley bottoms would had some wetland vegetation (the kind typical of seasonal California wetlands...canyon bottoms, not classic vernal pools), but the area where Felt is located was/is fairly dry. The current reservoir is the second version. A smaller reservoir existed at the site from 1876 to 1929 – at which time the current expanded reservoir was built.

GIS MAPS

GIS Streets



GIS Topography

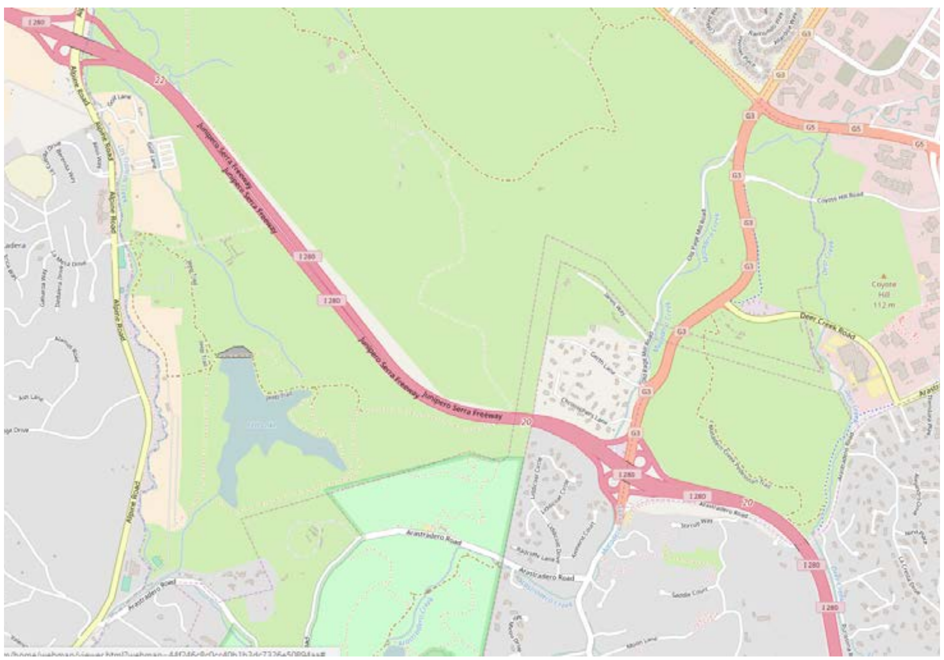


GIS White

GIS Topography

GIS Black

GIS National Geographic



GIS Open Street


GIS Rendered

18.28.010 Purposes
Open Space District [OS] The purpose and intent of this district is to:
(1) protect the public health, safety, and welfare;
(2) protect and preserve open space land as a limited and valuable resource;
(3) permit the reasonable use of open space land, while at the same time preserving and protecting its inherent open space characteristics to assure its continued availability for the following: as agricultural land, scenic land, recreation land, conservation or natural resource land; for the containment of urban sprawl and the structuring of urban development; and for the retention of land in its natural or near-natural state, and to protect life and property in the community from the hazards of fire, flood, and seismic activity; and
(4) coordinate with and carry out federal, state, regional, county, and city open space plans.

Open Space/Controlled Development
Land having all the characteristics of open space but upon which some development may be allowed. Open space amenities must be retained in these areas. Residential densities range from 0.1 to 1 dwelling unit per acre but may rise to a maximum of 2 units per acre where second units are allowed, and population densities range from 1 to 4 persons per acre.

Major Institution/University Lands/ Academic Reserve and Open Space:
Academic lands having all the characteristics of open space but upon which some academic development may be allowed provided that open space amenities are retained. These lands are important for their aesthetic and ecological value as well as their potential for new academic uses.

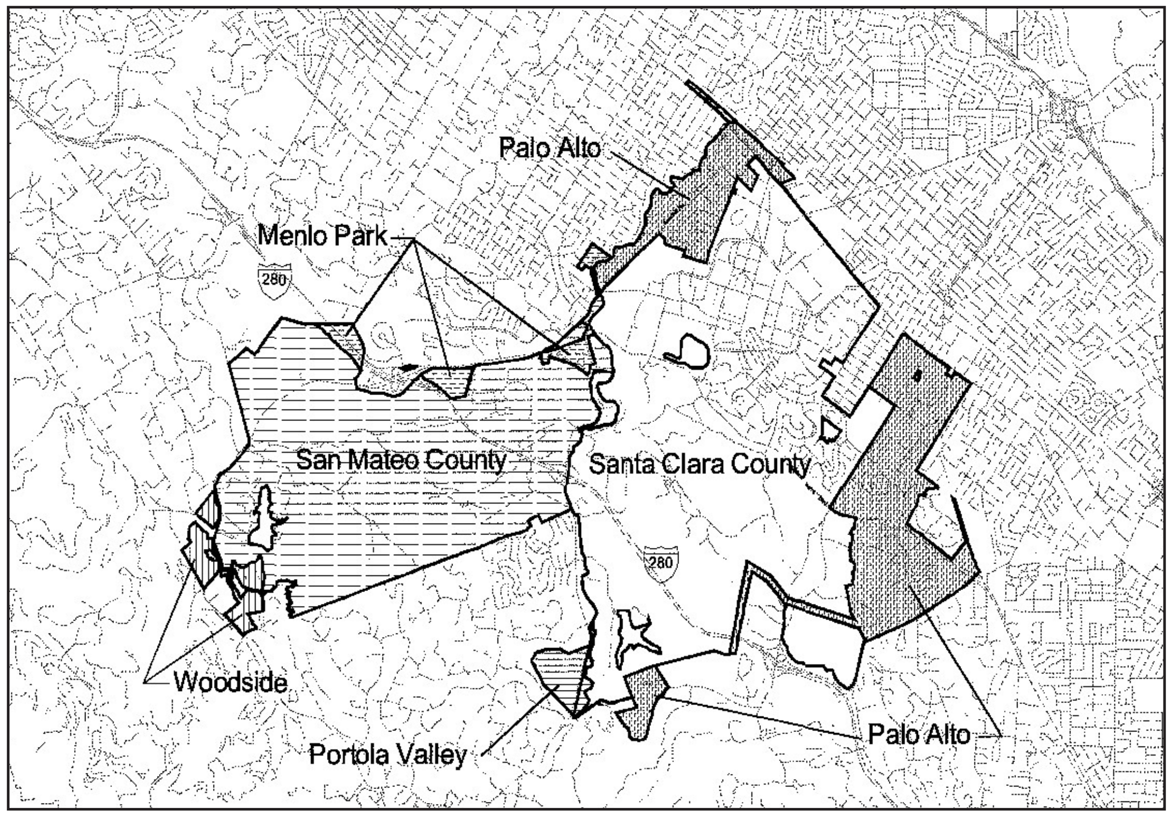


Figure Intro.1: Governmental Jurisdiction on Stanford Land

(a) Development Standards

The development standards for the special purpose districts are specified in Table 2, provided that more restrictive regulations may be recommended by the Architectural Review Board, pursuant to Section 18.76.020 of the Palo Alto Municipal Code.

TABLE 2
SPECIAL PURPOSE DISTRICT SITE DEVELOPMENT STANDARDS

	PF	OS	AC	Subject to Regulations in Chapter:
Minimum Site Specifications				
Site Area (acres)		10	5	
Site Width (ft)			250	
Site Depth (ft)			250	
Minimum Setbacks (ft)	*Setback lines imposed by a special setback map pursuant to Chapter 20.08 of this code shall apply*			
Front Setback	– (2)	30	30	
Rear Setback	– (2)	30	30	
Interior Side Setback	– (2)	30	15	20.08
Street Side Setback	– (2)	30	24	
Maximum Floor Area Ratio	1:1 (3)			
Site Coverage and Impervious Coverage				
Maximum Site Coverage	30% (3)		10%	
Additional Site Area permitted covered by impervious ground surfaces			10% (1)	
Maximum Impervious Coverage		3.5% (4)		18.28.070(l)
Height Restrictions				
Maximum Height (ft)	50	25	35	
Maximum Height within 150 feet of a residential district (ft)	35			18.28.060(a)
Maximum Number of Stories		2		
Daylight Plane for site lines abutting a residential district				
Initial height (ft)	10			
Slope	1:2			
Residential Density			1 unit/acre	

Zone O-S: Open Space

Permitted Uses:
-Campgrounds, crops, grazing of animals, resource management

Minimum Required Area:
-No minimum required area

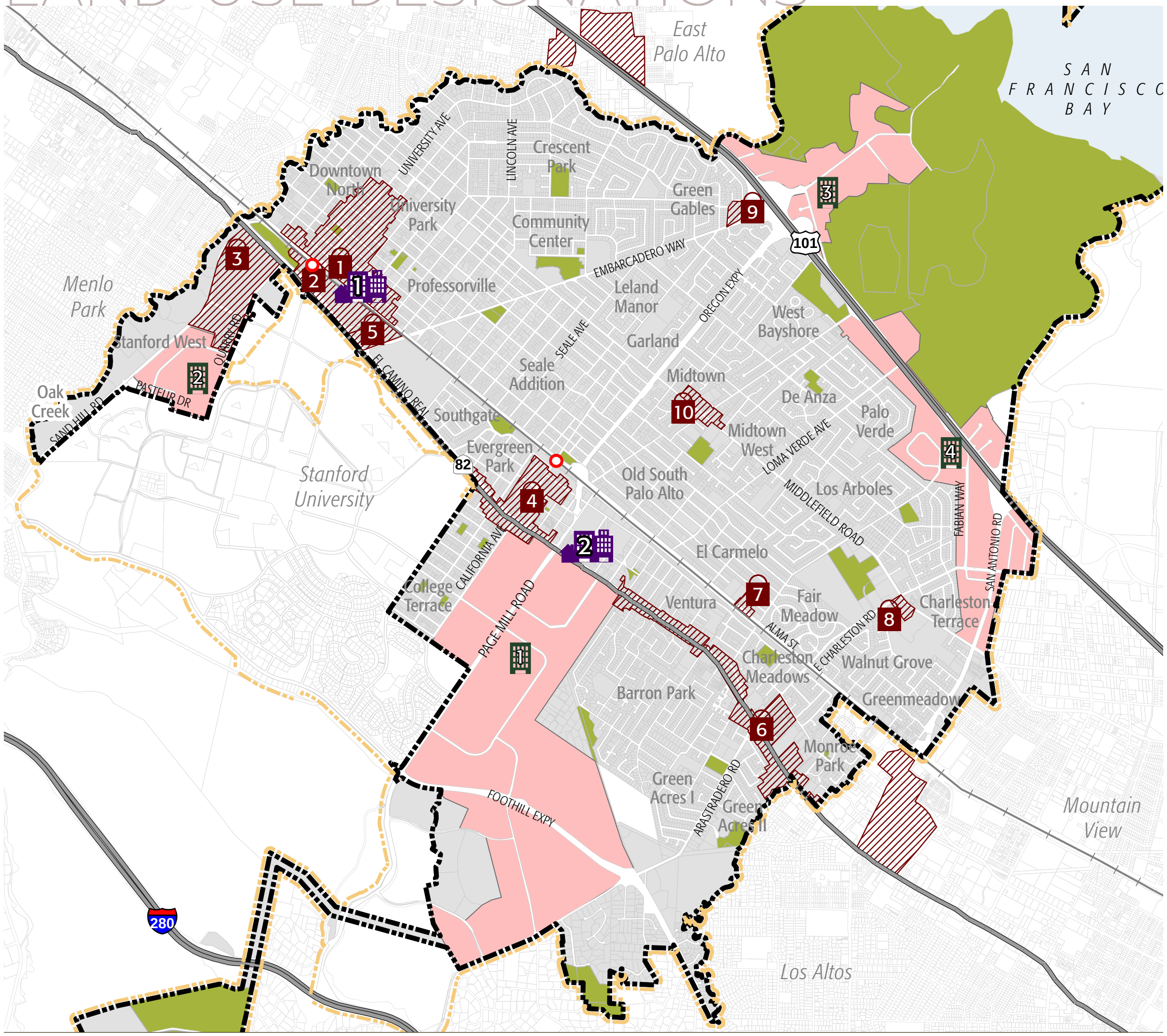
Maximum Height Limit:
-35 feet or two stories

Minimum Required Parking:
-See applicable use--Part 11, Chapter 22.52

Building Setback:
-Certain use setbacks apply

Maximum Lot Coverage:
-No applicable

LAND-USE DESIGNATIONS



Commercial Districts

Commercial Centers

1. University Avenue/Downtown
2. University Avenue/multi-modal transit station
3. Stanford Shopping Center
4. California Avenue
5. Town & Country Village
6. South El Camino Real
7. Alma Plaza
8. Charleston Center
9. Edgewood Plaza
10. Midtown

Mixed Use Areas

1. South of Forest Area (SOFA)
2. Cal-Ventura

Employment Districts

Employment Centers

1. Stanford Research Park
2. Stanford Medical Center
3. East Bayshore
4. San Antonio Road/Bayshore Corridor

Park/Open Space

Caltrain Stations

Railroads

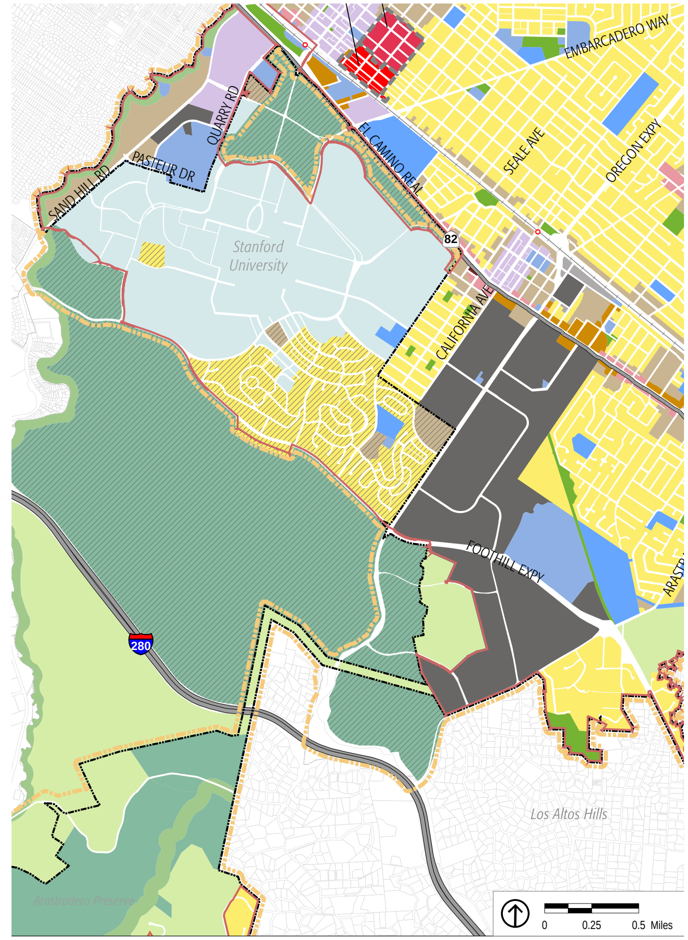
Highways

City Boundary

Sphere of Influence

0 1 2

Scale (Miles)



Comprehensive Plan Land Use Designations

Residential
- Single Family Res
- Multi-Family Res
- Multi-Family Res (w/Hotel Overlay)
- MIUL/Campus Multiple Family
- Mixed Use
- MIUL/Campus Single Family

Commercial
- Hotel Commercial
- Service Commercial
- Neighborhood Commercial
- Regional/Community Commercial

Business/Industrial
- Light Industrial
- Research/Office Park

Other
- SOFA II CAP
- SOFA I CAP
- School District Land
- Major Institution/Special Facility
- MIUL/Campus Educational Facility
- Streamside Open Space
- Public Park
- Open Space/Controlled Development
- MIUL/Academic Reserve and Open Space
- Public Conservation Land

- Caltrain Stations
- Railroads
- Urban Service Area
- City Boundary
- Sphere of Influence

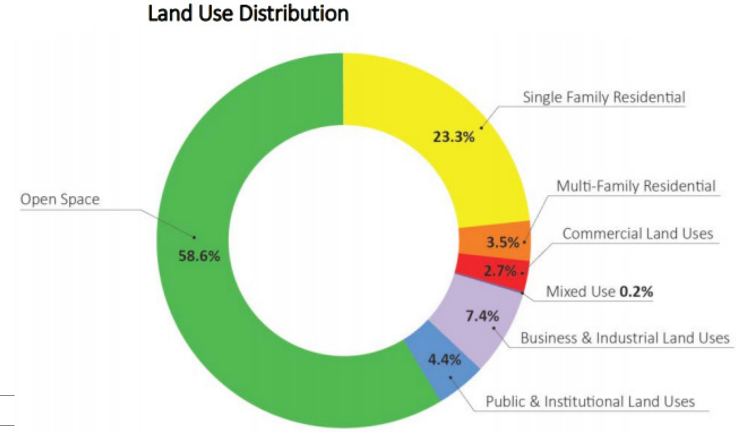


TABLE 8-1 PALO ALTO ZONING DISTRICTS ALLOWED IN COMPREHENSIVE PLAN LAND USE DESIGNATIONS

	ZONING DISTRICTS																										
Comprehensive Plan Land Use Designations	RE	R-1	R-1 (7,000)	R-1 (8,000)	R-1 (10,000)	R-1 (20,000)	R-2	RM-15	RM-30	RM-40	CN	CC, CC (2)	CS	CD-C	CD-S	CD-N	MOR	ROLM/ROLM €	RP	GM	PF	OS	AC	PTOD Cal Ave	PTOD Univ Ave	HD	PC
Residential																											
Single-Family Residential	X	X			X		X															X					X
Multiple-Family Residential (w/Hotel Overlay)																											
Multiple-Family Residential		X						X	X	X														X			X
MIUL/Campus Multiple Family																											
Mixed Use									X		X																X
MIUL/Campus Single Family																											
Commercial																											
Hotel Commercial										X			X														
Service Commercial										X				X	X												X
Neighborhood Commercial									X							X											X
Regional/Community Commercial												X		X							X			X			X
Business/Industrial																											
Light Industrial																				X							X
Research/Office Park								X	X								X	X	X		X						X
Other																											
SOFA I CAP								X	X	X												X					
SOFA II CAP																											X
School District Land			X														X				X						
Major Institution/ Special Facility									X								X				X						
MIUL/Campus Educational Facility																											
Streamside Open Space									X			X									X	X					
Public Park																					X						X
Open Space/Controlled Development	X																				X	X	X				X
MIUL/Academic Reserve and Open Space																											
Public Conservation Land																					X	X					
Park/Open Space																											

Source: City of Palo Alto Zoning Code, 2014.

CONSERVATION ZONING

Figure BIO.3: Conservation Easements and No-Build Areas

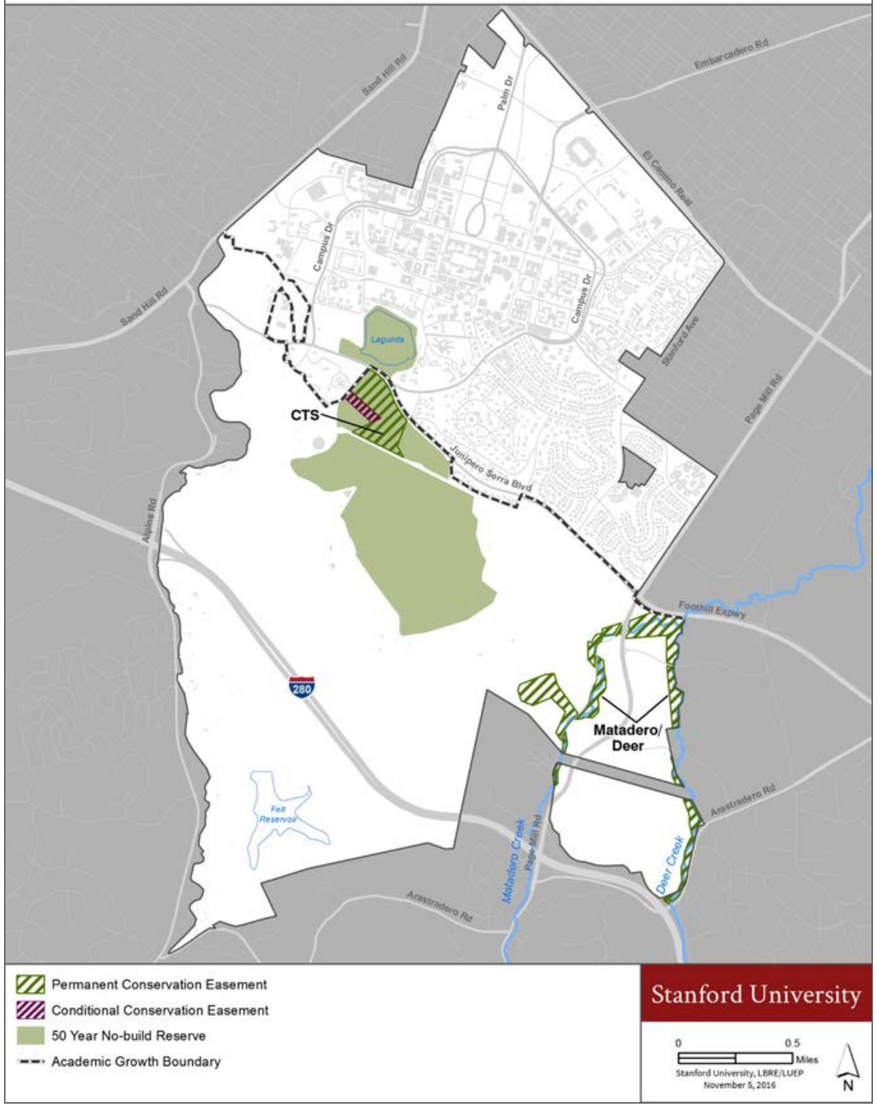
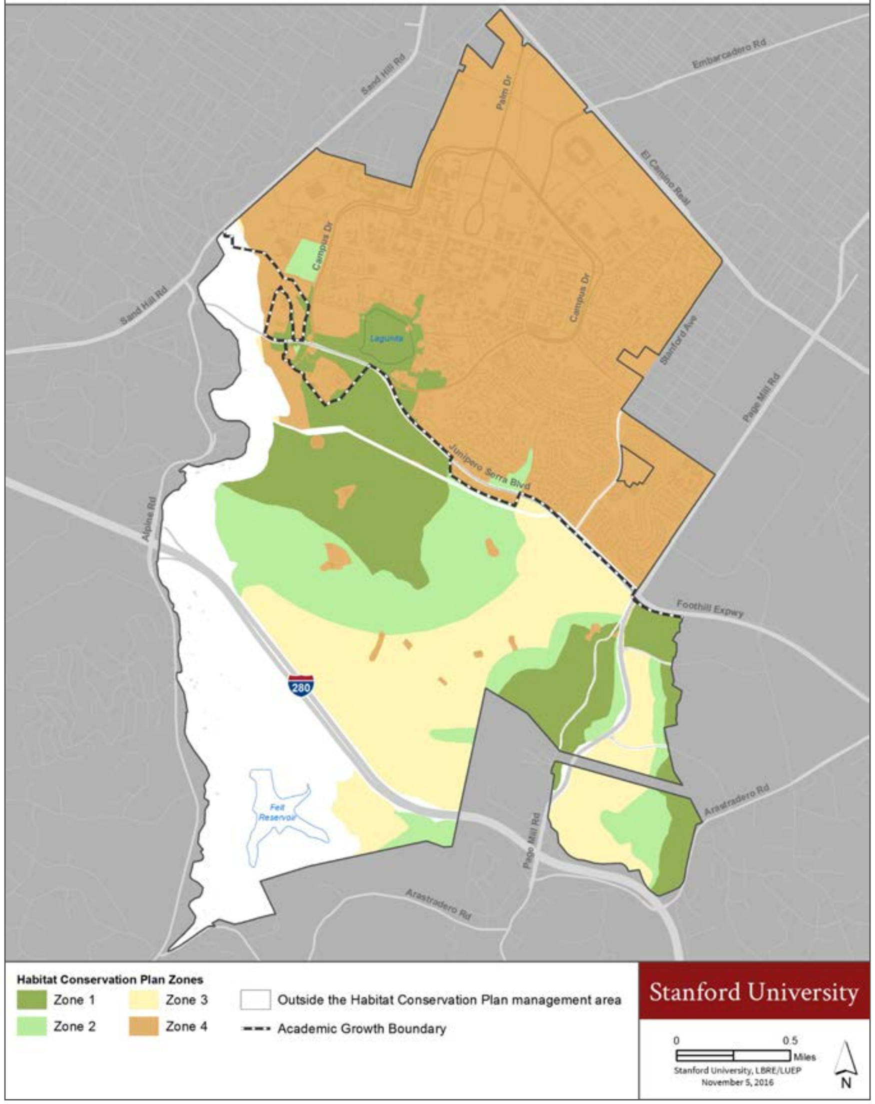
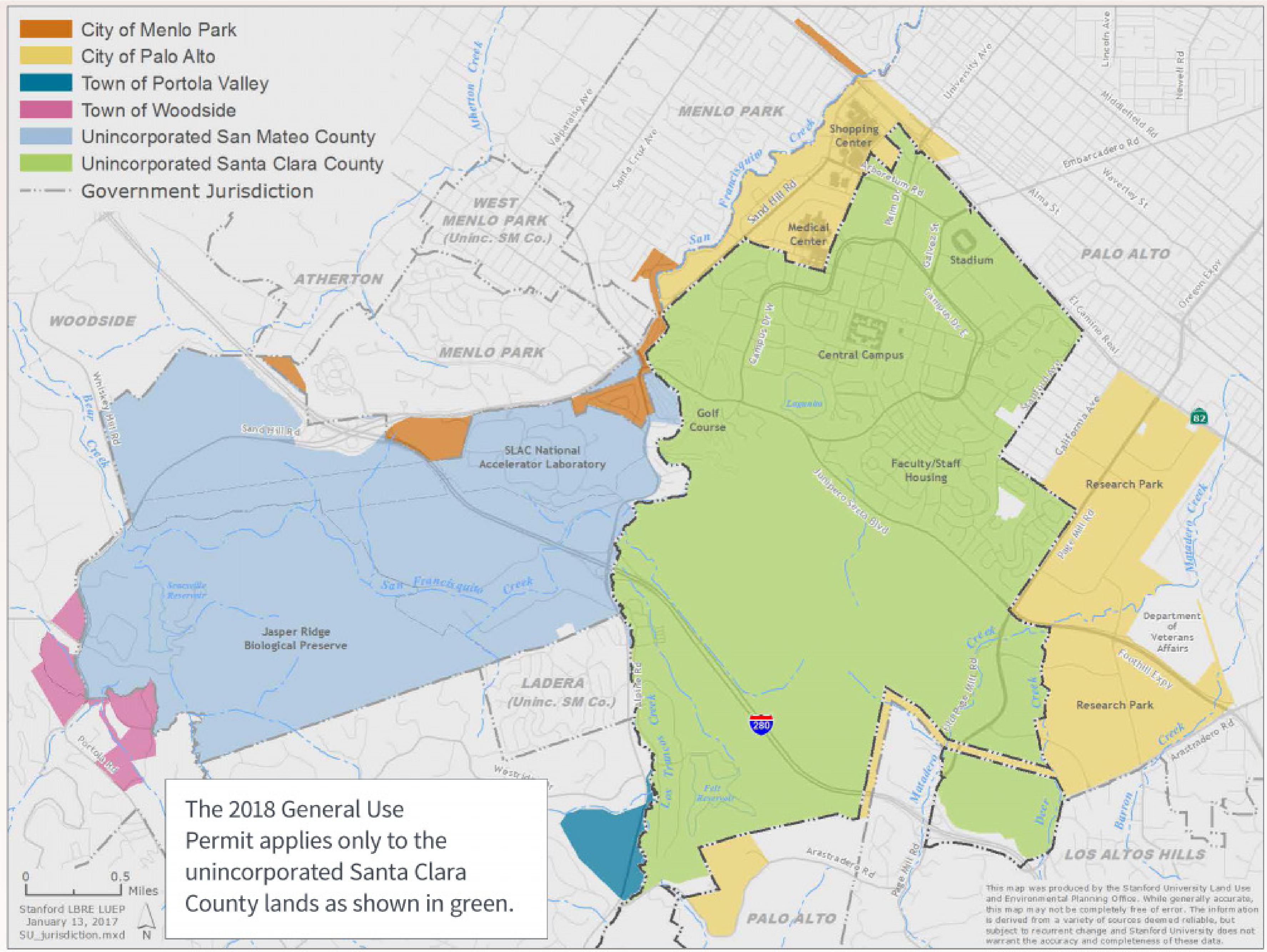
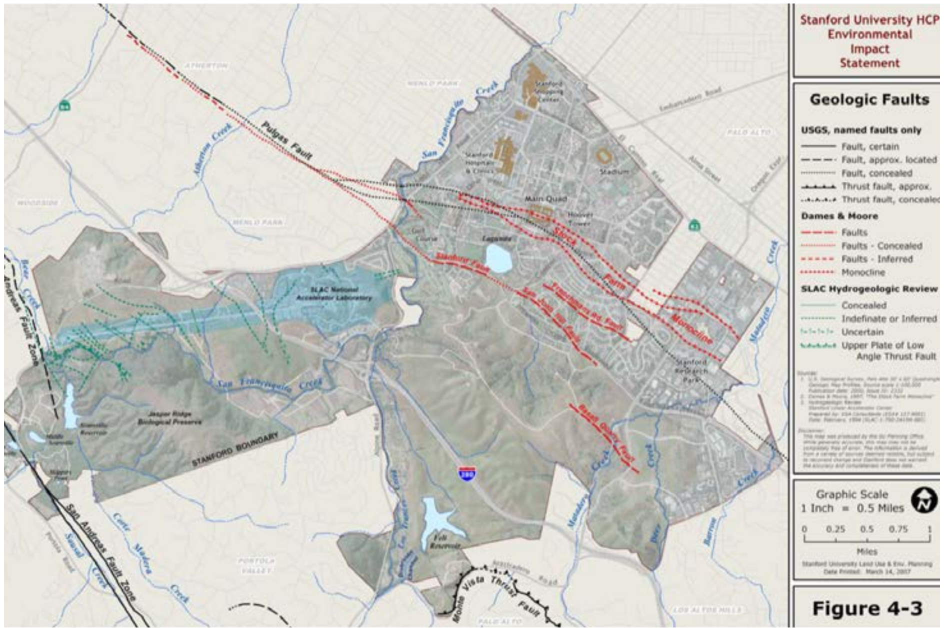


Figure BIO.4: Habitat Conservation Plan Zones

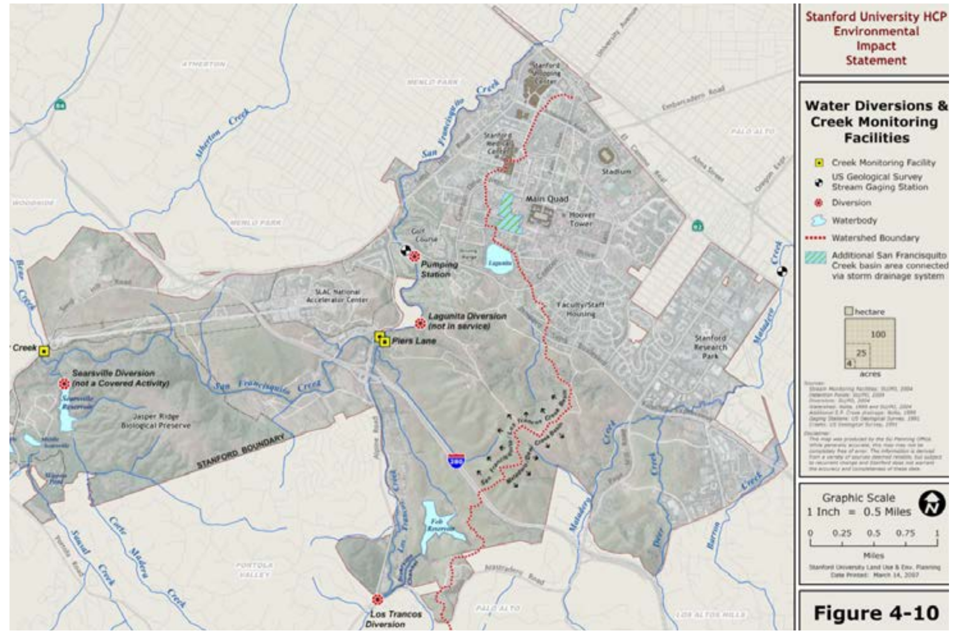




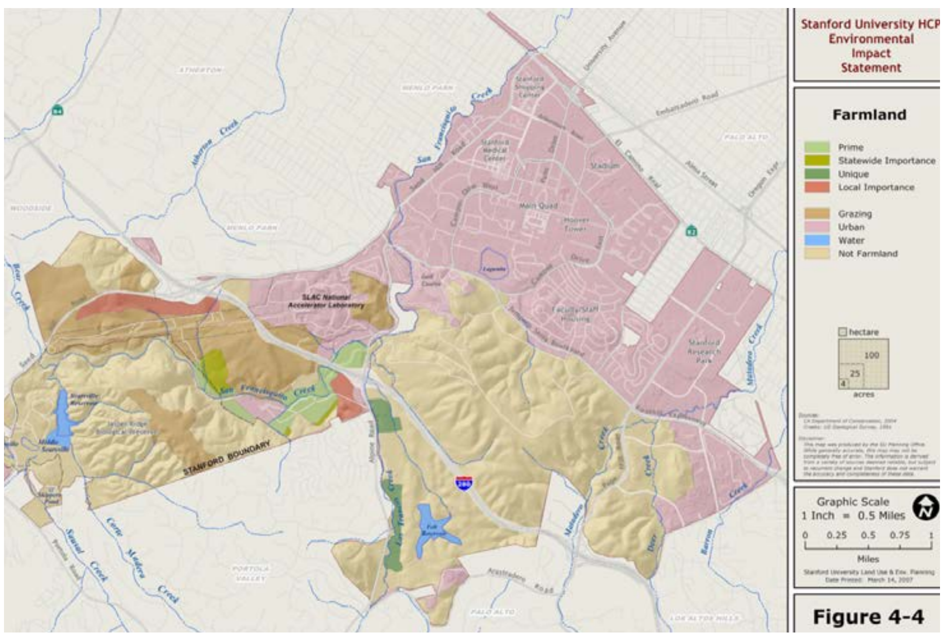
The 2018 General Use Permit applies only to the unincorporated Santa Clara County lands as shown in green.



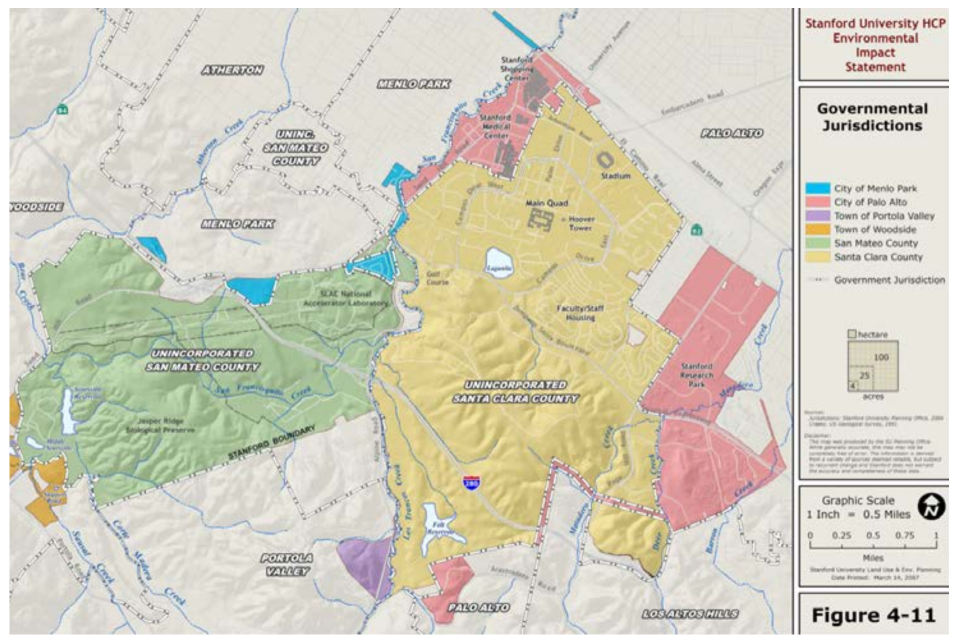
Geologic Faults



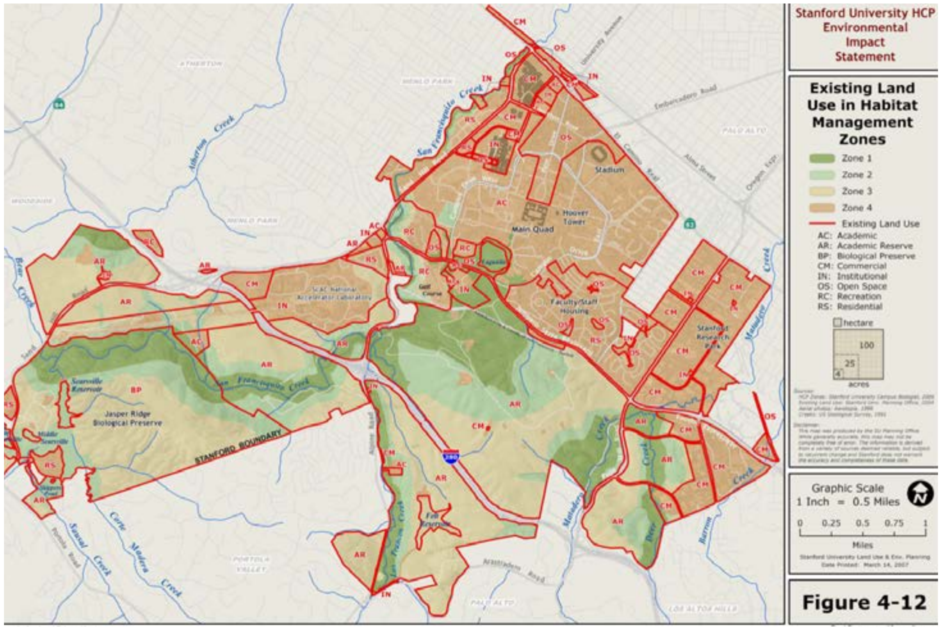
Water Diversions & Creek Monitoring Facilities



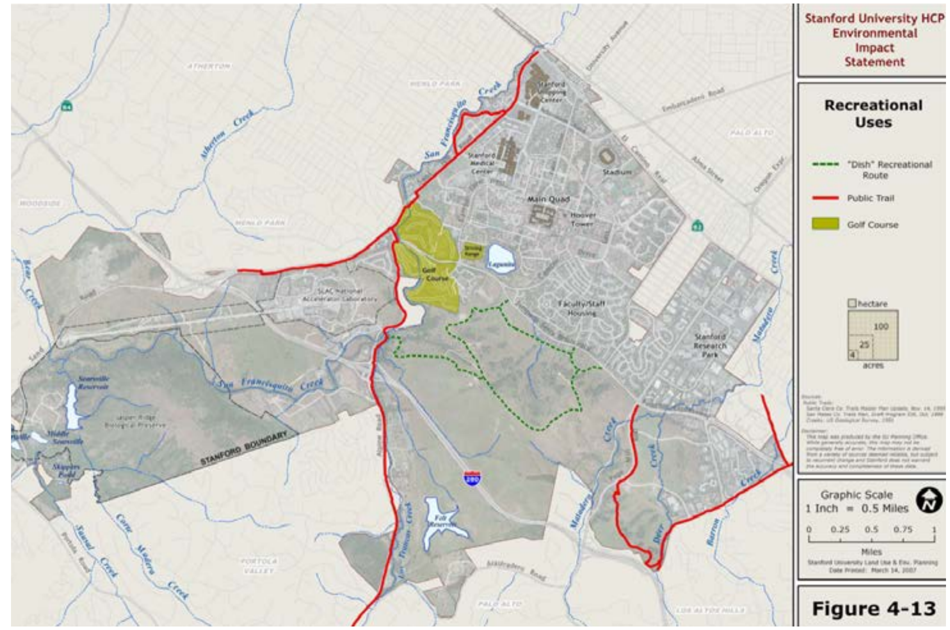
Farmland



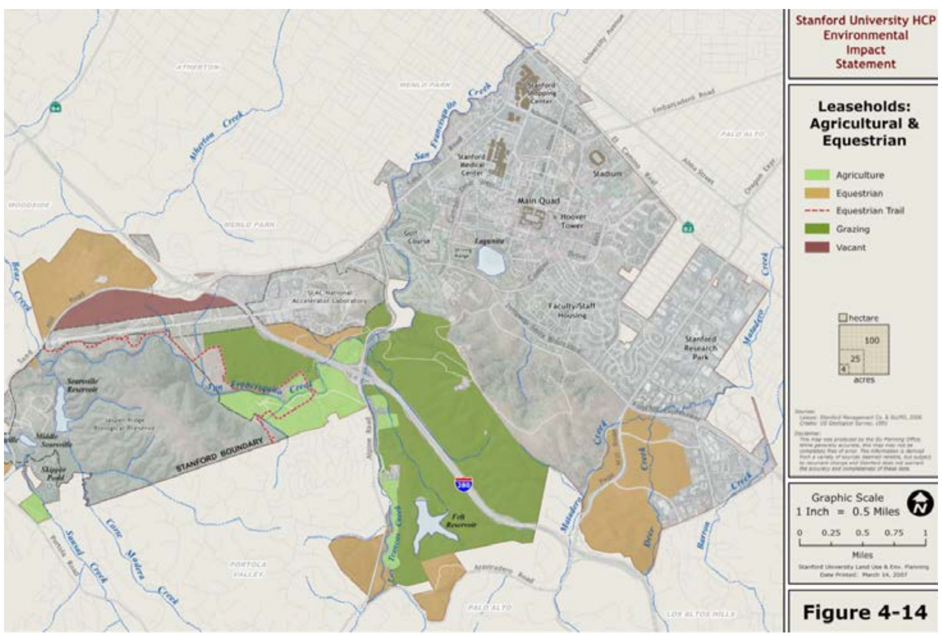
Governmental Jurisdictions



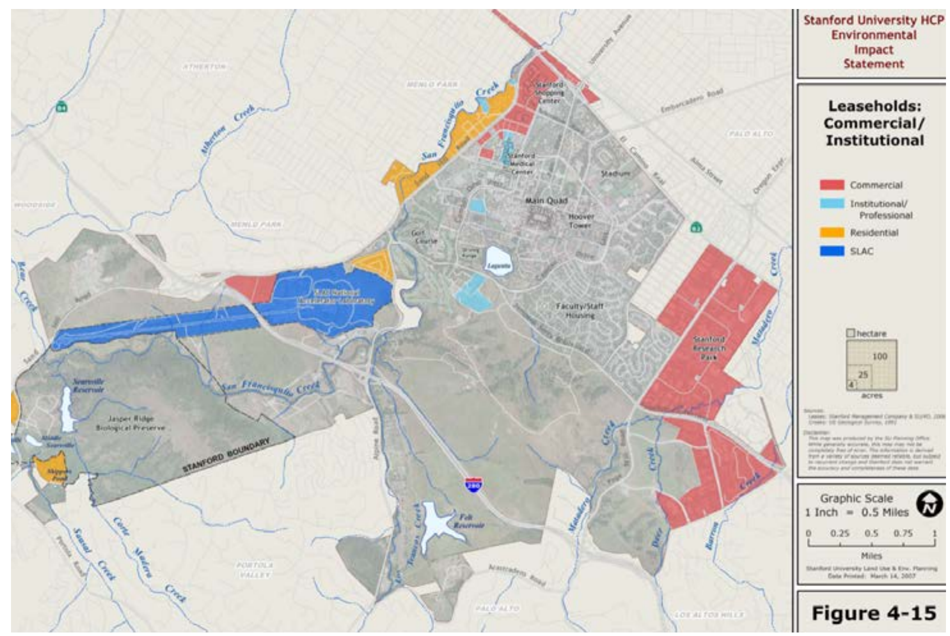
Existing Land Use Habitat Management Zones



Recreational Uses



Leaseholds: Agricultural & Equestrian

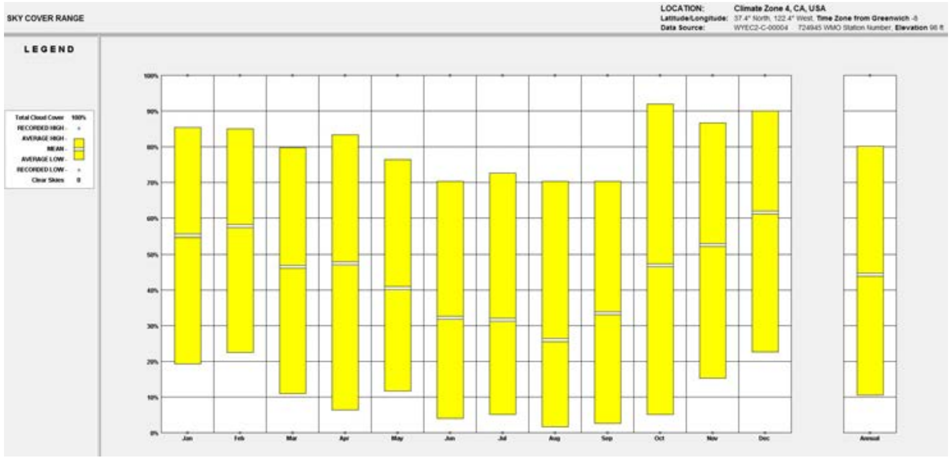


Leaseholds: Commercial/Institutional

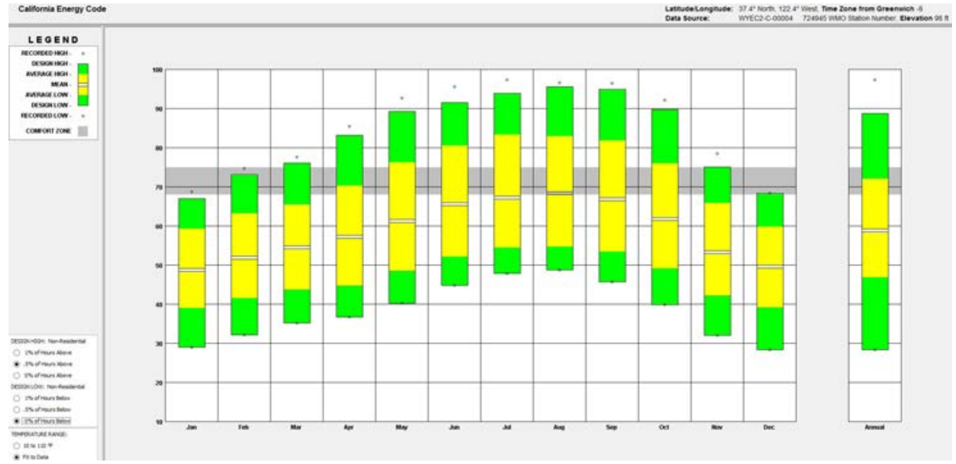
CHAPTER 10

ENVIRONMENTAL CONSIDERATIONS

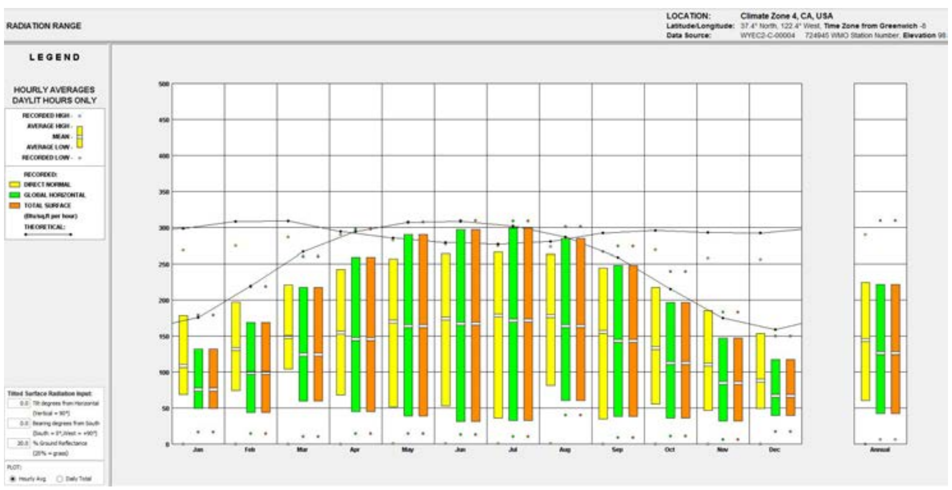
CLIMATE STUDY



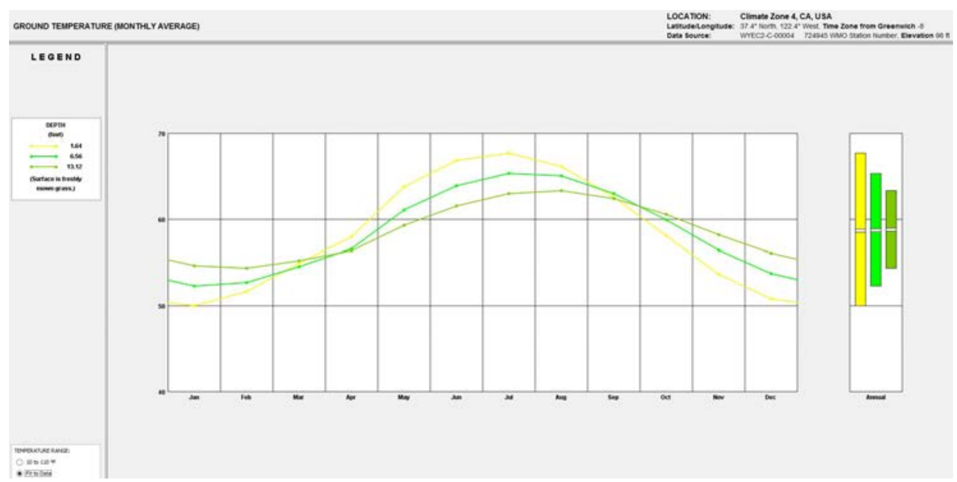
-Annual cloud coverage is at 45%
-Lowest cloud coverage level is in August at approx. 5%
-Highest cloud coverage level is in October at approx. 90%



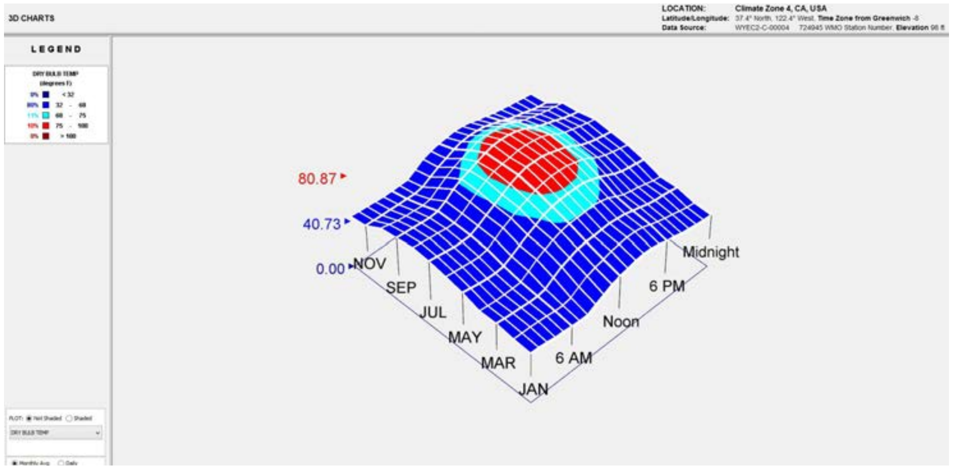
-Average yearly energy levels at approx. 60 hours
-Lowest energy levels in December at approx. 50 hours
-Highest energy levels in August at approx. 95 hours

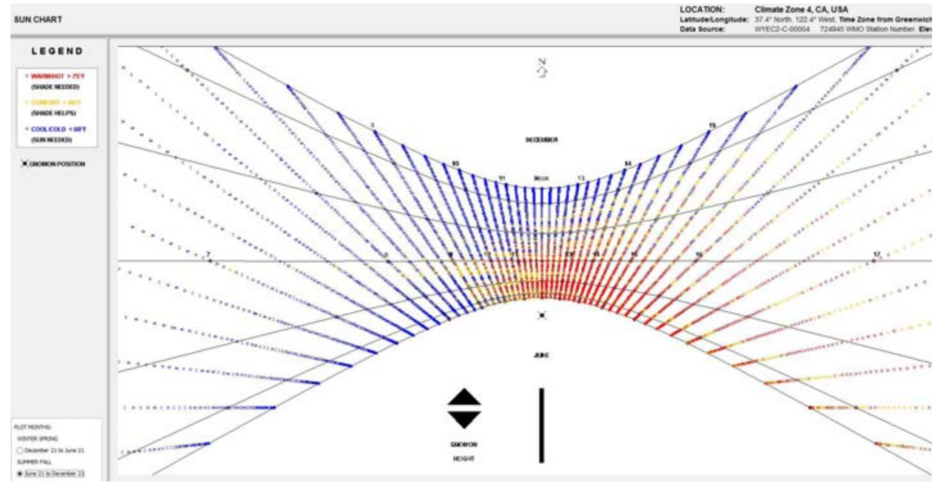


-Average annual radiation levels are approx. 125



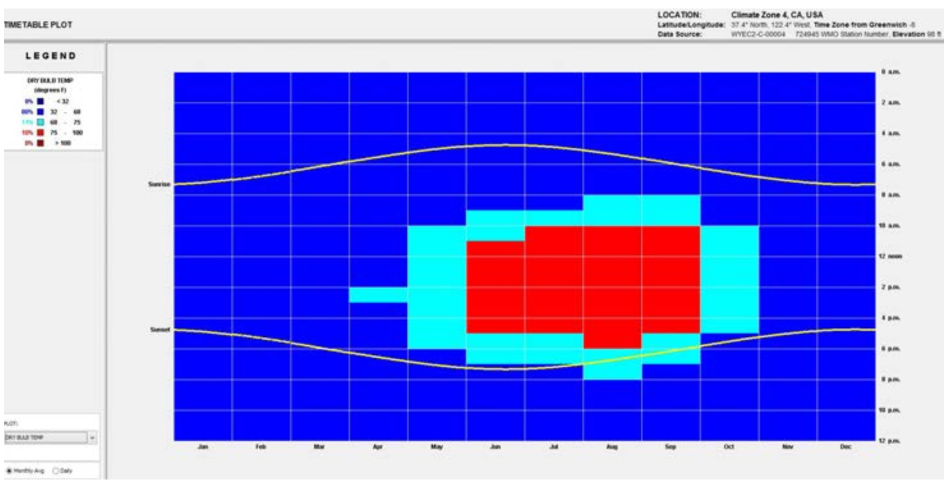
-Average annual ground temperature is approx. 59 degrees Fahrenheit

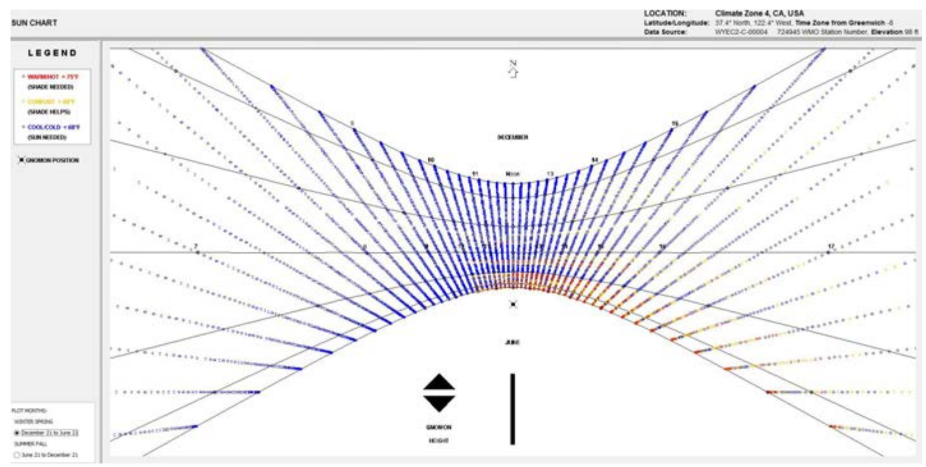




-Dry bulb temperature is at highest levels between 10 am and 4 pm between June-September at 75-100 degrees Fahrenheit
-Dry bulb temp lowest levels are 32-68 degrees Fahrenheit

-June 21 to December 21 (Summer/Fall) sun chart indicates that the sun experiences cool/cold, comfort, and warm/hot temperatures



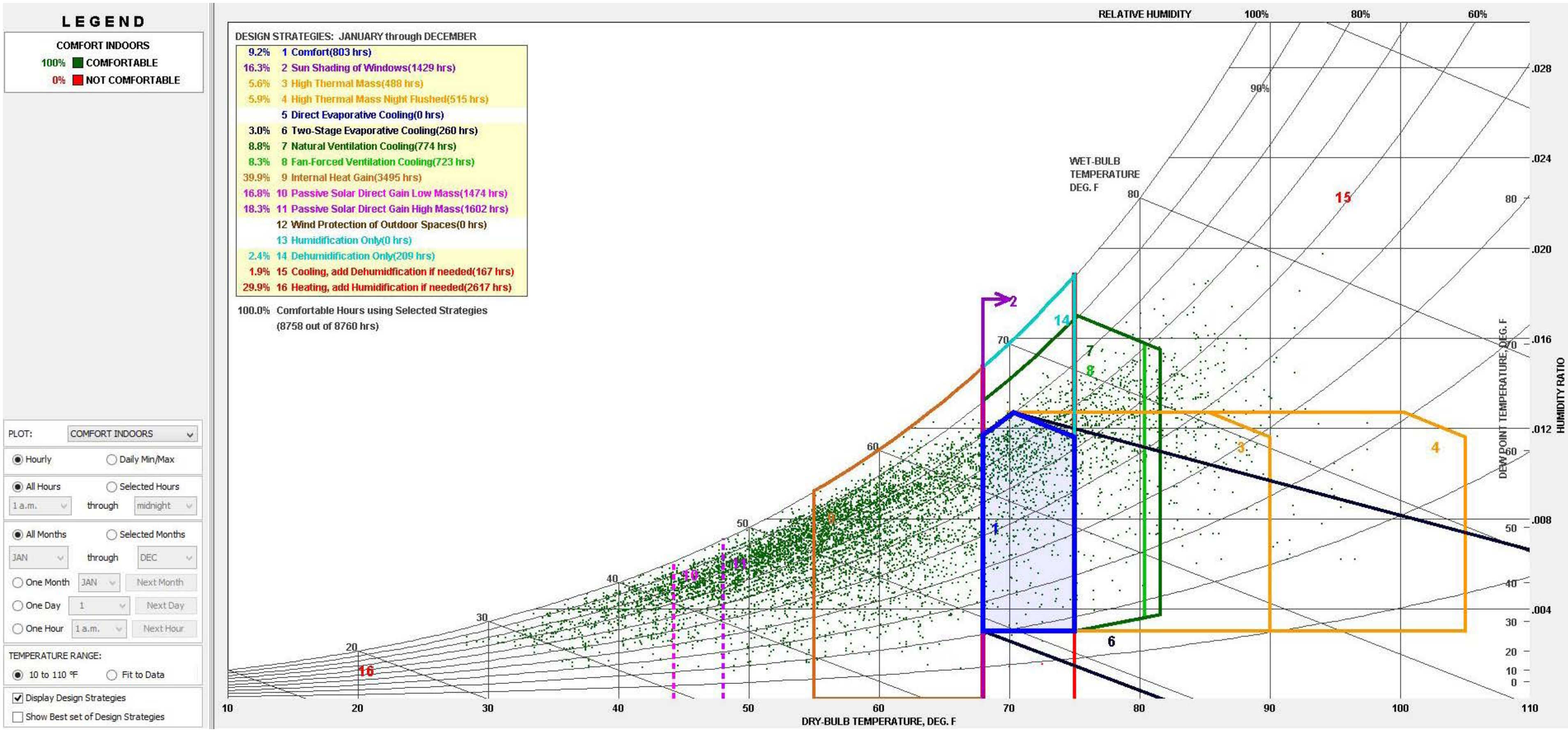


-Dry bulb temperature is at highest levels between 10 am and 4 pm between June-September at 75-100 degrees Fahrenheit

-December 21 to June 21 (Winter/Spring) sun chart indicates that the sun is mostly cool/cold at <68 degrees Fahrenheit
-The sun experiences comfort and warm/hot temperatures

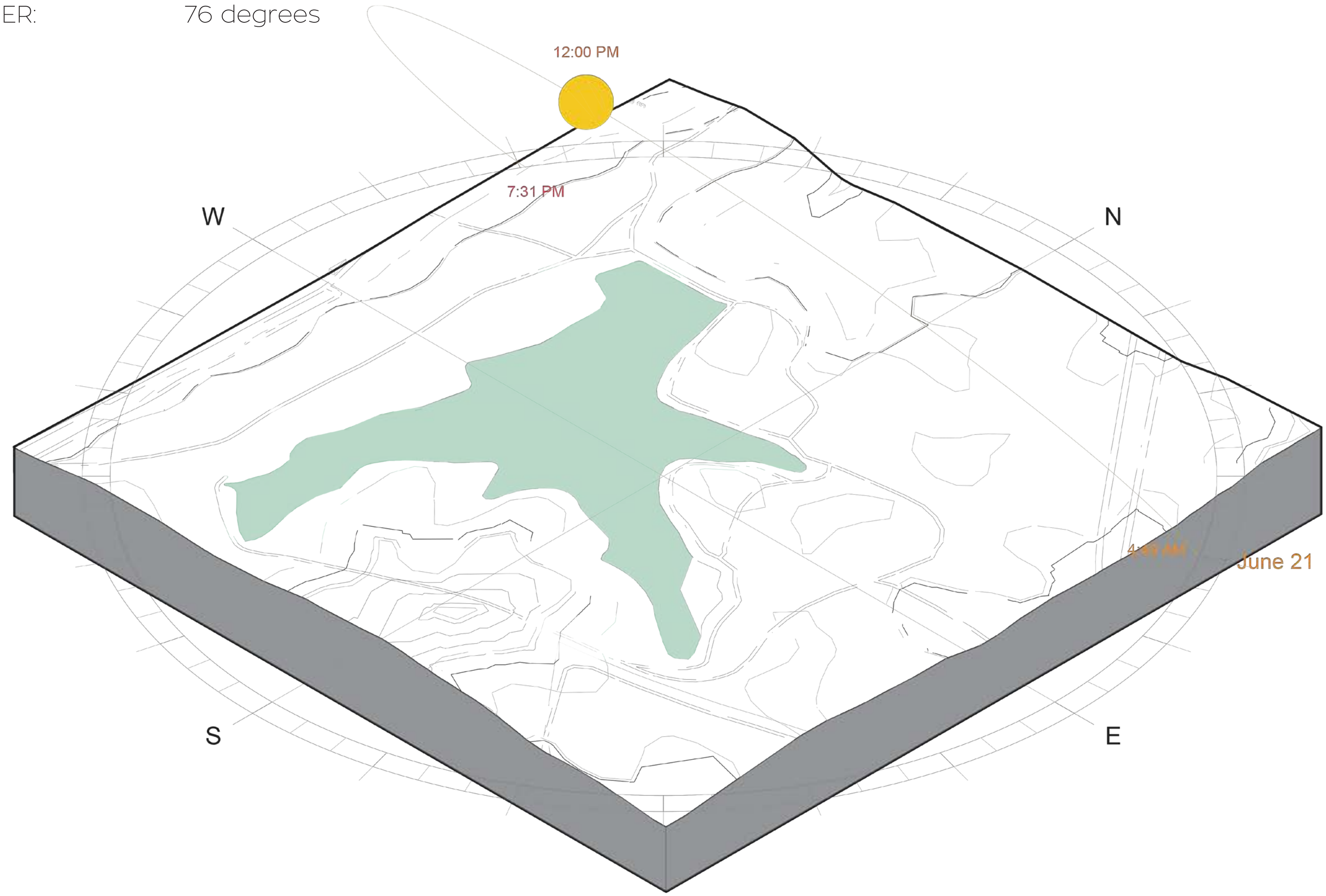
SOLAR STUDY

PSYCHROMETRIC CHART



The psychrometric chart indicates that a combination of active and passive strategies are required to sustain a comfortable indoor environment. Active systems such as heating, cooling, and humidification are recommended, while passive strategies should incorporate sun shading and ventilation. California has generally low humidity levels and high temperatures year round.

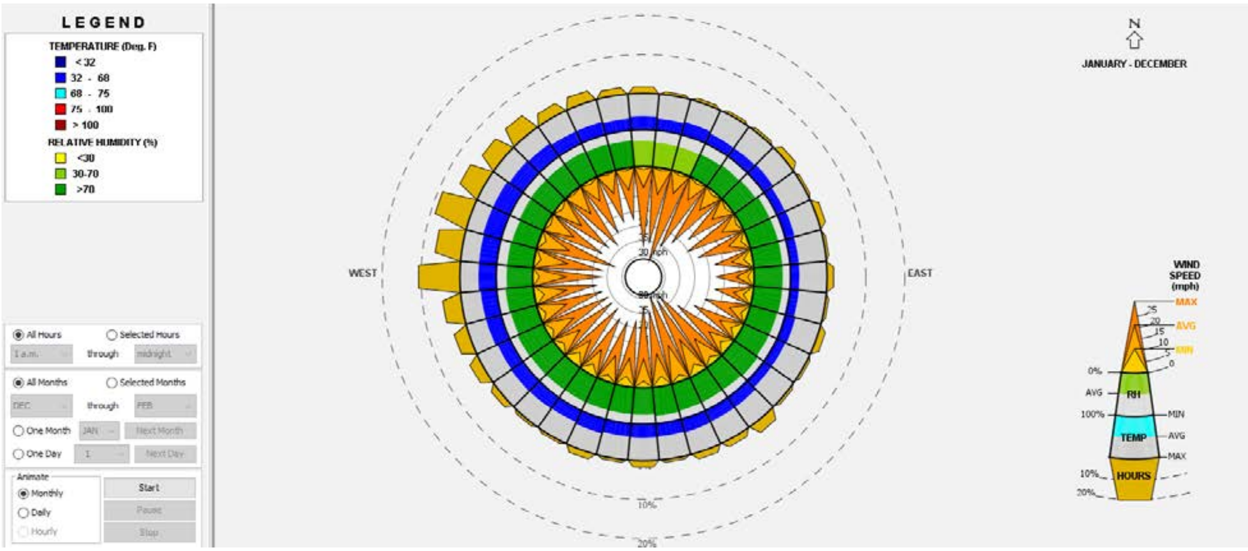
WINTER:	30 degrees
SPRING/FALL:	53 degrees
SUMMER:	76 degrees



3D SOLAR STUDY (SUMMER/WINTER SOLSTICES)

WIND STUDY

WIND WHEEL

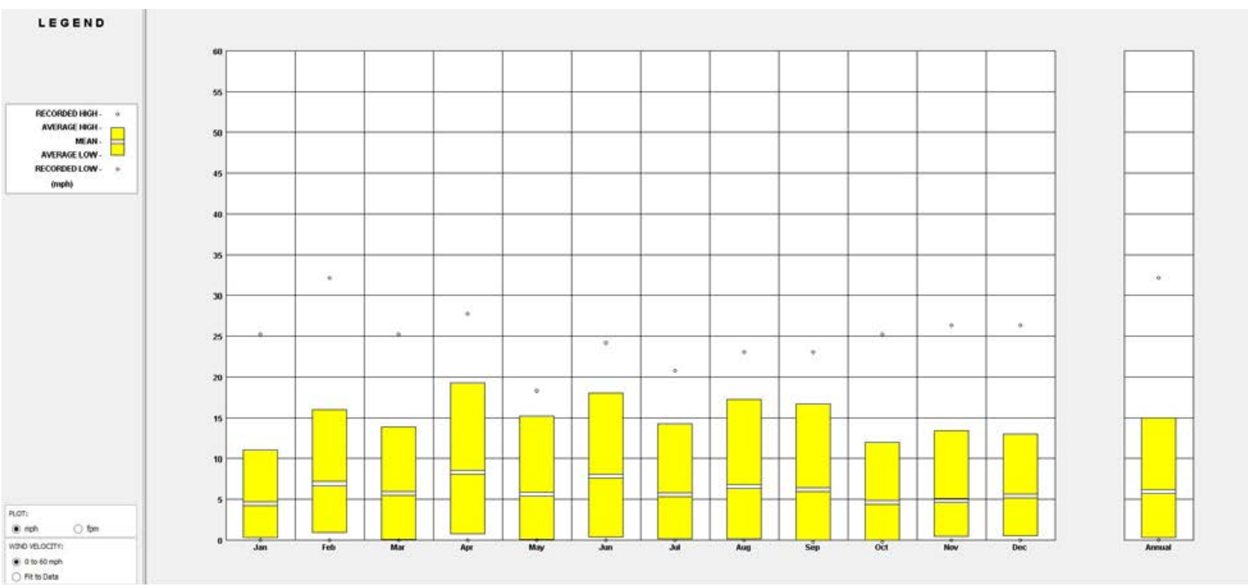


-The wind wheel indicates the annual relative humidity is 30-70%

-The average temperature of the wind remains at 32-68 degrees Fahrenheit

-Primarily North West winds and South East winds

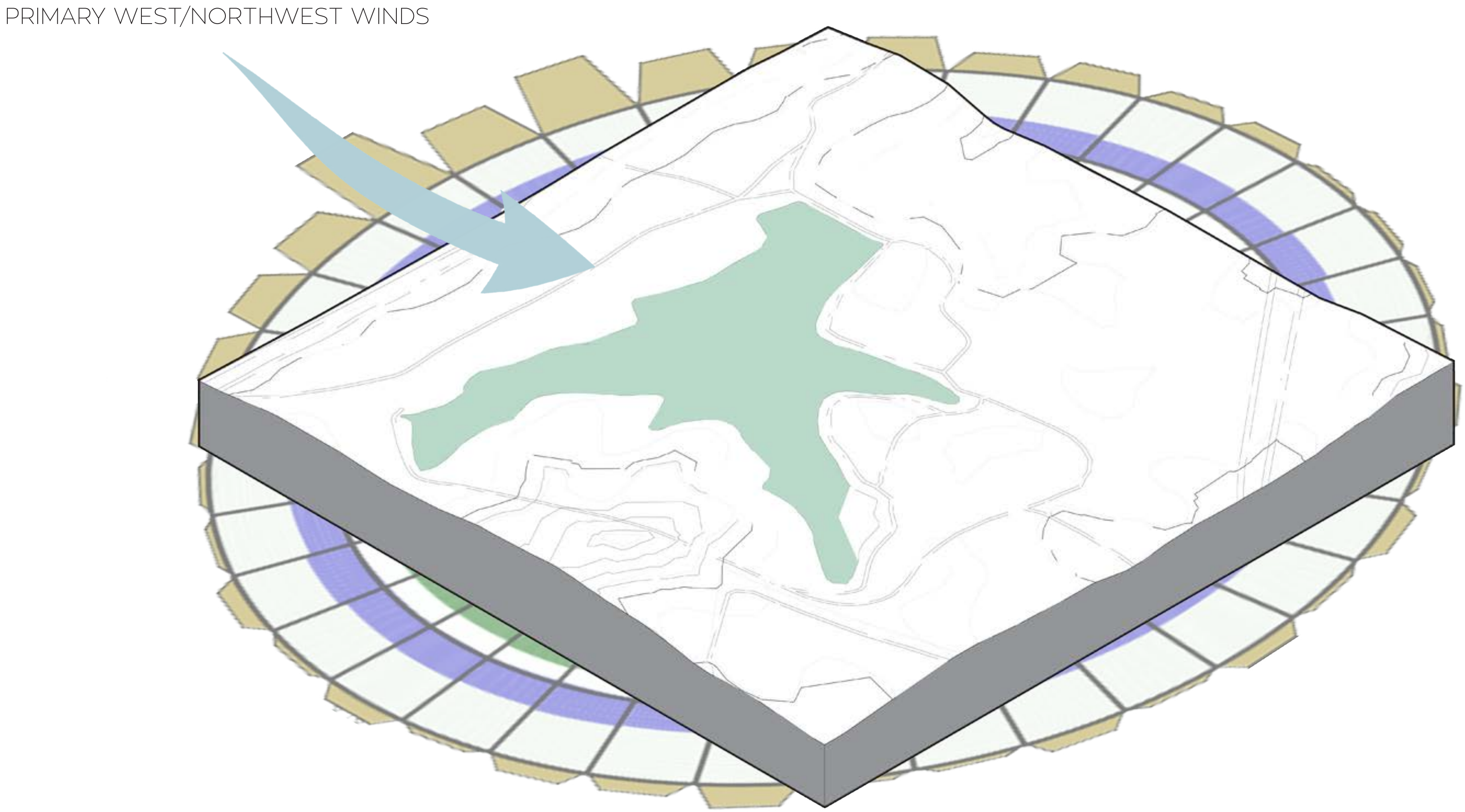
WIND VELOCITY RANGE



-The wind velocity range indicates that wind speeds are highest in the spring and summer months (particularly April and June) at nearly 20 mph

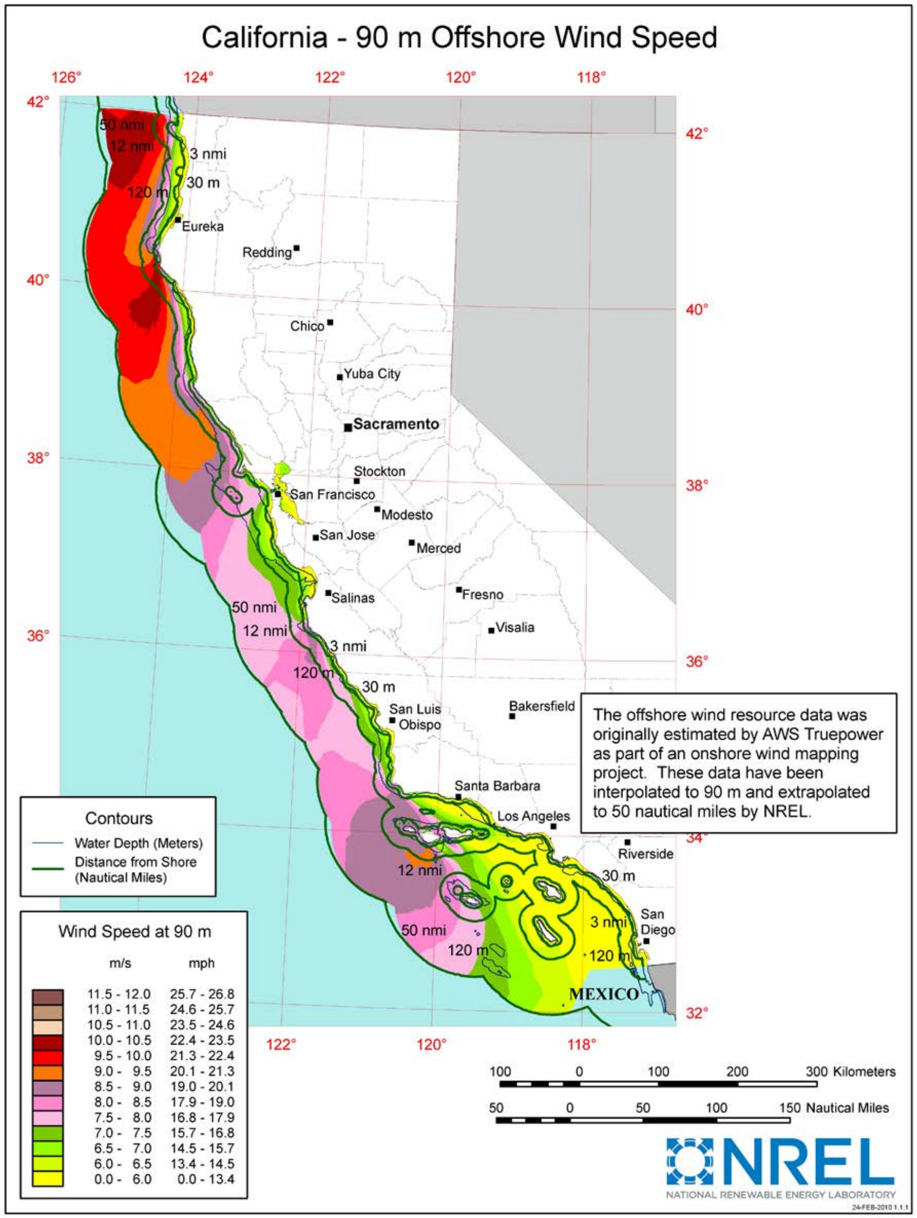
-Wind speeds are at their lowest in the fall and winter months (particularly January and October) at 11 mph

-Annual wind speed average at 15 mph



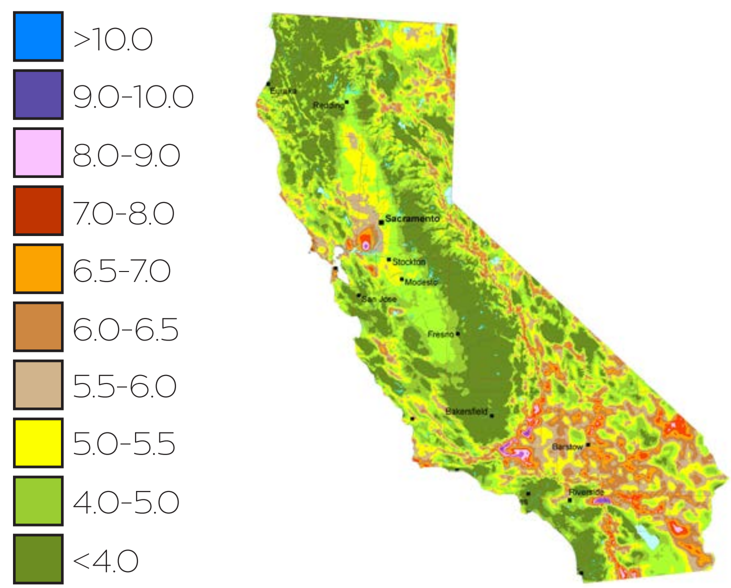
3D WIND STUDY

WIND STUDY



CA AVERAGE WIND SPEED (mps)

- Average annual wind speed is 80 mph (south east, 5.0-5.5)
- Areas with annual average wind speeds around 6.5 meters per second and greater at 80-m height are suitable



Offshore wind resource by state and wind speed interval within 50 nm of shore.

	Wind Speed at 90 m (m/s)							
	7.0 - 7.5	7.5 - 8.0	8.0 - 8.5	8.5 - 9.0	9.0 - 9.5	9.5 - 10.0	>10.0	Total >7.0
State	Area km^2 *(MW)*	Area km^2 *(MW)*	Area km^2 *(MW)*	Area km^2 *(MW)*	Area km^2 *(MW)*	Area km^2 *(MW)*	Area km^2 *(MW)*	Area km^2 *(MW)*
California	11,439 *(57,195)*	24,864 *(124,318)*	23,059 *(115,296)*	22,852 *(114,258)*	13,185 *(65,924)*	15,231 *(76,153)*	6,926 *(34,629)*	117,555 *(587,773)*

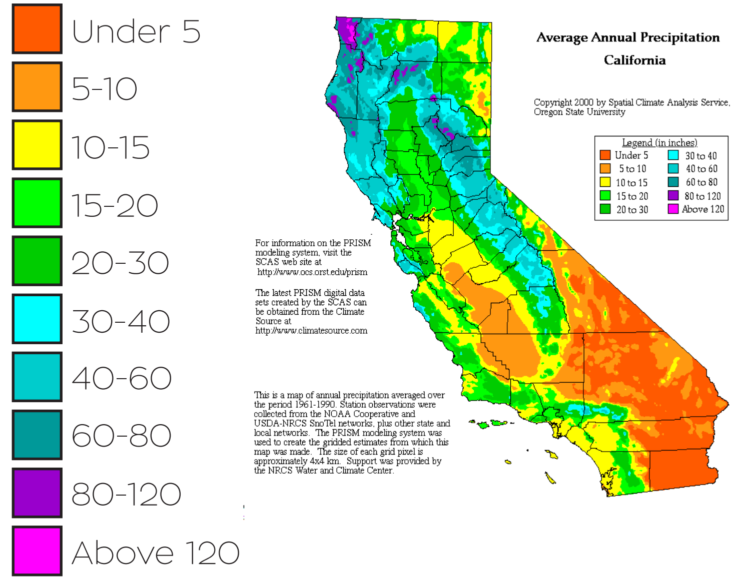
Offshore wind resource area by state with potential by wind speed interval, water depth, distance from shore

		Distance from Shoreline									
		0 - 3 nm[1]			3 - 12 nm			12 - 50 nm			
		Depth Category (m)			Depth Category (m)			Depth Category (m)			
	Wind Speed	0 - 30	30 - 60	> 60	0 - 30	30 - 60	> 60	0 - 30	30 - 60	> 60	Total
State	at 90m m/s	Area (km^2) *(MW)*	Area (km^2) *(MW)*	Area (km^2) *(MW)*	Area (km^2) *(MW)*	Area (km^2) *(MW)*	Area (km^2) *(MW)*	Area (km^2) *(MW)*	Area (km^2) *(MW)*	Area (km^2) *(MW)*	Area (km^2) *(MW)*
California	7.0-7.5	266.2 *(1,331)*	236.2 *(1,181)*	257.4 *(1,287)*	100.9 *(504)*	456.8 *(2,284)*	4,554.0 *(22,770)*	7.7 *(38)*	22.9 *(115)*	5,536.8 *(27,684)*	11,438.9 *(57,195)*
	7.5-8.0	239.1 *(1,196)*	256.9 *(1,285)*	189.6 *(948)*	78.8 *(394)*	595.7 *(2,978)*	3,854.6 *(19,273)*	0.0 *(0)*	32.9 *(165)*	19,616.1 *(98,080)*	24,863.7 *(124,318)*
	8.0-8.5	125.2 *(626)*	178.2 *(891)*	281.8 *(1,409)*	7.1 *(36)*	105.8 *(529)*	4,539.1 *(22,695)*	0.0 *(0)*	0.0 *(0)*	17,822.2 *(89,111)*	23,059.3 *(115,296)*
	8.5-9.0	43.2 *(216)*	141.7 *(708)*	176.4 *(882)*	0.6 *(3)*	38.0 *(190)*	4,559.8 *(22,799)*	0.0 *(0)*	0.0 *(0)*	17,892.0 *(89,460)*	22,851.6 *(114,258)*
	9.0-9.5	2.1 *(10)*	18.8 *(94)*	14.9 *(74)*	0.0 *(0)*	0.9 *(4)*	988.0 *(4,940)*	0.0 *(0)*	0.0 *(0)*	12,160.2 *(60,801)*	13,184.8 *(65,924)*
	9.5-10.0	0.0 *(0)*	6.0 *(30)*	13.9 *(69)*	0.0 *(0)*	0.0 *(0)*	656.1 *(3,280)*	0.0 *(0)*	0.0 *(0)*	14,554.8 *(72,774)*	15,230.7 *(76,153)*
	>10.0	0.0 *(0)*	0.0 *(0)*	0.1 *(1)*	0.0 *(0)*	0.0 *(0)*	288.1 *(1,441)*	0.0 *(0)*	0.0 *(0)*	6,637.6 *(33,188)*	6,925.8 *(34,629)*

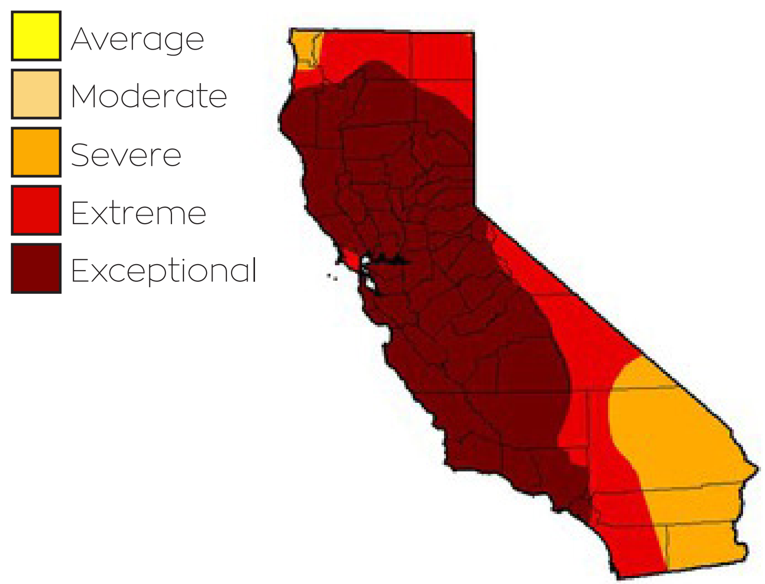
PRECIPITATION/DROUGHT STUDY

CA AVERAGE PRECIPITATION (in)

- Average annual precipitation is 20-30 inches

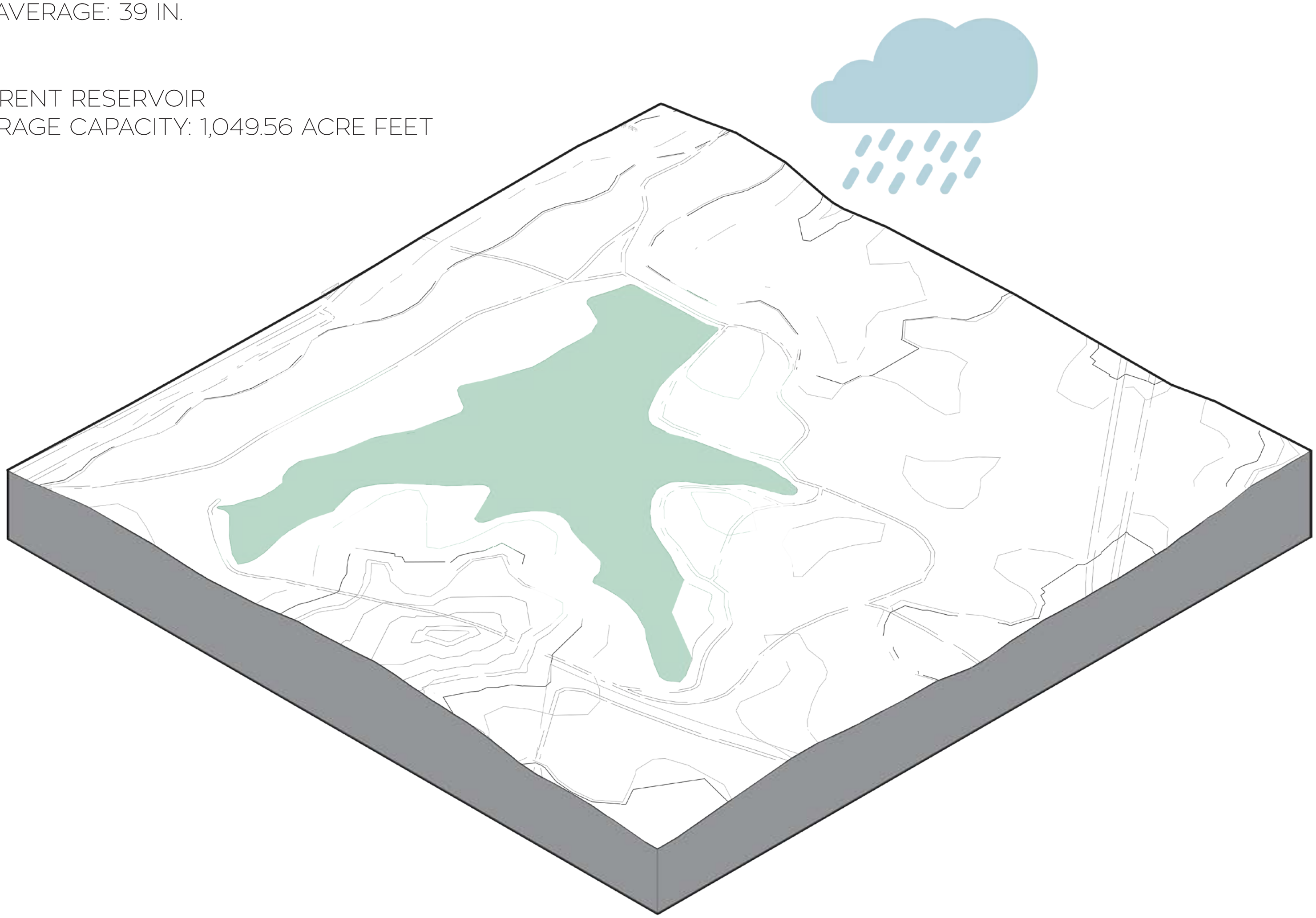


CA DROUGHT REGIONS (2014)
-The state recently experienced record-breaking drought levels
-41% of the state faced "exceptional drought"



PALO ALTO: 22 IN.
U.S. AVERAGE: 39 IN.

CURRENT RESERVOIR
STORAGE CAPACITY: 1,049.56 ACRE FEET



3D ANNUAL RAINFALL STUDY

CHAPTER 11

CONCEPTUALIZATION

SITE INTERVENTION

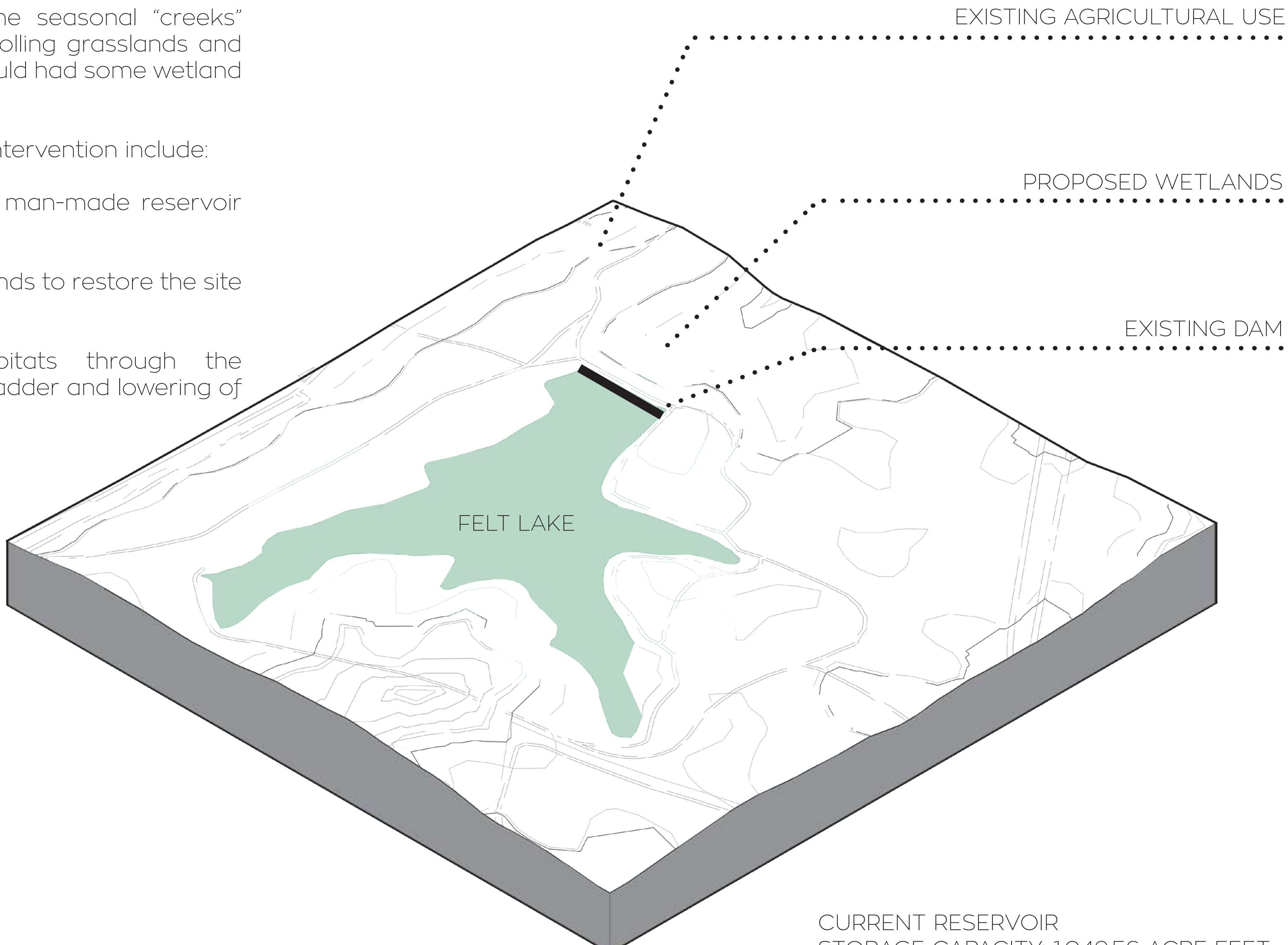
The site intervention intends to restore the landscape to its prior riparian state, before the introduction of the man-made reservoir that is known today as Felt Lake. The area would have had some seasonal "creeks" running through the rolling grasslands and the valley bottoms would had some wetland vegetation

The goals of the site intervention include:

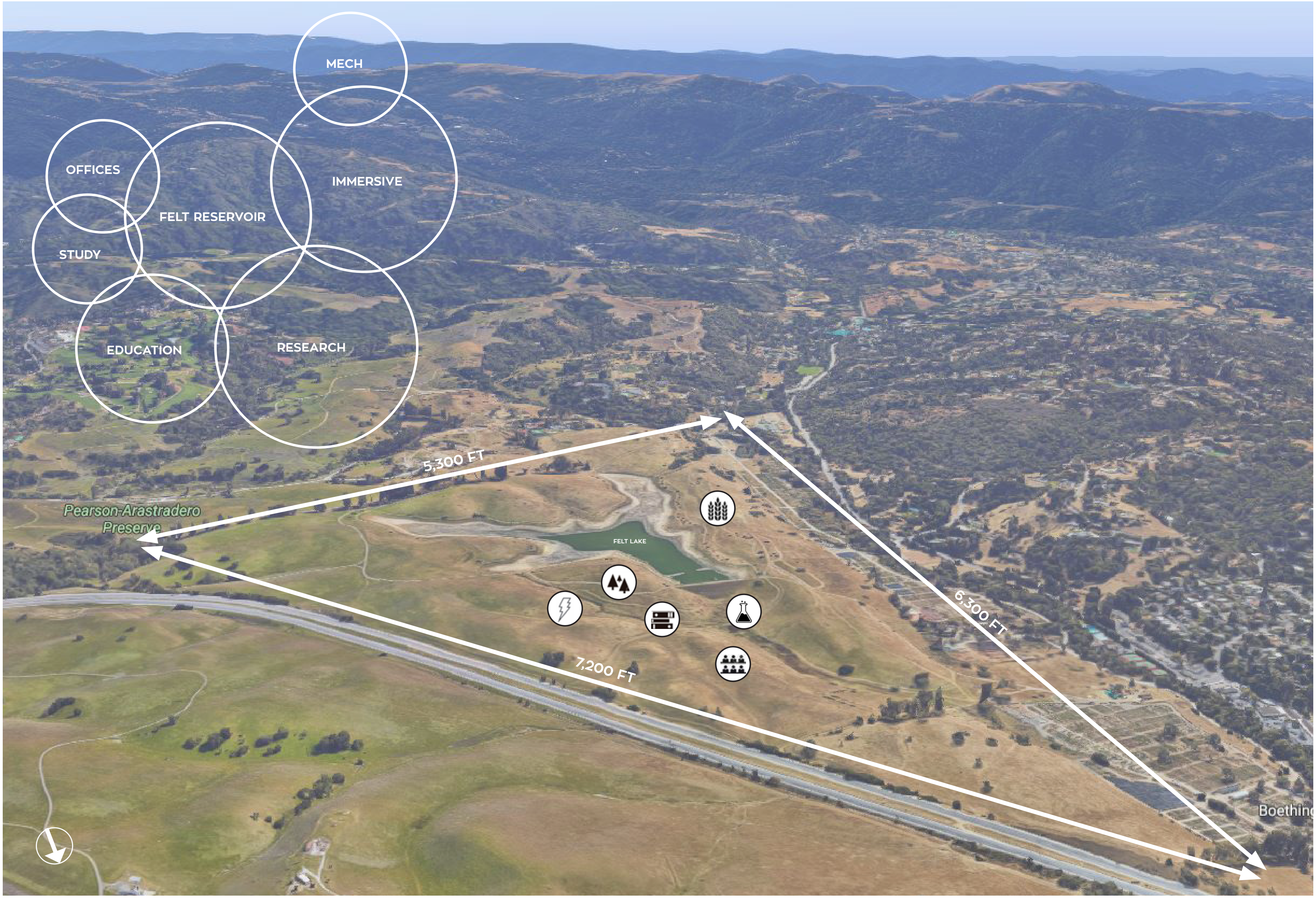
- Integration with the man-made reservoir and earthen dam

- Introduction of wetlands to restore the site to its riparian state

-Restoration of habitats through the introduction of a fish ladder and lowering of the existing dam



CURRENT RESERVOIR
STORAGE CAPACITY: 1,049.56 ACRE FEET


MECH
OFFICES
IMMERSIVE
FELT RESERVOIR
STUDY
EDUCATION
RESEARCH
5,300 FT
Pearson-Arastradero
Preserve
FELT LAKE
6,300 FT
7,200 FT
Boething

ARCHITECTURAL INTERVENTION

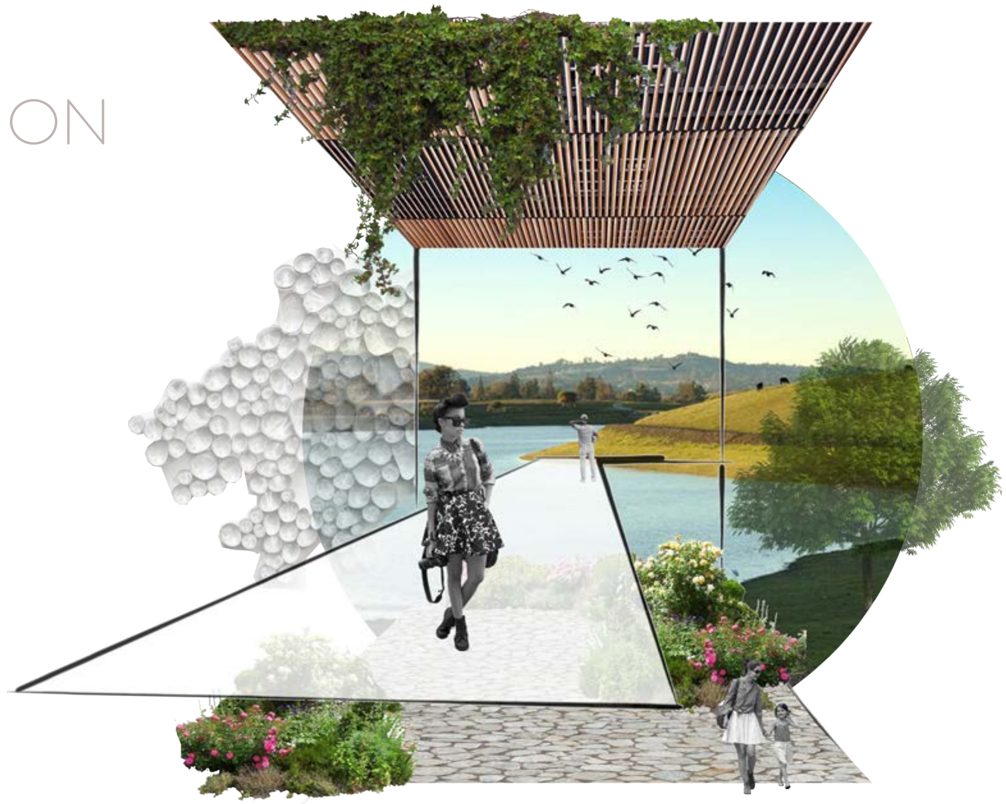
The goals of the architectural intervention include:

- Achieve maximum energy-efficiency through the use of renewable energy harvesting tools, i.e. solar, hydro, and wind energy

- Facilitate the production of biomimetic design and research

- Allow the building itself to be used as a teaching tool

- incorporate natural materials, natural light, vegetation, nature views and other experiences of the natural world to achieve a biomimetic / biophilic design

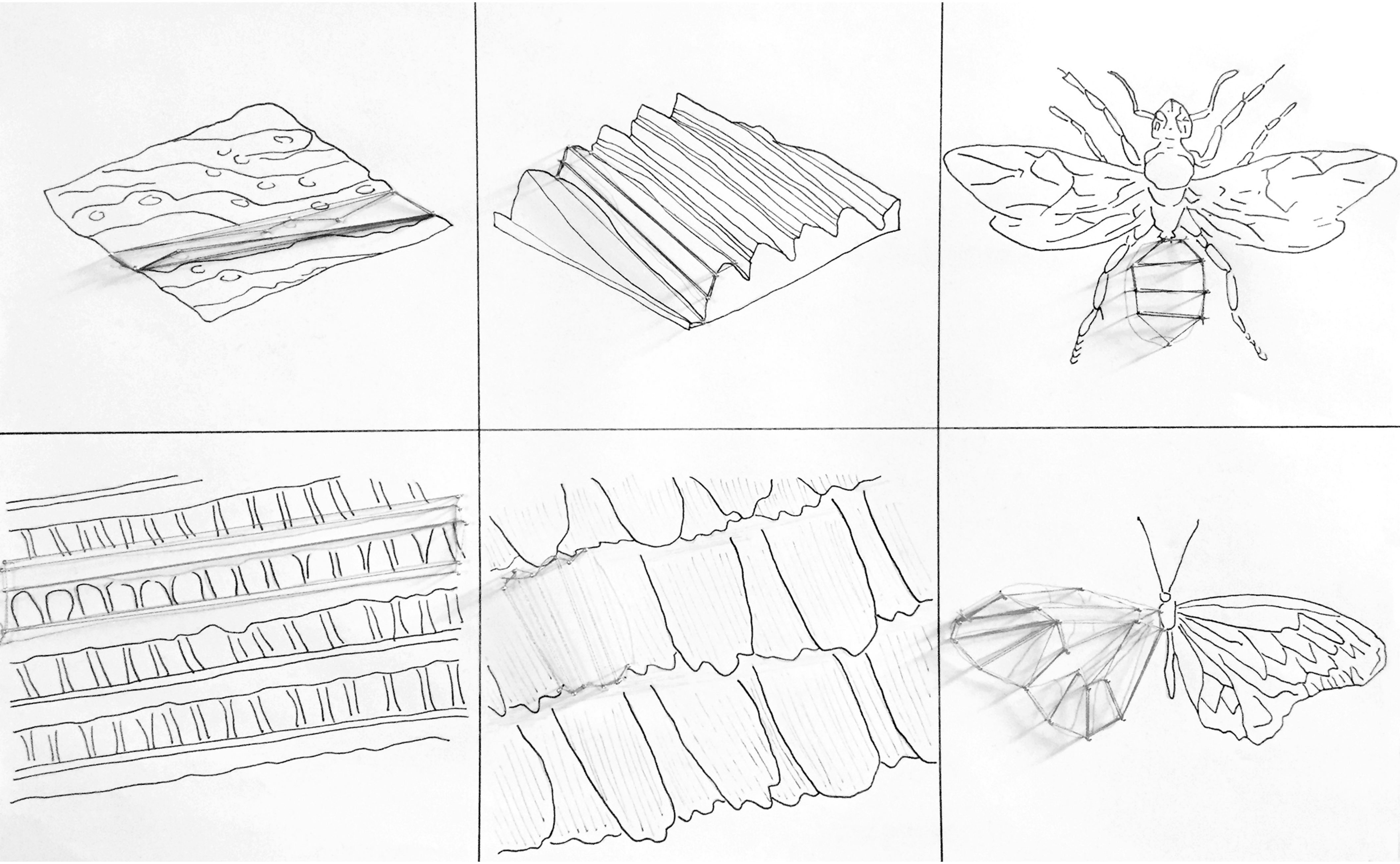


FELT Biomimicry Research + Innovation Center / / Biomimicry Incubator

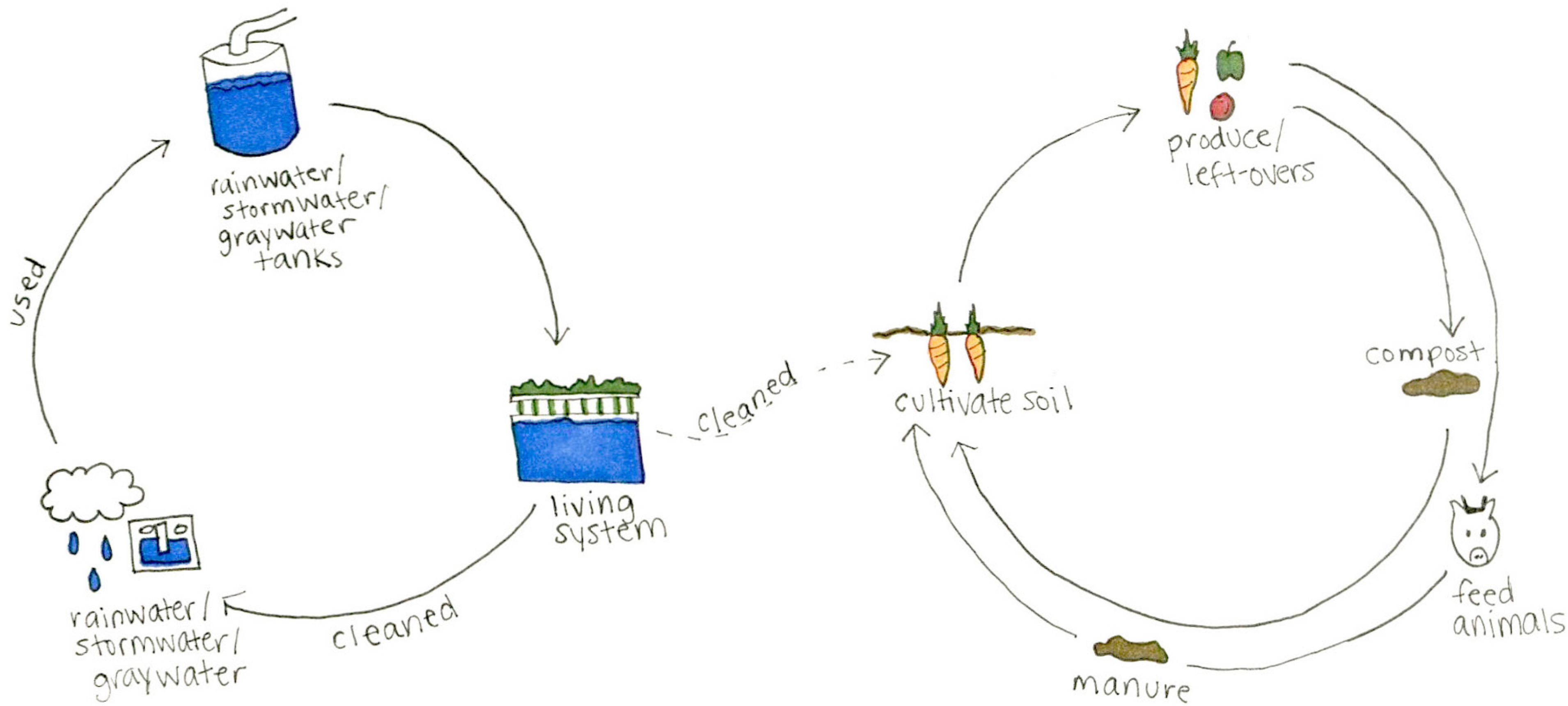
		Program	Area (sq ft)	Number	Total Area (sq ft)	Height requirements	Required elements/equipment	Description
EDUCATION		Lobby/Atrium	400	1	1,000			public meeting space for users and visitors; large light installation on the ceiling and a green wall; circulation paths clearly visible; entrance lobby is an active living space which encourages collaboration through shared multilevel meeting spaces
	Education	Classroom (Type I)	750	10	7,500			traditional classroom
		Classroom (Type II)	950	10	9500			shop-style classroom
		Lecture Hall	2,000	1	2000			public/student seminars about nature environment biomimicry
		Micro Meeting Space	100	6	600			Located between admin and education spaces. small, sound-proof areas for telephone calls, two -man conferences or personnel meetings
	Research	Computer Lab	12000	1	12,000			design/research desks; connection to the outdoors. Visible from the entry courtyard.
		Laboratory	10000	1	10,000		Haas OM-2A CNC machine, Laser Cutter, Universal Robot	traditional laboratory; located near growing areas / wildlife
		library storage						
		Library	2000	2	4,000		desks, bookshelves, main desk,	Biology, energy, technology, and design textbooks for research and study.
	Innovation	Meeting Rooms	600	4	2,400			Promote an environment of collaboration and ongoing discussion.
		Think Tanks			0			
		Workshops			0			expandable by flexible partitions. All the furniture and the stands are on wheels and support agile working.
		Innovation Studio	8000	1	8,000			In close proximity to the research laboratory and production rooms; flexible and agile working environment
		Production Room	12000	1	12,000			3D printers, prototype build stations. In close proximity to the research laboratories and exhibition space.
	Exhibition	Exhibition Hall	2,000	1	2000			To inspire the users to draw inspiration from the surrounding environment.
ADMINISTRATION		Office	350	20	7,000			The faculty offices should be separate from but located near the educational space.
		Staff Lounge	800	4	3,200			Adjacent to the offices; retreat for faculty and staff.
		Staff Lavatories			0			*Calculate
ECOLOGY		Greenhouse						closed loop system for rainwater storage; educational tool for students
		Visitor Center	1000	1	1000			Biodiversity in Bay Area
		Lecture Hall	2,000	1	2000			public seminars about nature environment biomimicry
		Biodiversity/Biomimicry Museum	1000	1	1000			Exhibits of biomimicry examples in the arts and sciences
		Immersive Education Area	1000	1	1000			adjacent to the museum; show films (3d) - science museum
		Nature Observatory	300	1	300			viewing deck/tower
SUPPORT		Service Core			0			core that receives all serving and technical features of the building such as the emergency stairwell, the elevator, the technical infrastructure and the sanitary system.
		Cafe			0			closed loop system; for institute and visitors
		Kitchen			0			
		Storage	85	10	850			
		Mechanical Space	2000	1	2000			The mechanical equipment to be clearly displayed in some way that it may be used for educational purposes.
		Security/Camera Room	100	1	100			
		Lavatories	200	20	4000			*Verify* number of M/F toilets
OUTDOOR		Courtyard	400	1	400			growing area for plant species that can be studied in laboratories.
		Nature Trail	0		0			
		Ampitheater Seating	0		0			Outdoor classroom; opportunity for observation and teaching.
		Parking	162	80	12960			*Verify* number of spots

Total Net Area (sf)	**93450**

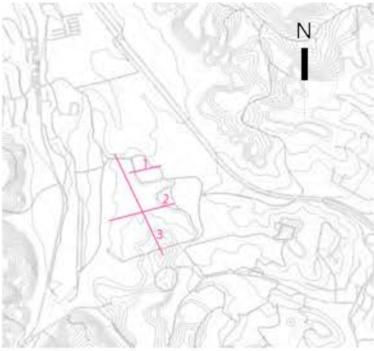
INITIAL BIOMIMETIC RESEARCH

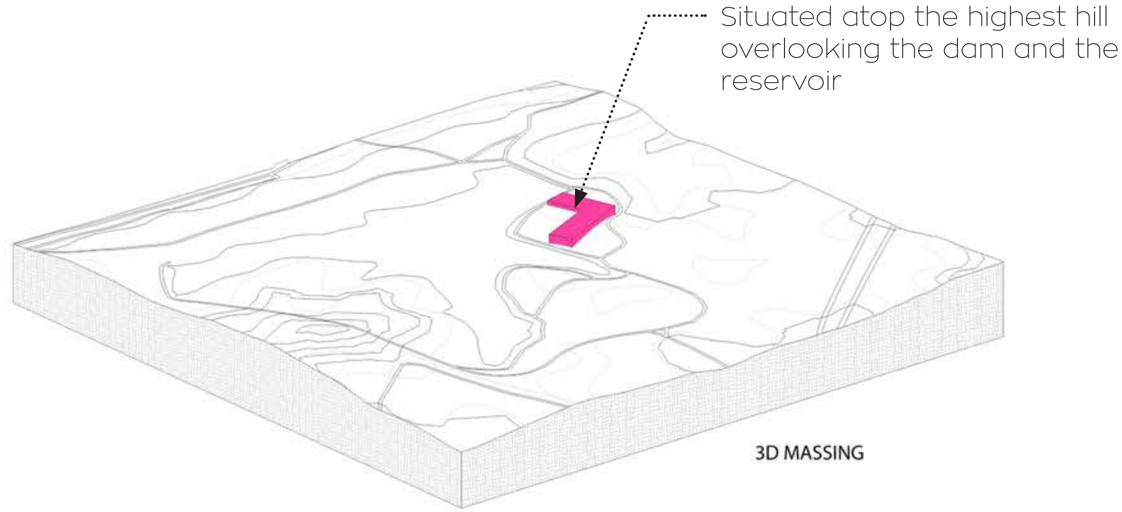


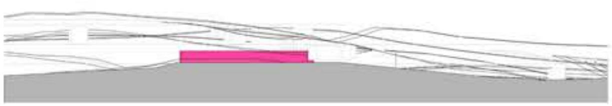
CLOSED-LOOP SYSTEM



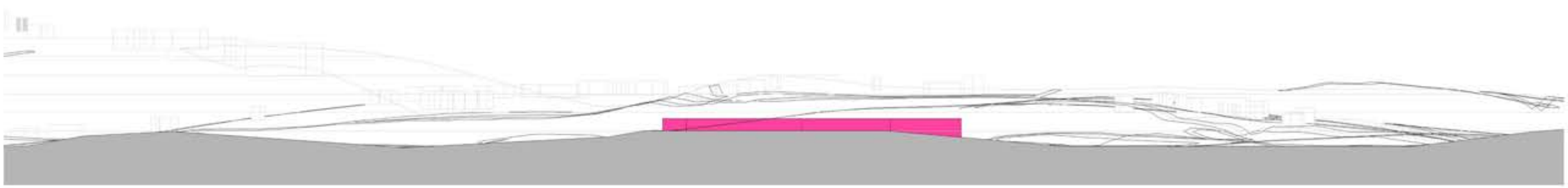
SCHEME #1: THE HILL



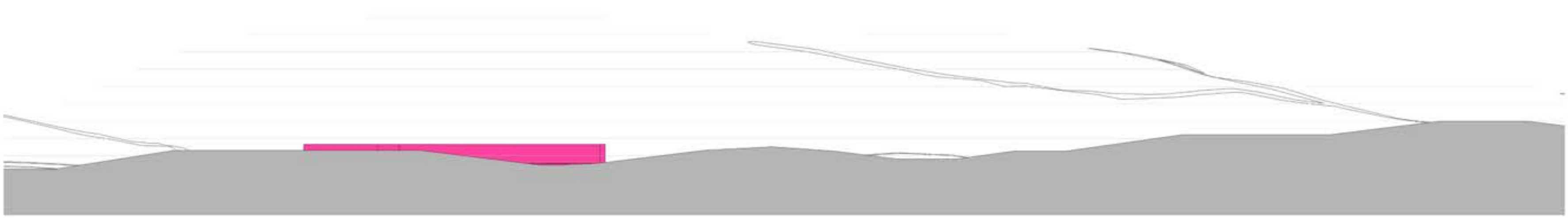




Section 1: Facing North

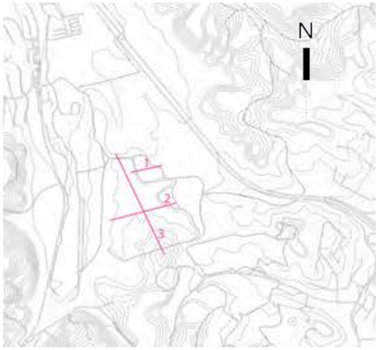


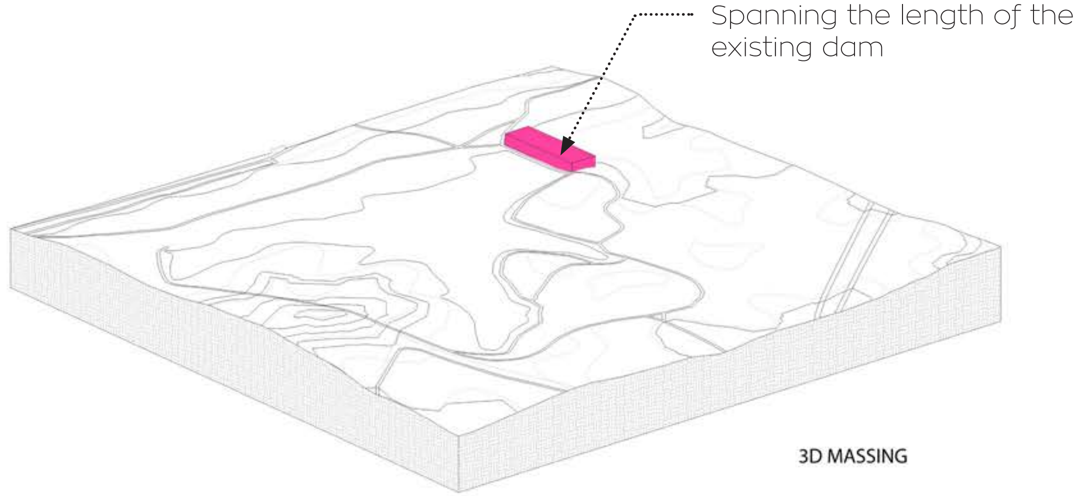
Section 2: Facing North



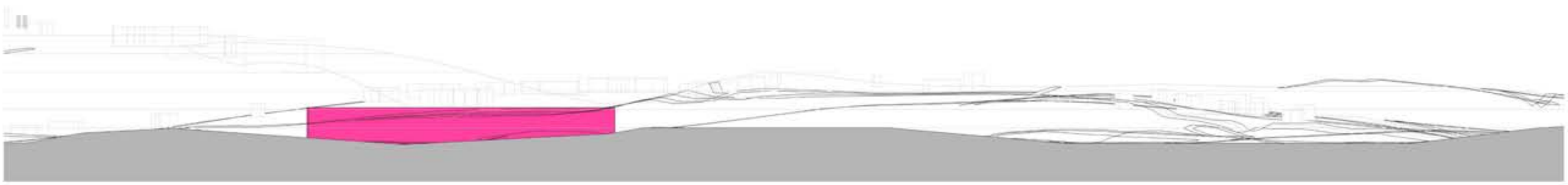
Section 3: Facing East

SCHEME #2: THE DAM

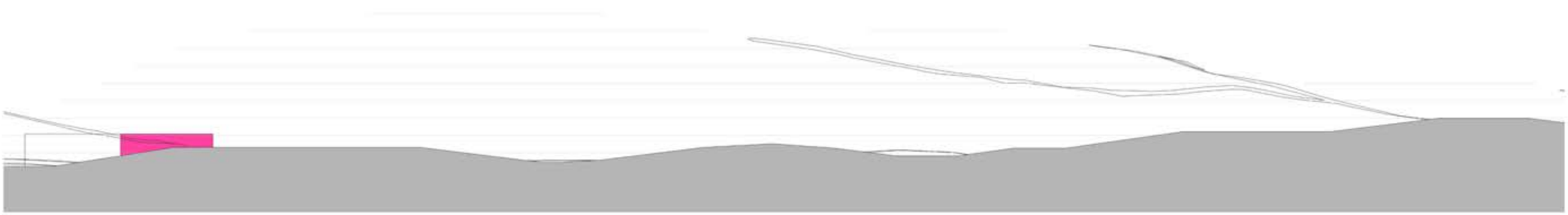




Section 1: Facing North

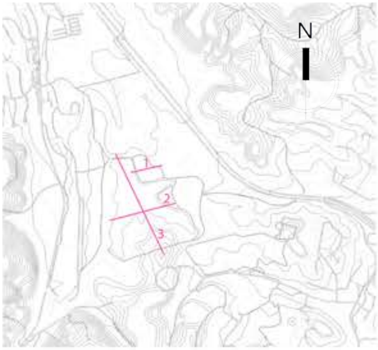


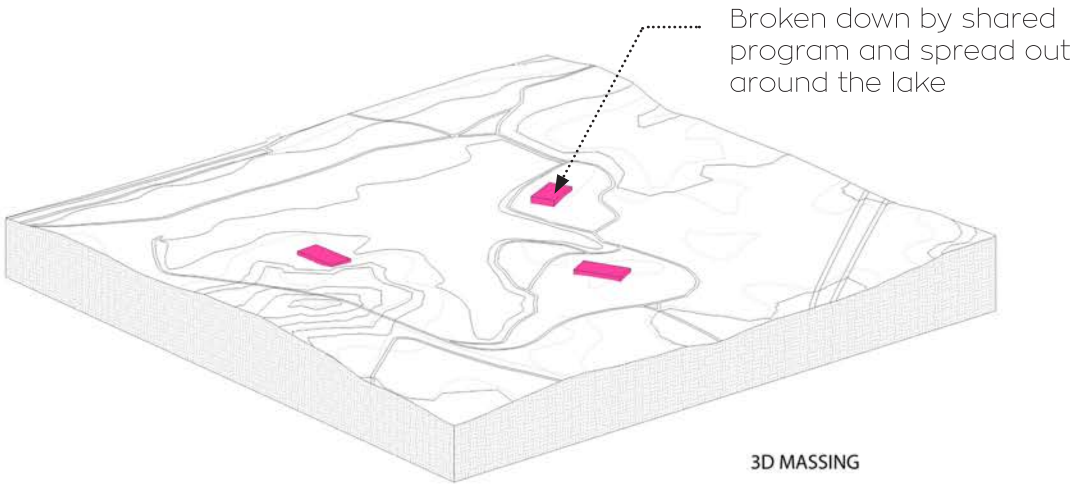
Section 2: Facing North

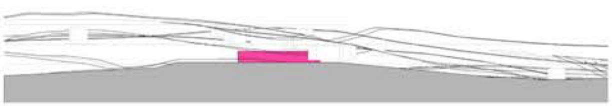


Section 3: Facing East

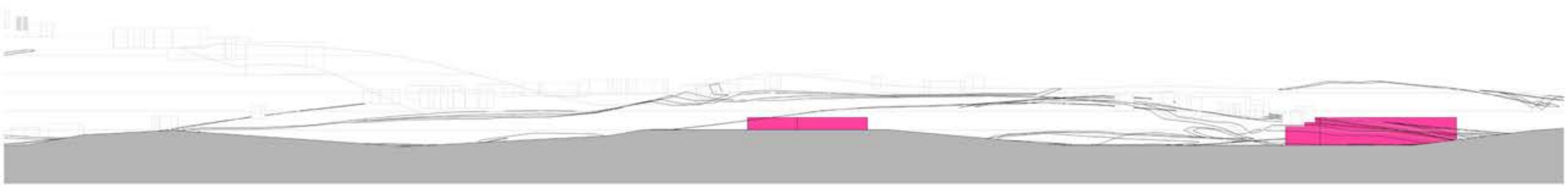
SCHEME #3: THE LAKE



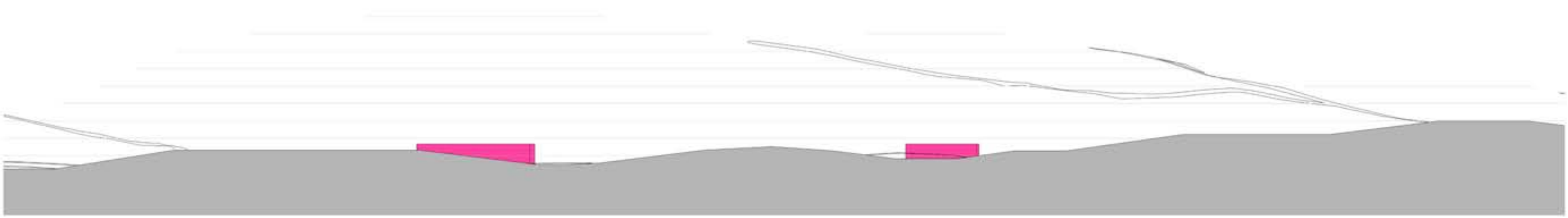




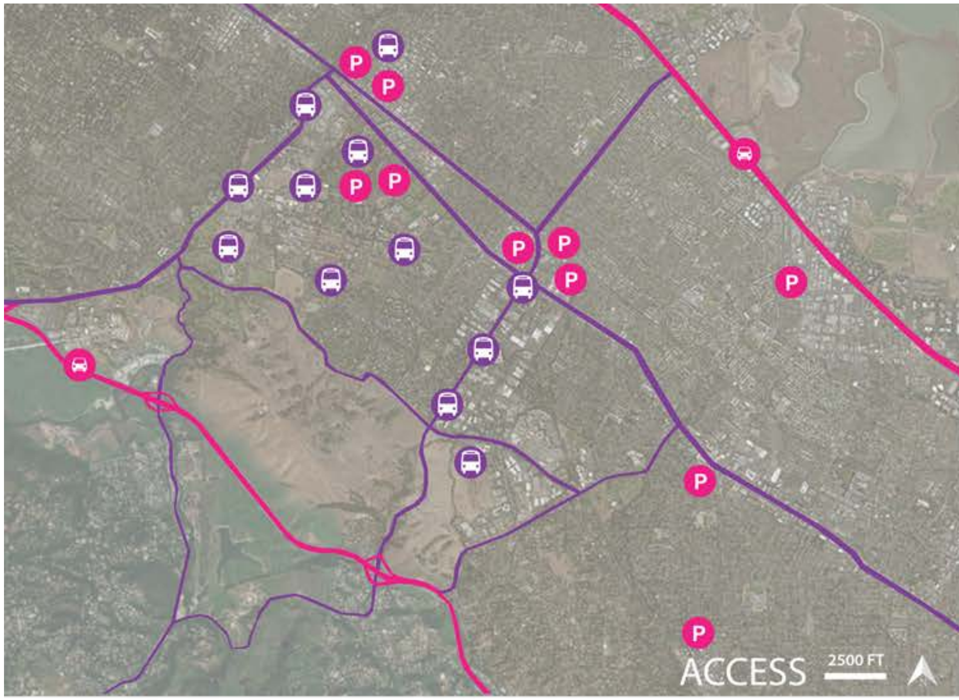
Section 1: Facing North

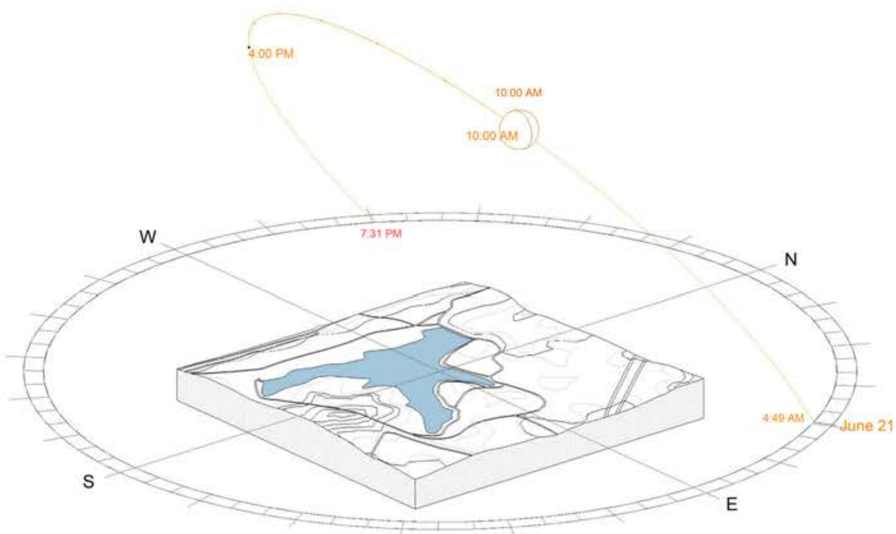


Section 2: Facing North

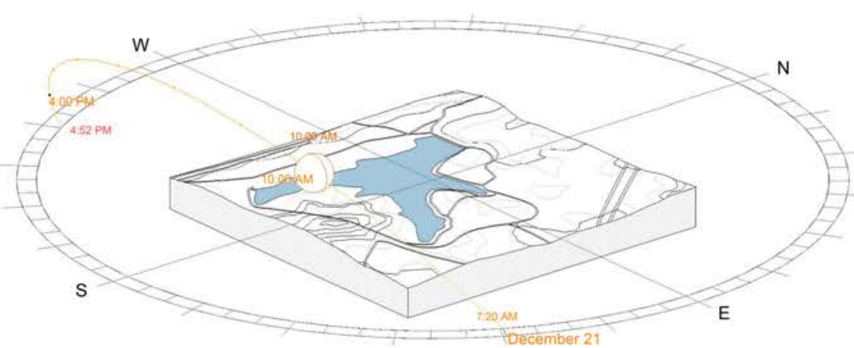


Section 3: Facing East





Summer Solstice



Winter Solstice

CHAPTER 12

D E S I G N   D E V E L O P M E N T

HYBRID SCHEME

As a result of the three studies in the conceptualization phase, the design that resulted was a hybrid between schemes 1 and 2, the hill and the dam. The refined architectural goals were to integrate with the dam, to provide program on either side of the dam, and to allow the passage of water beneath a bridge structure.

Each of these factors was considered all while integrating with the site topography and considering the environmental needs for renewable energy harvesting.

The following design development phase included a study of the arrangement of spaces in order to create a building that can be used as a teaching tool for the emerging practice of biomimicry.

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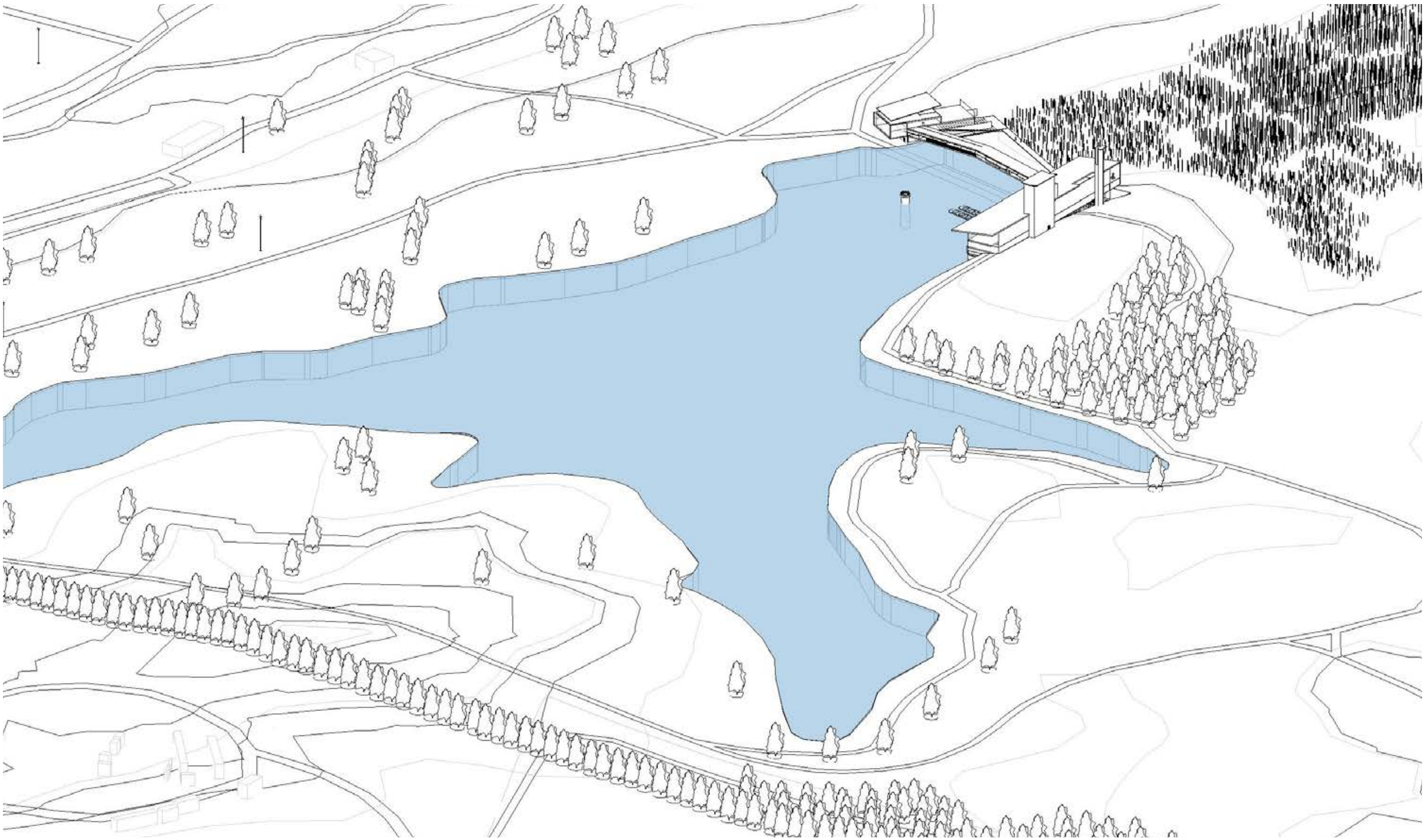

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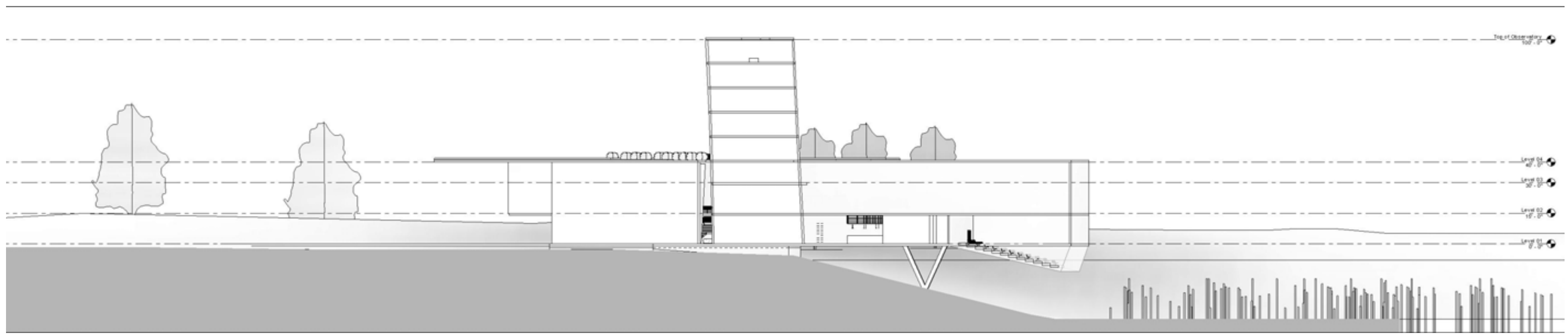

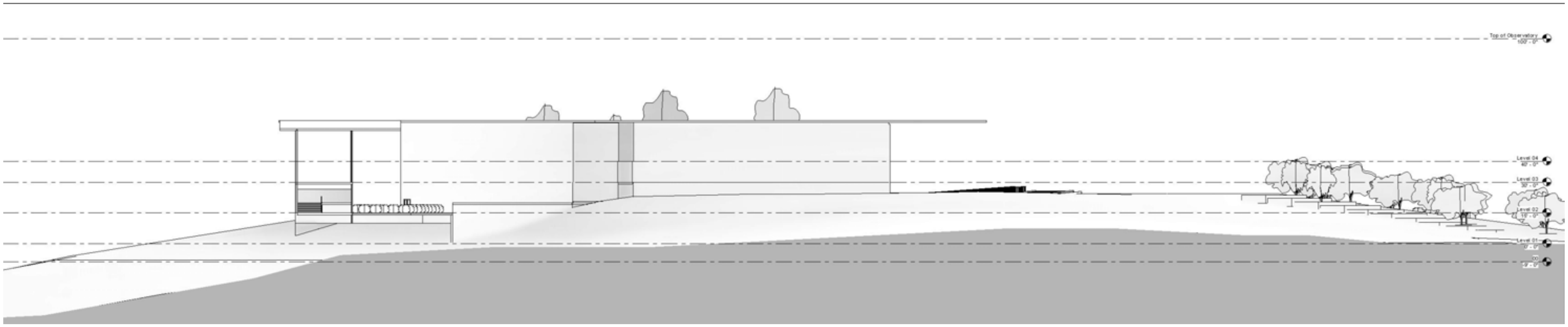

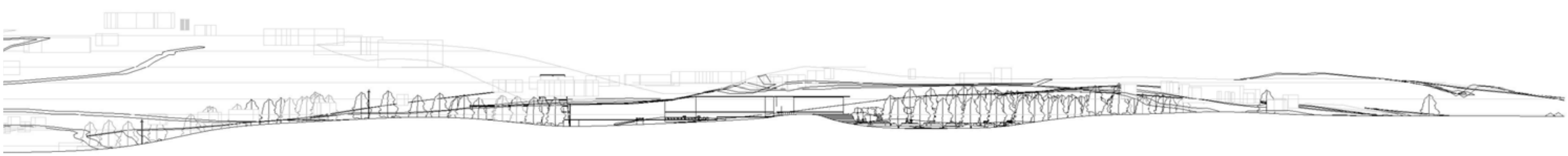

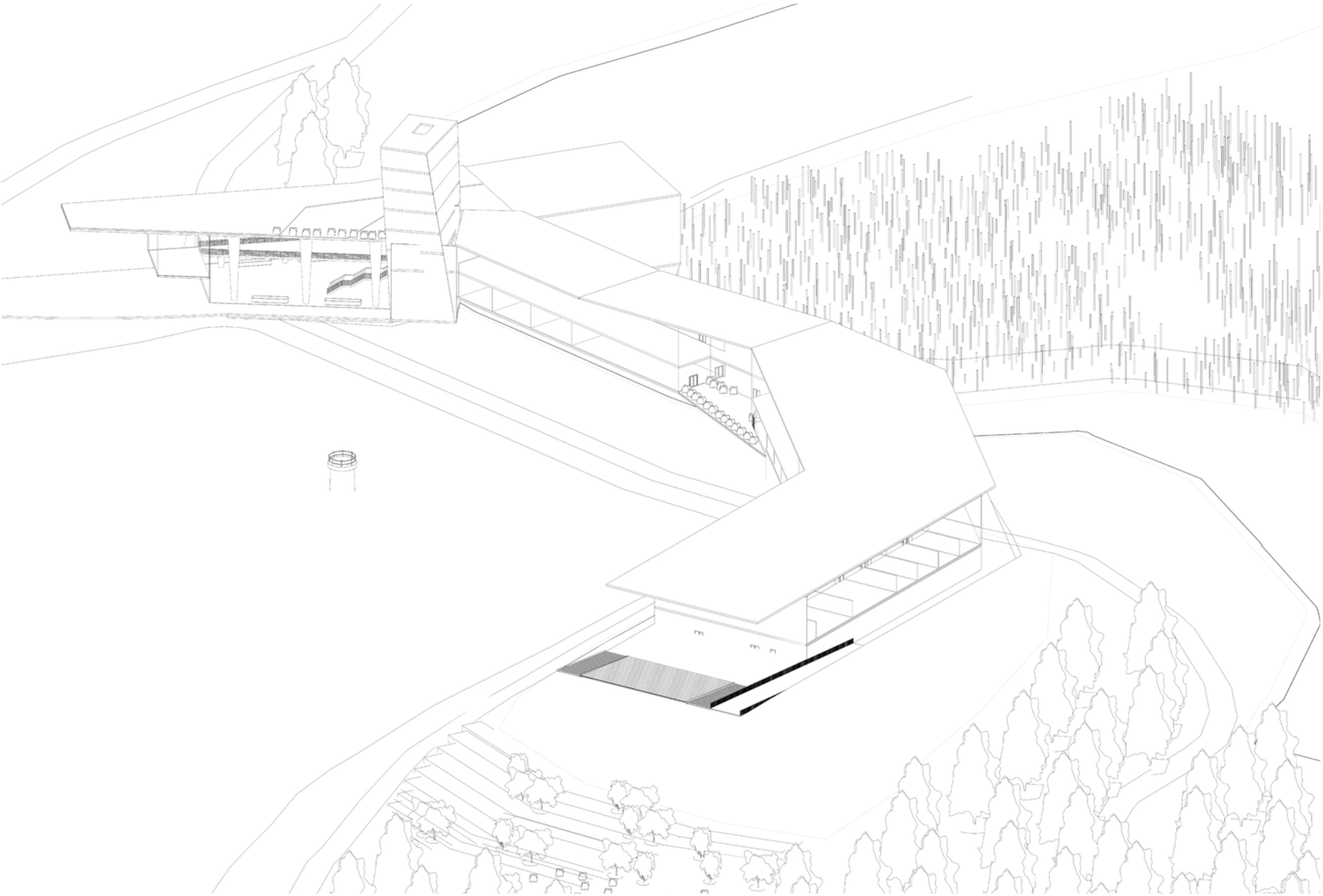

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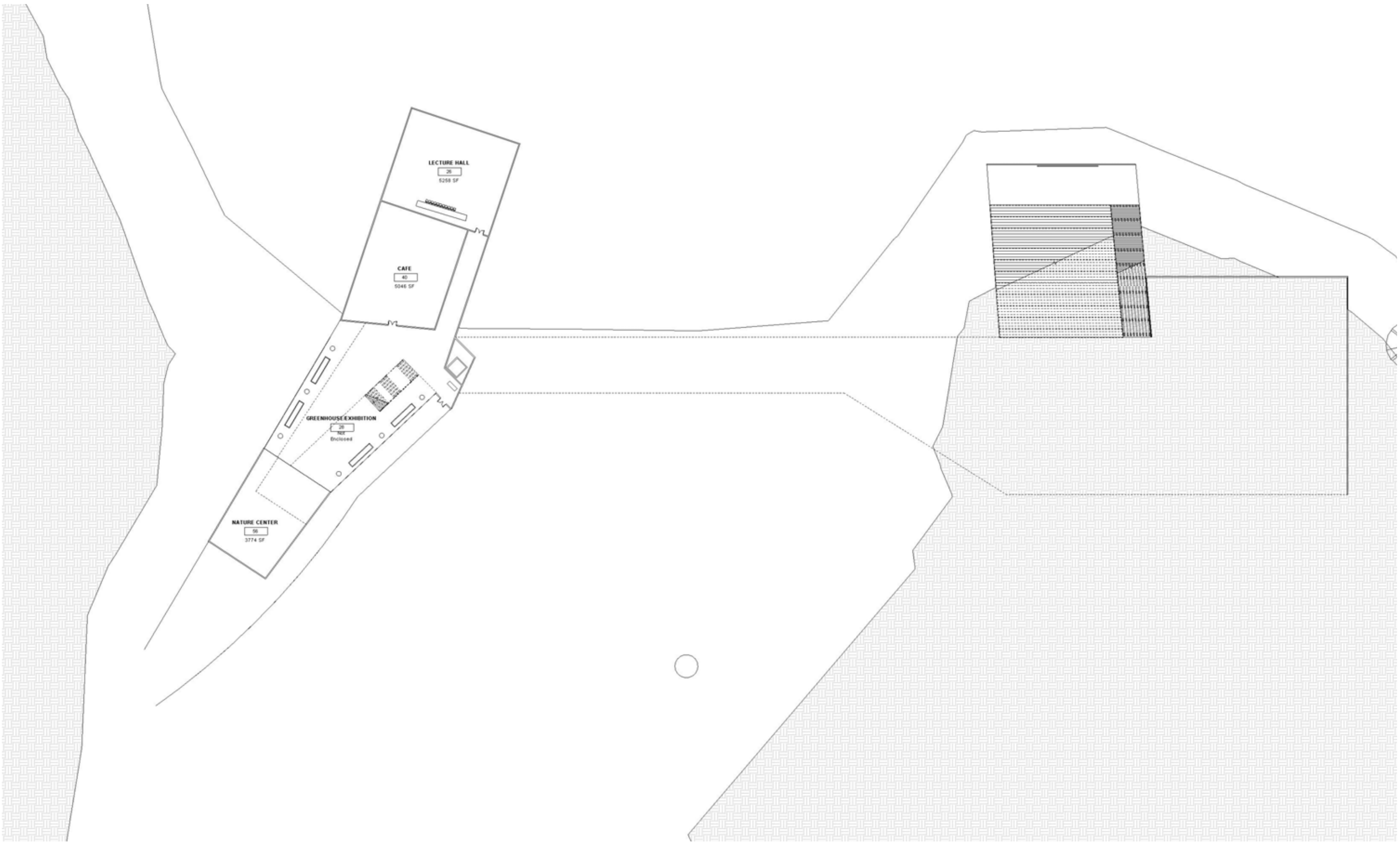

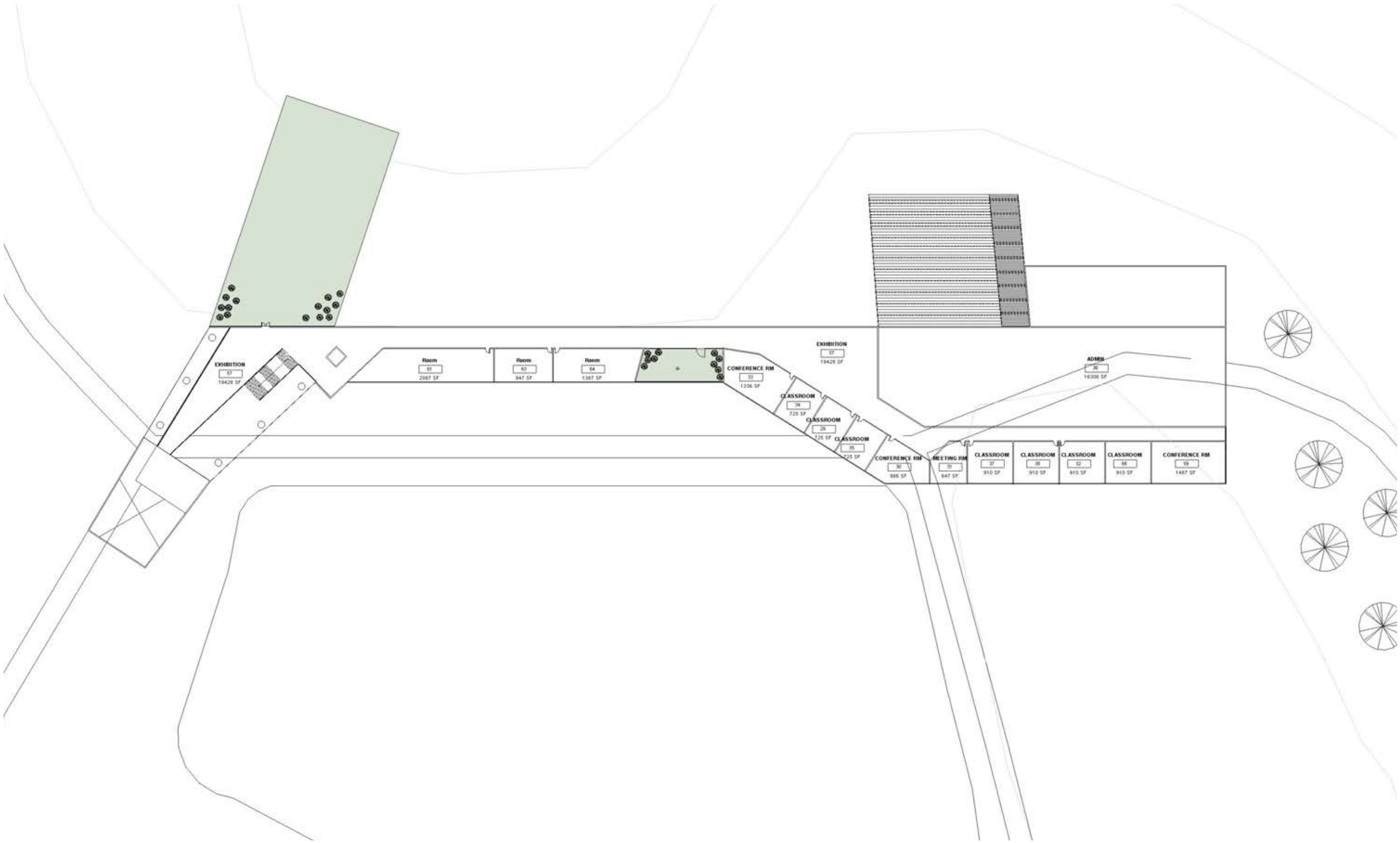
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Room
2087 SF
Room
947 SF
Room
1387 SF
CONFERENCE RM
1336 SF
EXHIBITION
19428 SF
CLASSROOM
725 SF
CLASSROOM
725 SF
CLASSROOM
725 SF
ADMIN
16306 SF
CONFERENCE RM
986 SF
MEETING RM
647 SF
CLASSROOM
910 SF
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CLASSROOM
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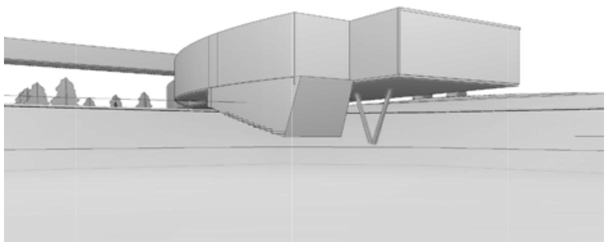
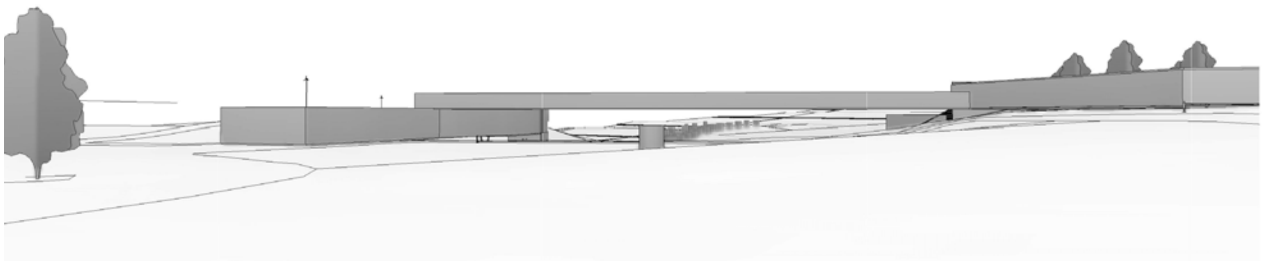
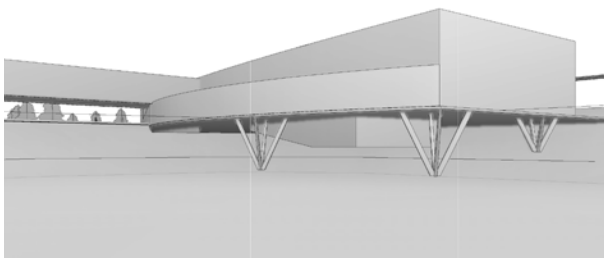
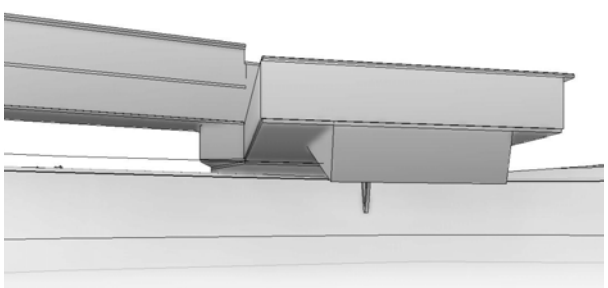
CONFERENCE RM
1487 SF

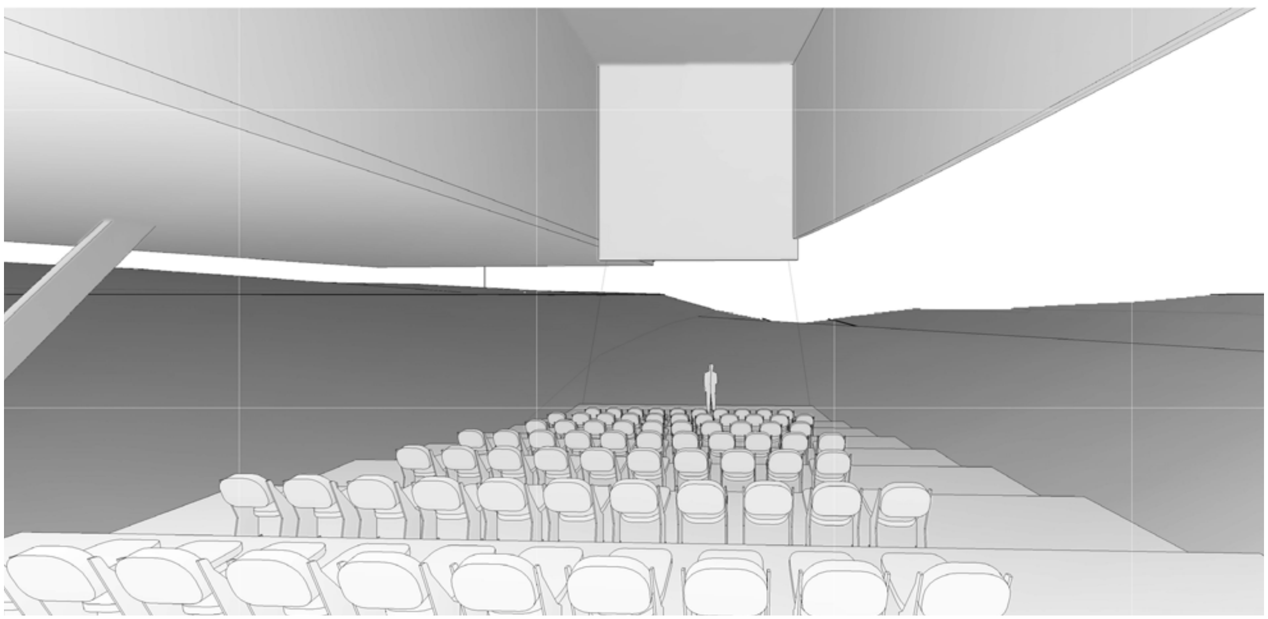
INITIAL RENDERINGS

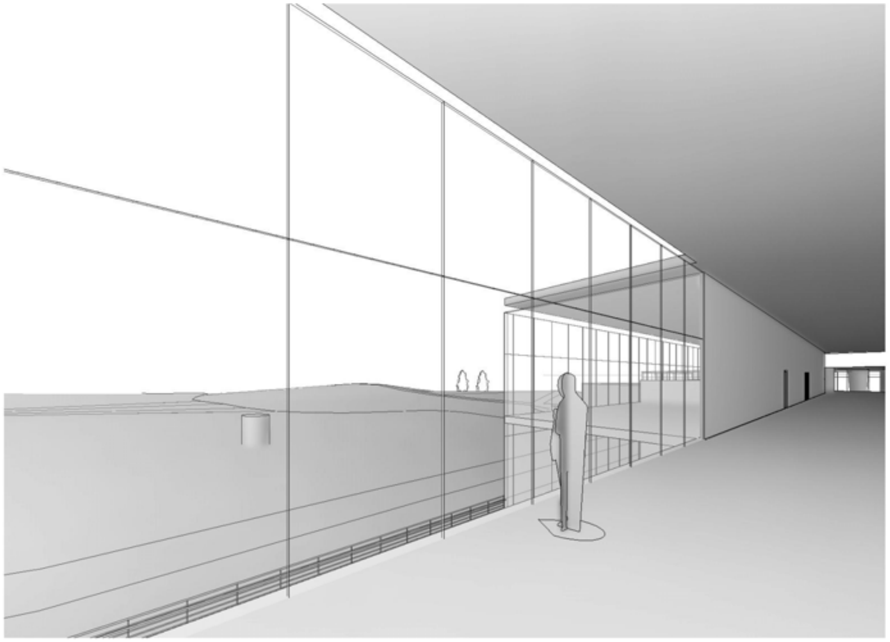
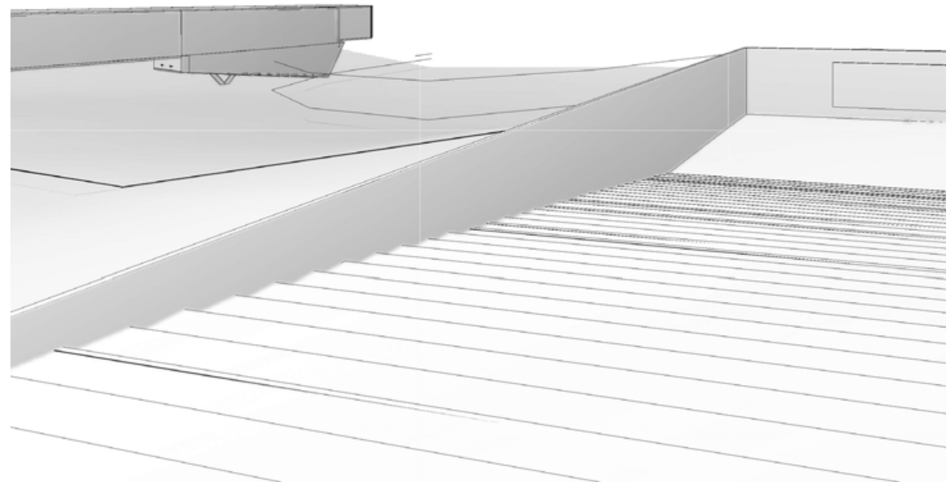
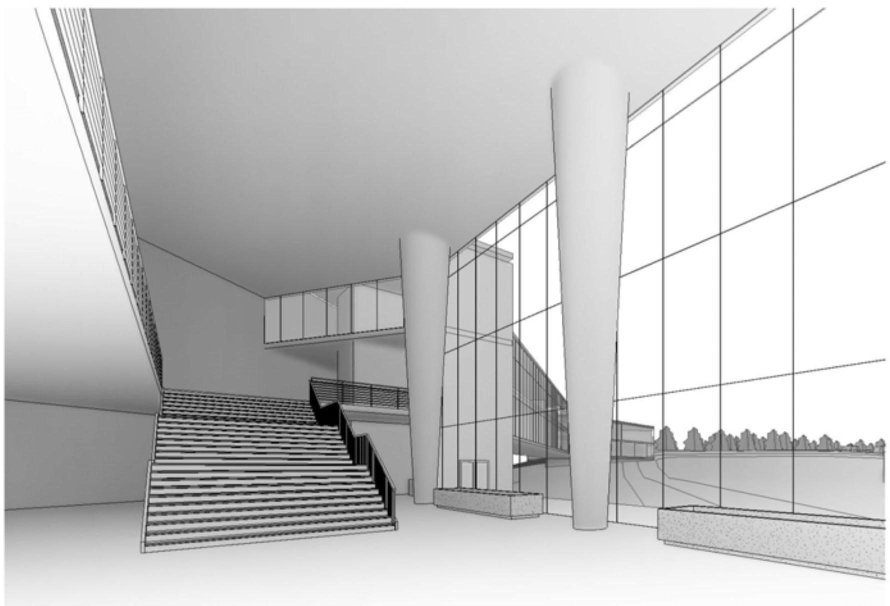
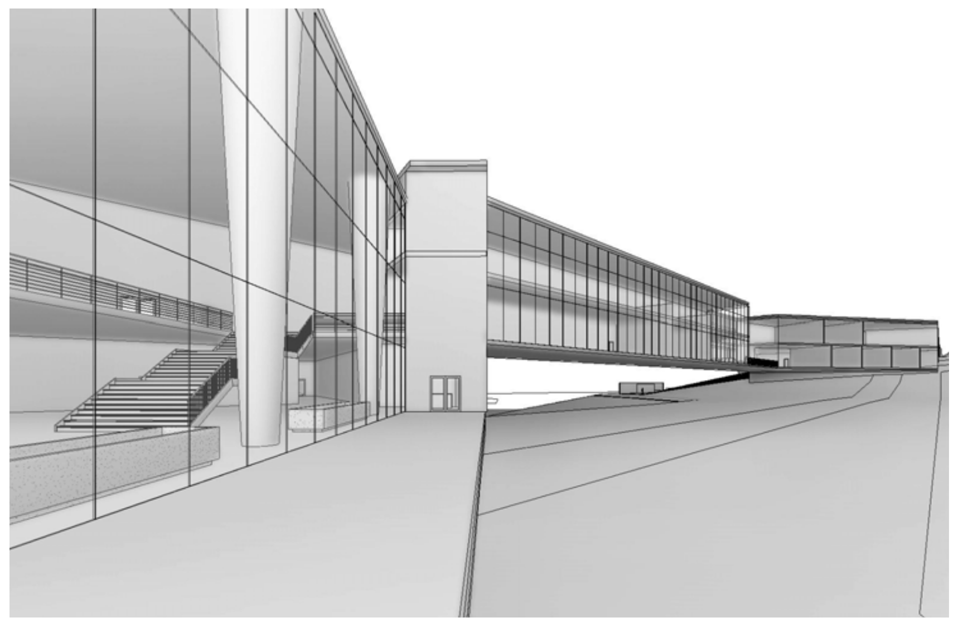










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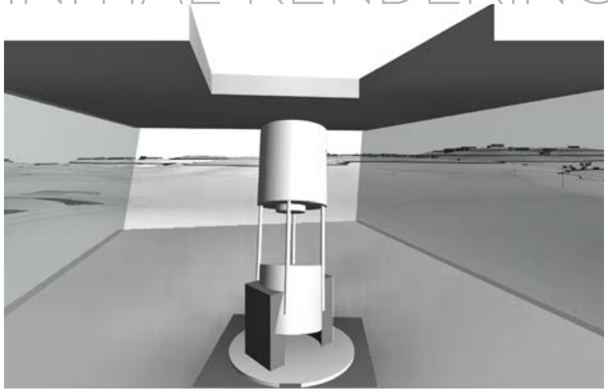
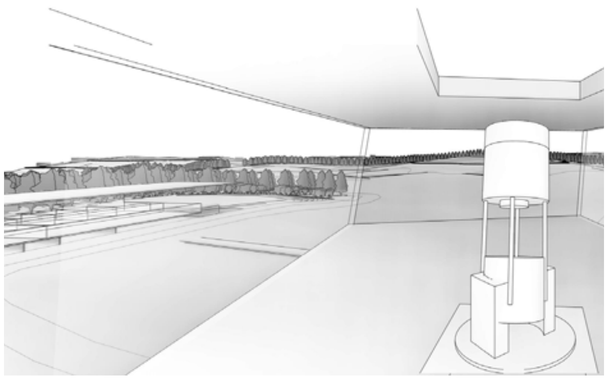
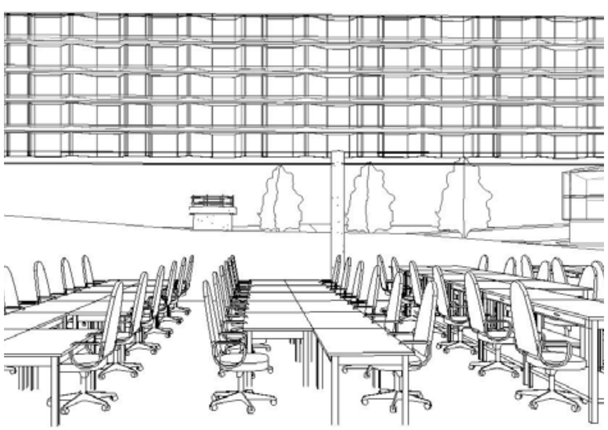
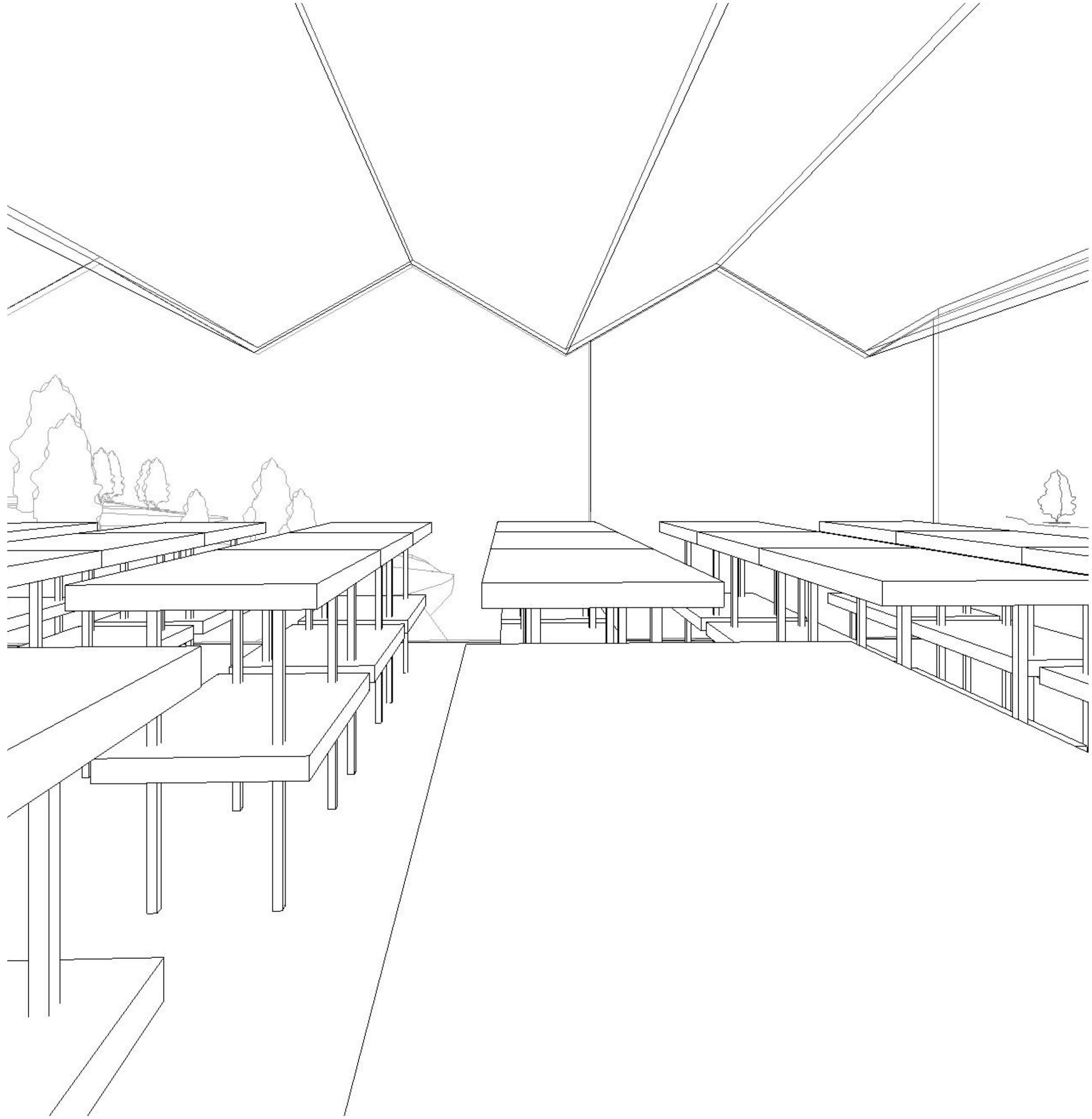
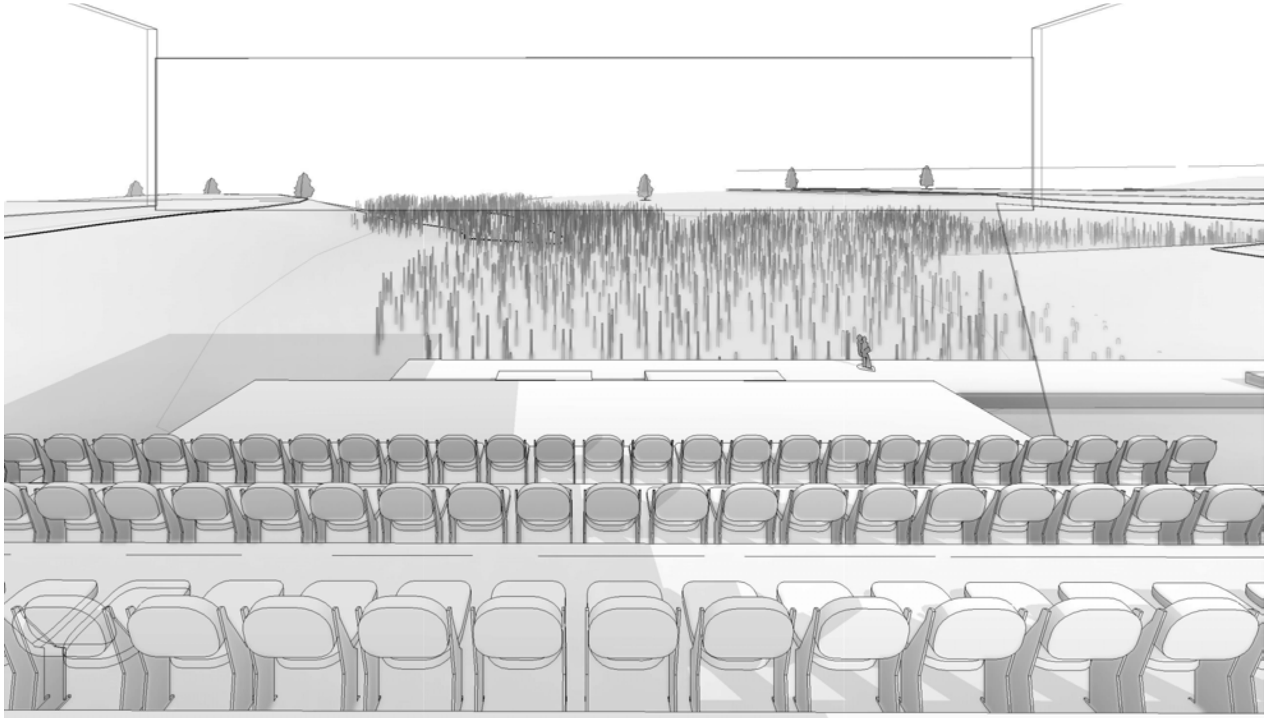
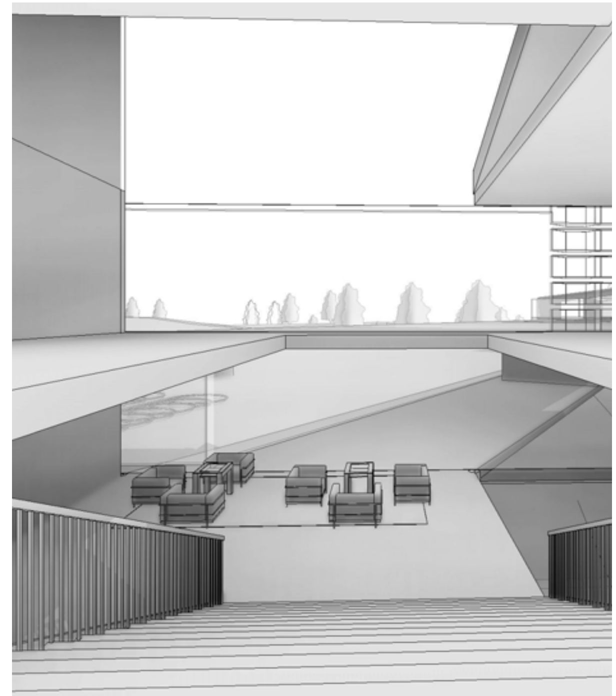


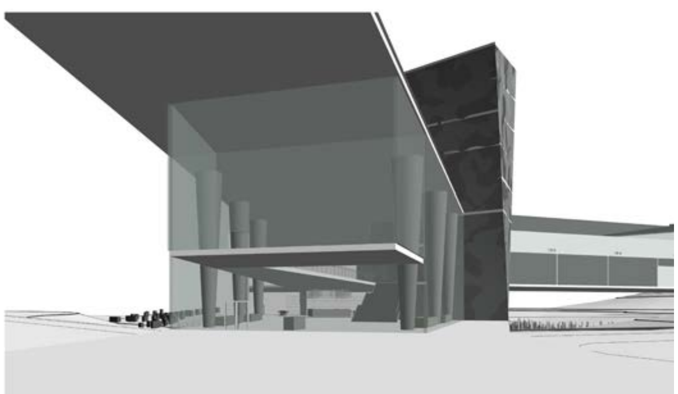


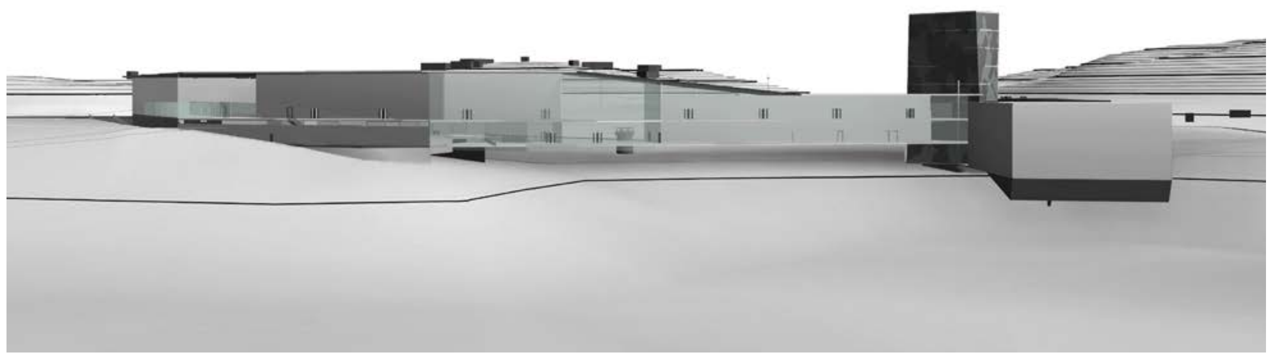












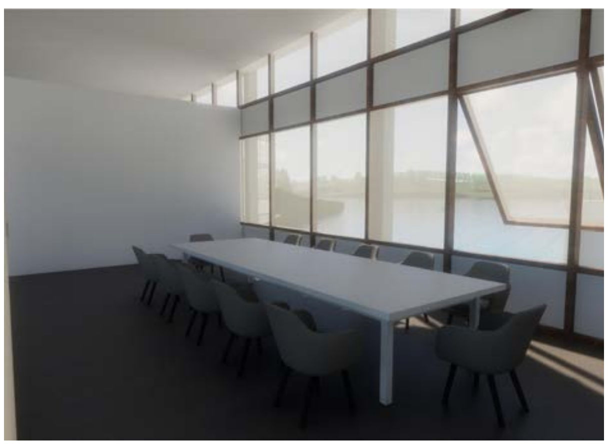
DESIGN DEVELOPMENT

UPDATED PROGRAM

The building square footage was adjusted to better fit the needs of the site, the building's energy efficiency goals, as well as the requirements for each of the programmatic elements.

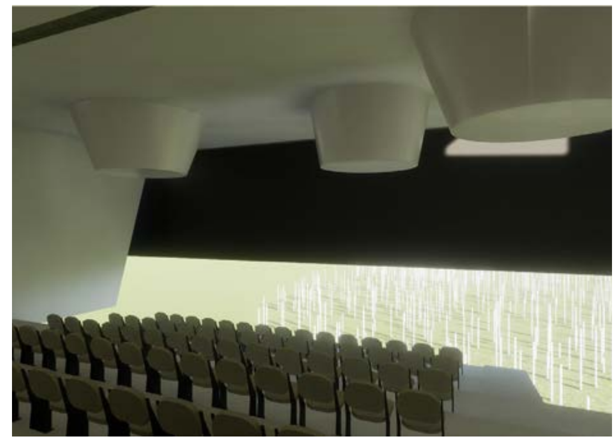
	Program	Count	Total Area (sq ft)
Education	Classrooms	8	3,000
	Conference Rooms	3	1,500
	Lecture Hall	1	3,000
			7,500
Research	Laboratory	2	12,000
	Library	1	1,700
	Computer Lab	1	450
	Greenhouse	1	7,000
	Observatory	1	1,400
			22,550
Production	Innovation Studio	1	4,700
	Workshop	1	420
	Robotics Lab	1	400
	3D Lab	1	400
			5,920
Exhibition	Exhibition Hall	1	5000
	Cafe	1	1500
	Kitchen	1	500
			7000
Administration	Administrative Offices	14	2,100
	Staff Amenities	1	2,500
			4,600
Support	Lobby	1	1400
	Student Lounge	1	1700
	Mechanical	1	1700
	Security	1	150
	Lavatories	34	1440
			6390
			53,960

RENDERING PROCESS








CHAPTER 13

F I N A L   D E S I G N

THE BIO-INSPIRED SOLUTIONS LAB

The final design is a result of a comprehensive study of building organization, orientation, and sustainablility. The program is separated into three distinct zones: exhibition, education, and research, and is arranged in such a way that the building can be used as a teaching tool for students and visitors alike.

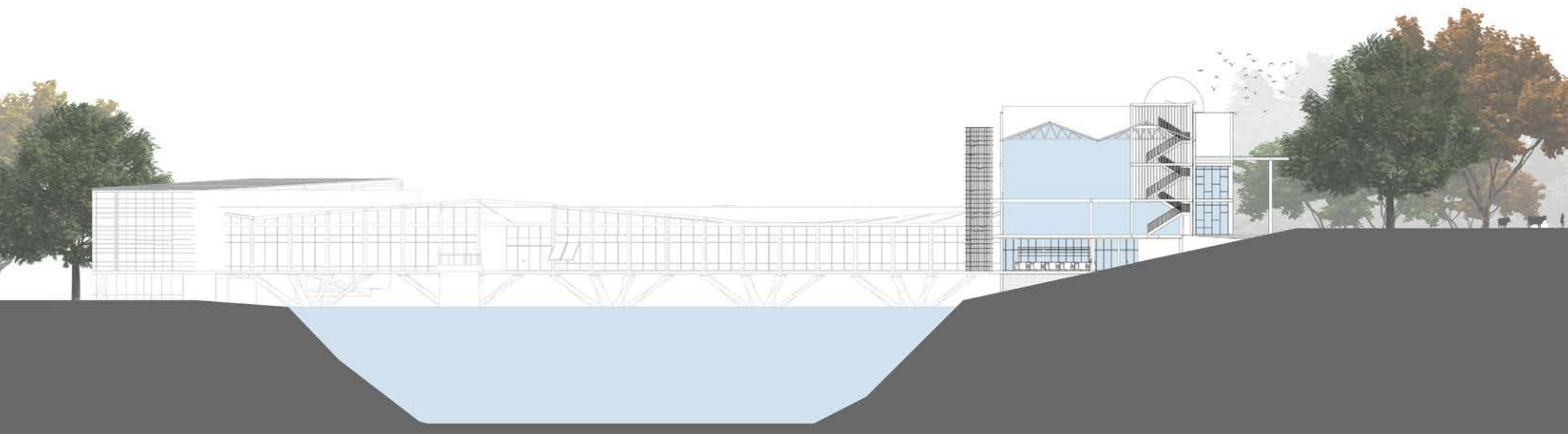
The 300-foot bridge spans across the existing earthen dam, acting as a threshold above the existing reservoir and the proposed riparian wetlands.

The building not only responds to but also integrates with its environment, restores the site to its riparian state, utilizes renewable energy resources, and facilitates research and the production of biomimetic prototypes. for an emerging practice and standardization of biomimicry.

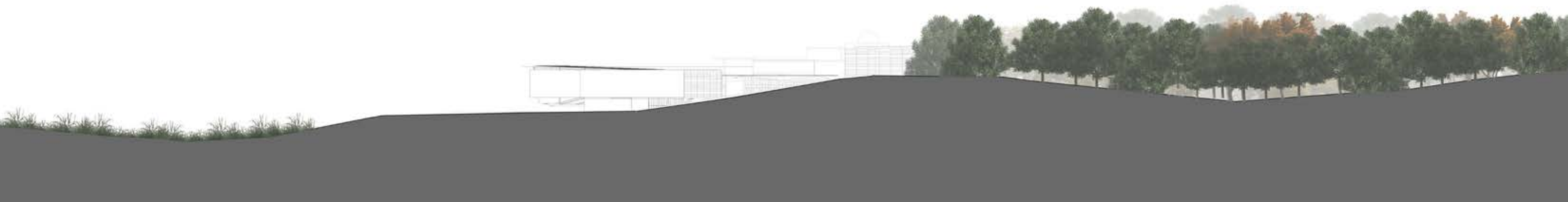

PROPOSED SITE PLAN
FOOTHILLS PARK
FARMLAND
WETLANDS
PARKING
FELT LAKE
RESIDENTIAL
STABLES
RESIDENTIAL
N
0'
400'
1000'
2000'
GRAPHIC SCALE

SECTIONS

Section 1: Facing North



Section 3: Facing North



Section 2: Facing East

Section 4: Facing West

BUILDING PROGRAM

Level 04

Library	850 SF
Computer Lab	450 SF
Greenhouse	7000 SF
Observatory	1400 SF

Level 03

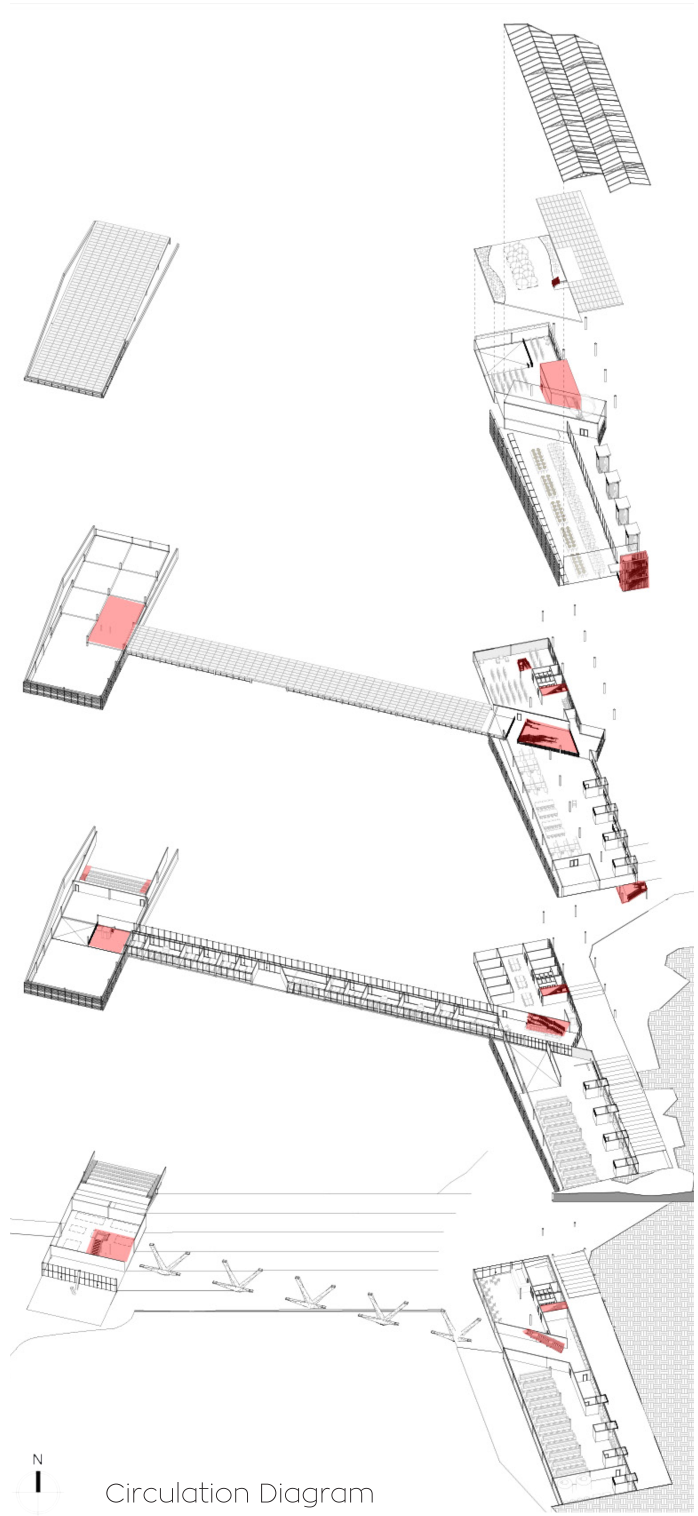
Exhibition	2000 SF
Library	850 SF
Innovation Studio	4700 SF
Workshop	420 SF
Robotics Lab	400 SF
3D Lab	400 SF

Level 02

Lobby	1400 SF
Exhibition	2000 SF
Lecture Hall	3000 SF
Office	2100 SF
Laboratory	6000 SF

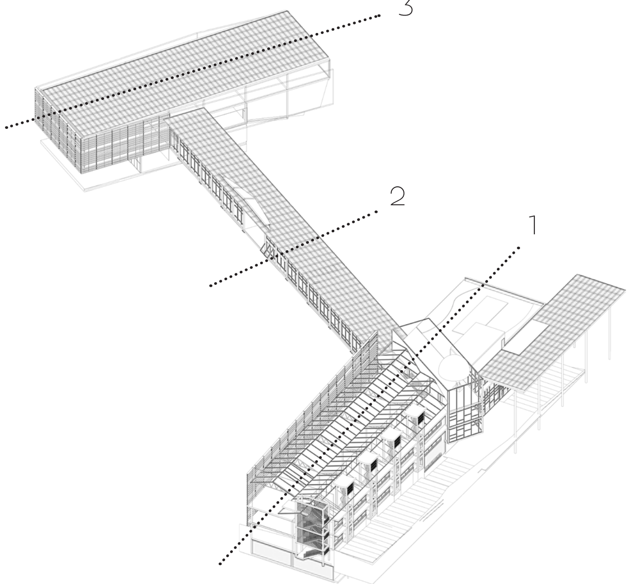
Level 01

Exhibition	1000 SF
Cafe	1500 SF
Laboratory	6000 SF
Mechanical	1700 SF

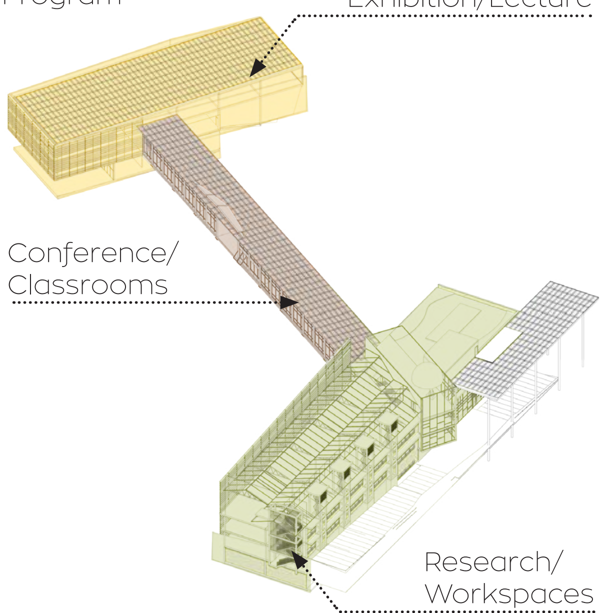


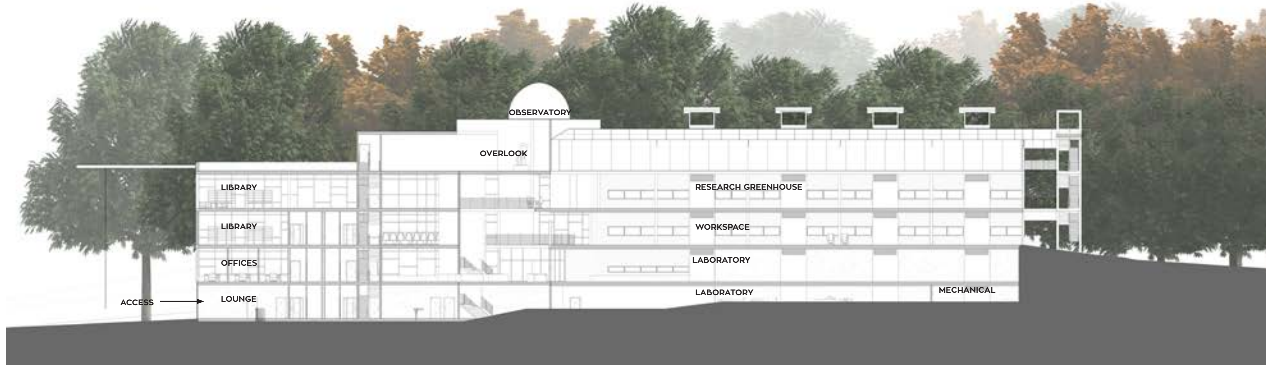
Circulation Diagram

Sections

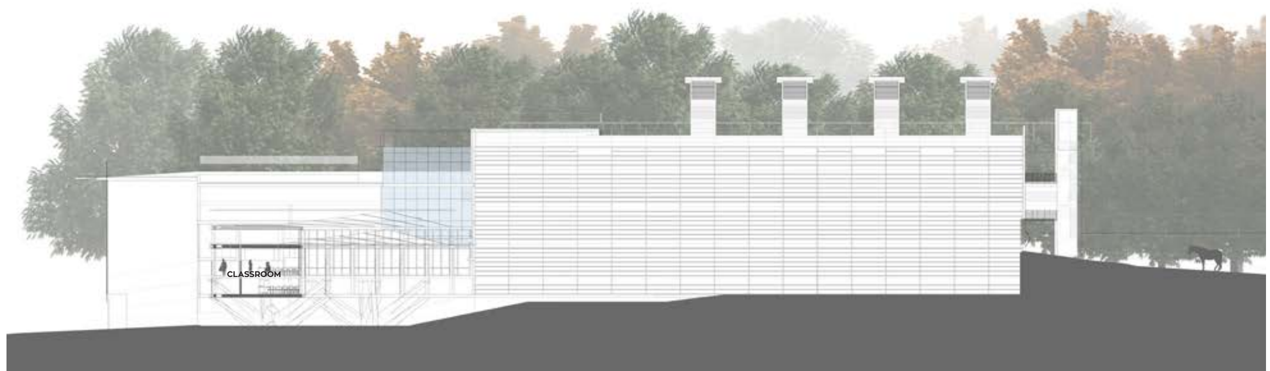


Program

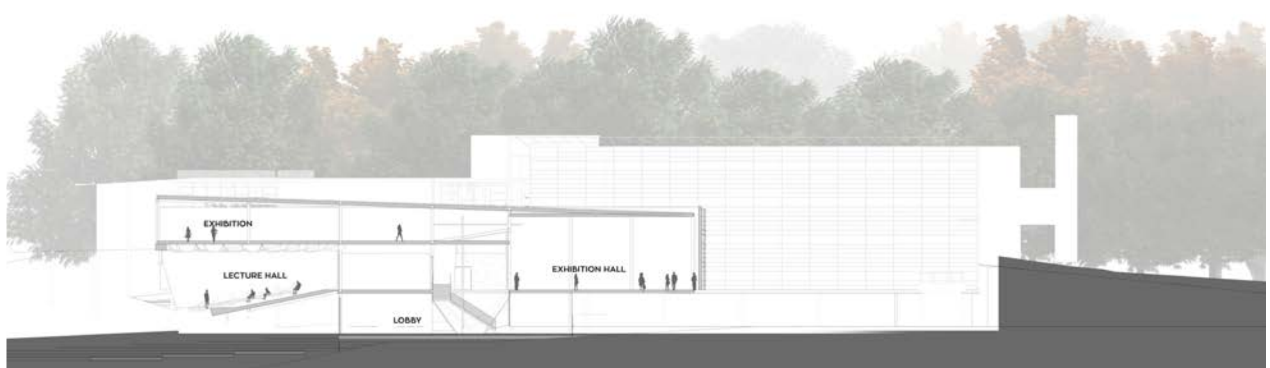




Section 1: Research/Workspaces



Section 2: Conference/Classrooms



Section 3: Exhibition/Lecture

EXTERIOR RENDERING

ENTRANCE LOBBY RENDERING

At the entrance level, the lobby contains a reception area, seating, connection to the bridge, and a living machine, all of which overlooks the double-heighted research laboratories. At the upper levels, users can access the research greenhouse, workspaces, and the observatory.

RESEARCH PROGRAM

Laboratories devoted to the development of biomimetic research allow the findings to be applied in the design phase.

The outdoor areas facilitate field research of biological habitats and riparian areas, such as the wetlands.

The Research Greenhouse is equipped with the latest technology in a climate controlled growth environnment. Visitors are provided an elevated observation space to view the greenhouse activity without disrupting the controlled experimentation below.

COLLABORATIVE PROGRAM

Classrooms and conference spaces along the bridge contain expansive views of Felt Lake and promote collaboration and flexible layouts.

The Exhibition Hall publicly displays the biomimetic prototypes that are produced within the Bio-Inspired Solutions Lab.

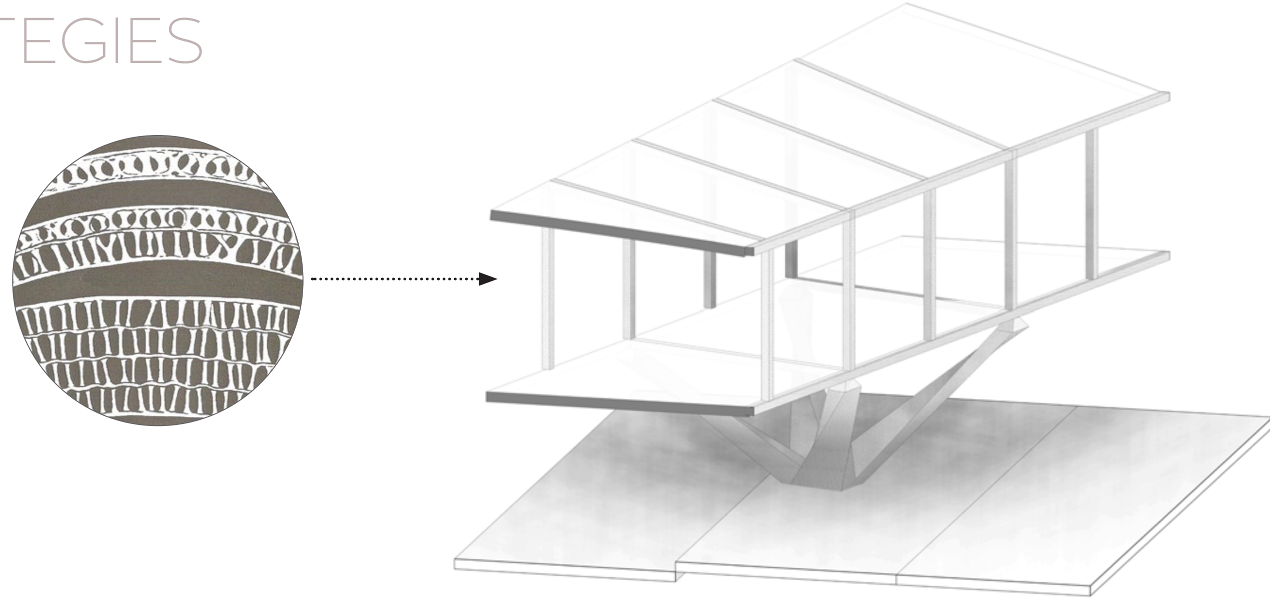
The Lecture Hall, which seats 250 visitors, is hung from the structure to allow for a direct, expansive view of the wetlands.

A large, flexible workspace facilitates the production of biomimetic prototypes in a studio-like environment.

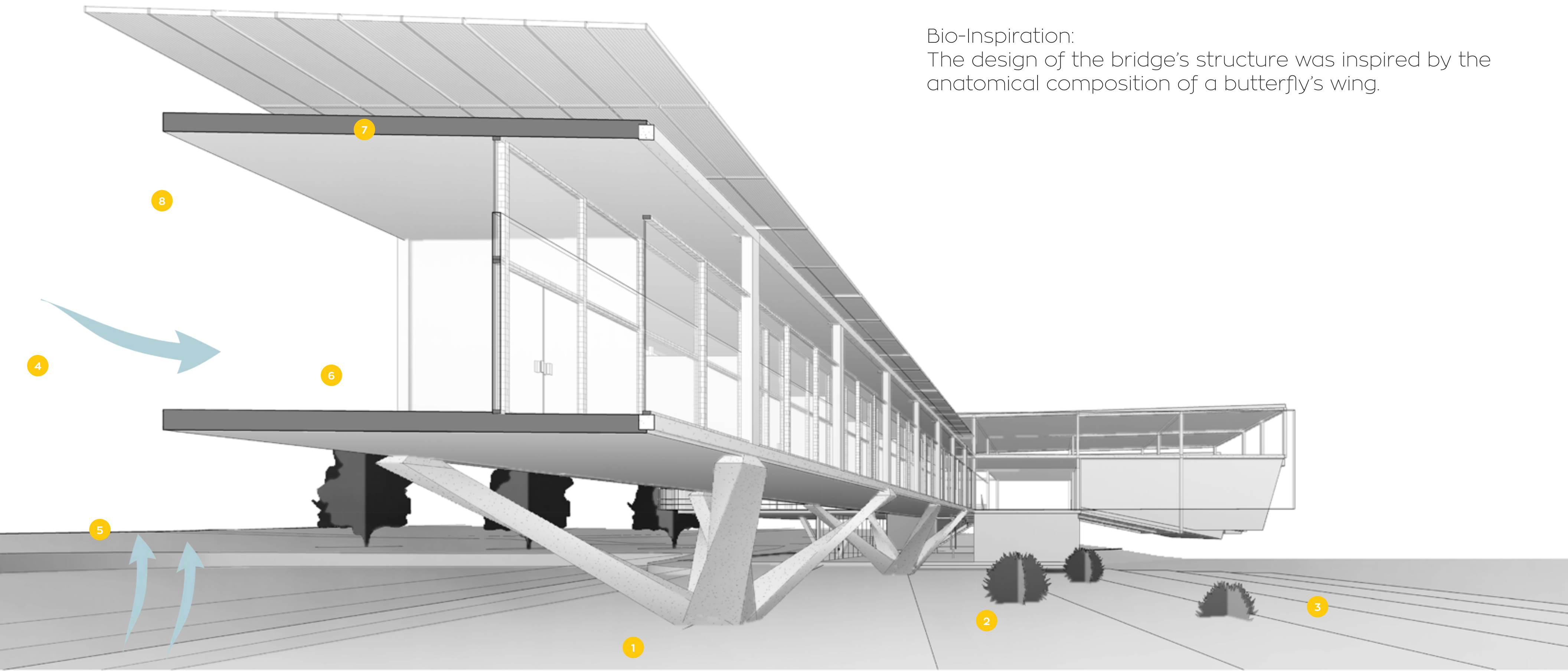
SUSTAINABLE STRATEGIES

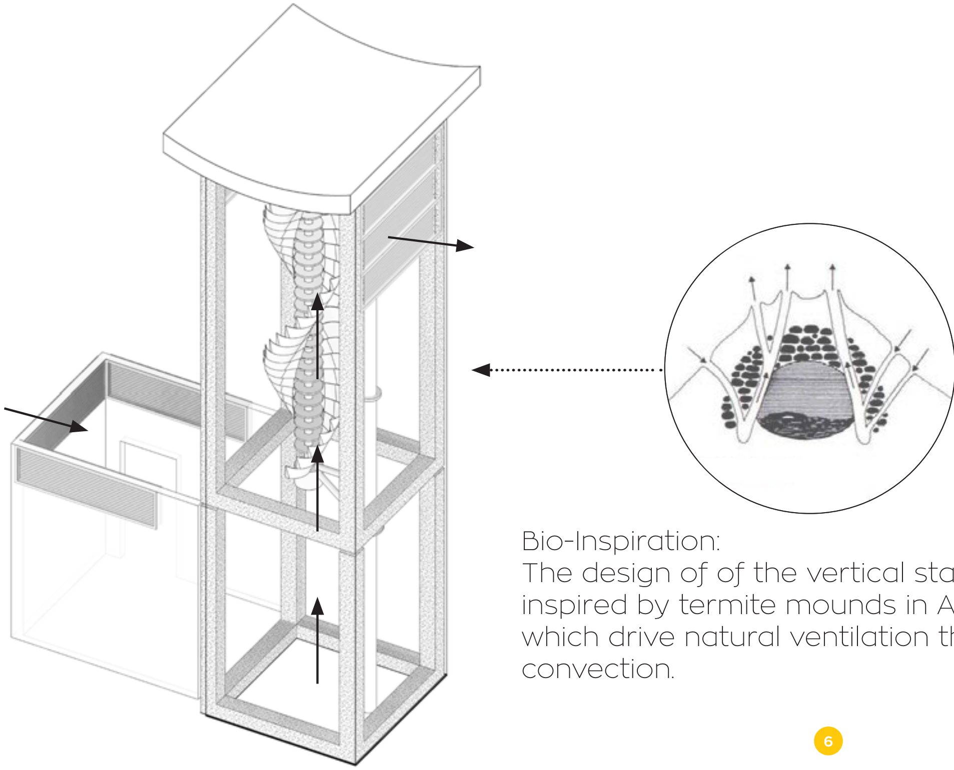
Section Through Conference/Classrooms:

1. habitat restoration
2. fish ladder
3. constructed wetlands
4. natural ventilation
5. evaporative cooling
6. fully daylit interiors
7. photovoltaics
8. deep overhangs for shading



Bio-Inspiration:
The design of the bridge's structure was inspired by the anatomical composition of a butterfly's wing.





Bio-Inspiration:
The design of of the vertical stacks was inspired by termite mounds in Africa which drive natural ventilation through convection.

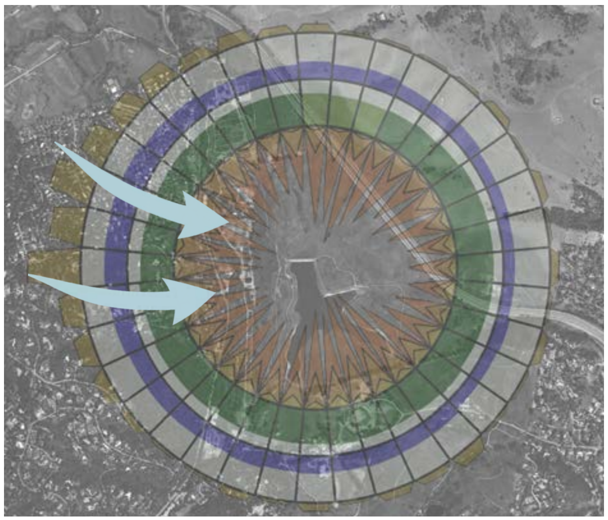
Section Through Research/Workspaces:

1. natural ventilation
2. evaporative cooling
3. louvered vent
4. wind harvesting
5. stack ventilation
6. fully daylit interiors
7. photovoltaics
8. shading device
9. rainwater harvesting
10. on-site cistern for water storage
11. pond source geothermal wells
12. thermal mass flooring

ENERGY HARVESTING

The building capitalizes on all aspects of its site by "harvesting" natural resources from the earth.

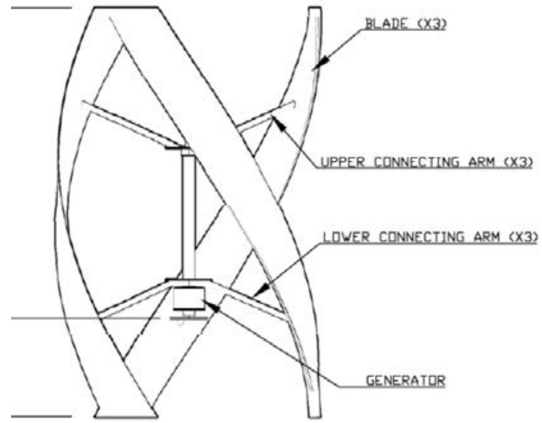
Wind Collection:

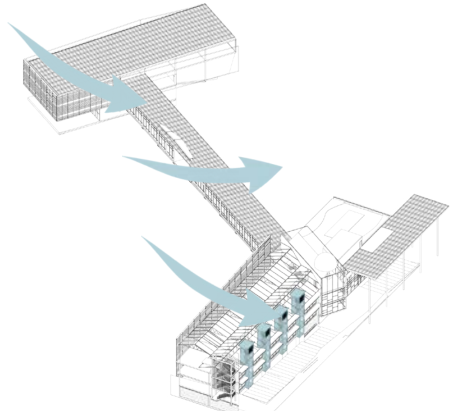


The strong western winds allow natural ventilation and evaporative cooling to cool off and ventilate each space. The bridge is slightly skewed in plan to also allow for such ventilation.

Four 8 ft x 8 ft chimney stacks provide a temperature differential to help push hot air out of the building interior and keep fresh air flowing throughout the building at all times.

Within the four stacks are four biomimetic vertical wind turbines, which capture the wind energy that results from the pressure differential.





Hydro Collection:

Rainwater is collected through the roof gutter system as well as on the u-shaped roofs of the chimney stacks. The water is then stored in on-site cisterns as well as in storage tanks within the basement level mechanical room.

Thermal energy is harvested from pond source geothermal wells that are located within Felt Lake and connected to the mechanical space in the basement level.

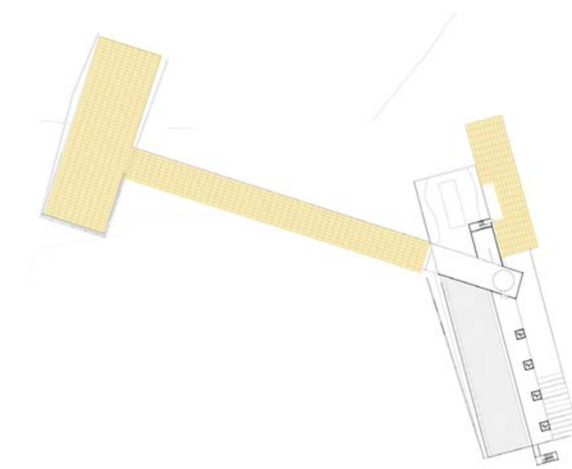
Evaporative cooling from Felt Lake lifts the air from the body of water in order to cool the building's interior.

Solar Collection:

The building captures solar energy through the use of 1,200 (77 in. x 39 in.) photovoltaic panels on its roof. for a solar collection value of **Energy = A * r * H * PR** = 523,102 kWh/an

A = Total solar panel Area (m^2) = 2,324.9 m^2
r = Solar panel yield (%) = 15%
H = Annual solar radiation = 2,000 kWh/m^2
PR = Performance ratio = 0.75

The solar panels are operable so that they can be oriented to the proper angles and achieve maximum solar gain. During the summer solstice, the panels should be adjusted to 76 degrees and during the winter solstice, 30 degrees.



SITE MODEL


Research/Workspaces
Conference/Classrooms
Exhibition/Lecture
Felt Lake
Constructed Wetlands

““I firmly believe that biomimicry is going to be one of the most important sources of solutions that will allow us to move from the industrial age to the ecological age of humankind.”

-Michael Pawlyn, 2013

CHAPTER 13

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IMAGES

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biomimicry

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energy harvesting

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precedents

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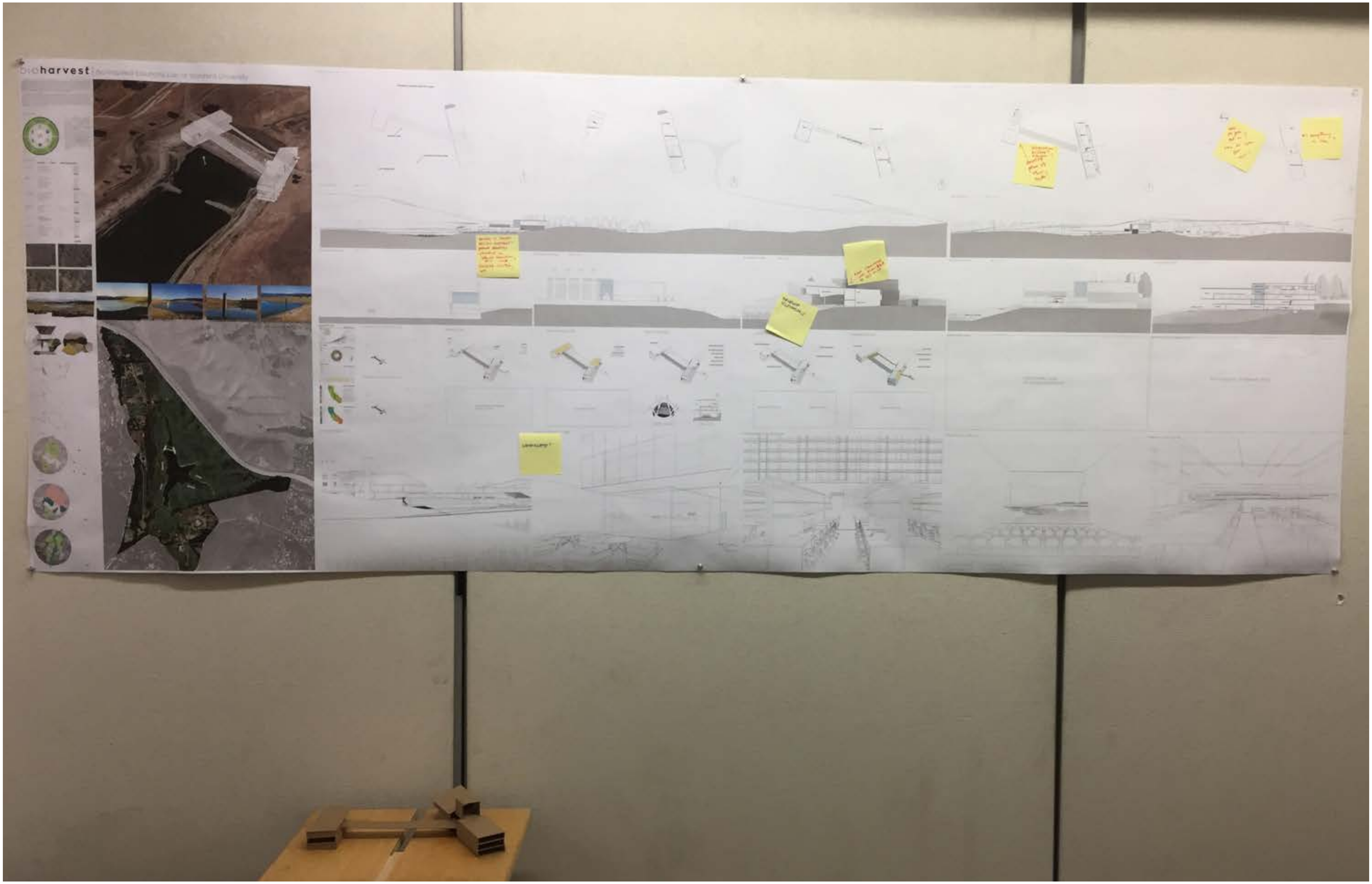
CHAPTER 14

APPENDIX

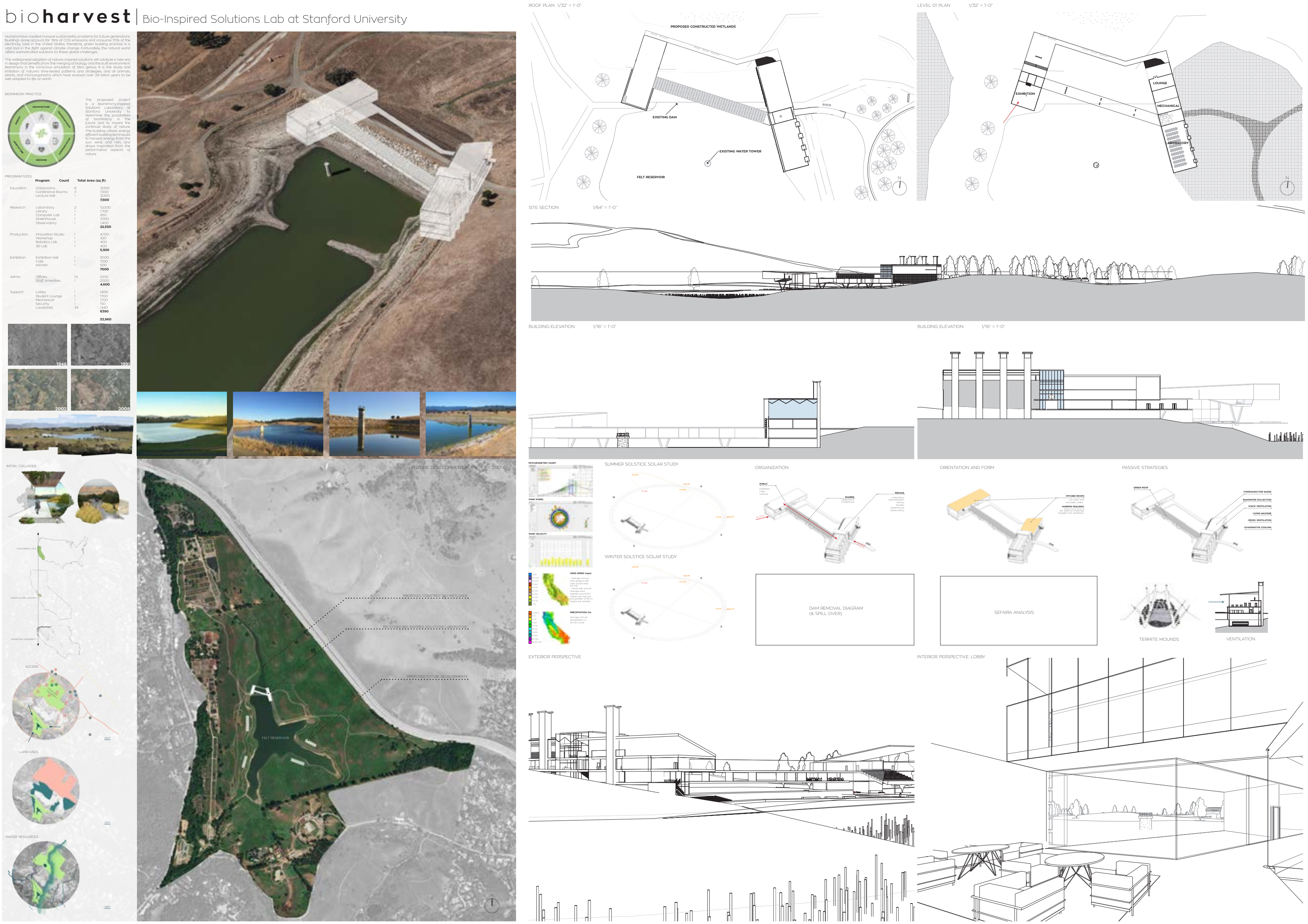
THE POSTER

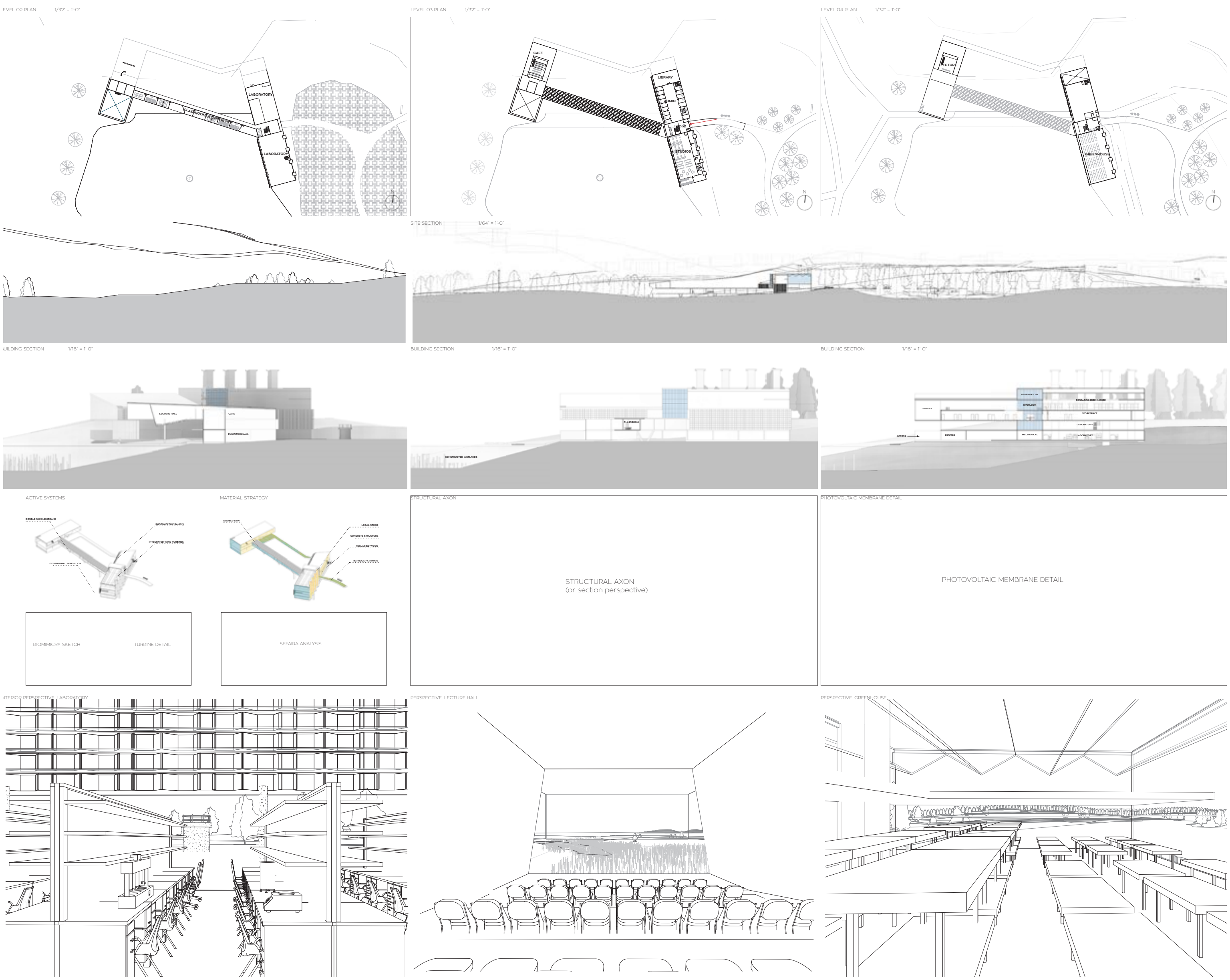

B I O H A R V E S T I N G
AN INVESTIGATION OF THE INTERFACES OF HYDRO AND SOLAR ENERGY HARVESTING FOR A NEW STANDARDIZATION OF BIOMIMETIC TECHNOLOGIES AT STANFORD UNIVERSITY IN STANFORD, CA, USA
BIOMIMETIC PRECEDENTS
ICD ITKE RESEARCH PAVILION
SITE ANALYSIS
CALIFORNIA, USA
STANFORD, CA
STANFORD UNIVERSITY
NEIGHBORING AREAS
SITE
STANFORD UNIVERSITY
PALO ALTO
JASPER RIDGE BIOLOGICAL PRESERVE
FELT LAKE
1948
1991
2002
2003
2008
2016
SITE EVOLUTION
CA AVERAGE WIND SPEED (mps)
- Average annual wind speed is 80 mph (south east, 5.0-5.5)
- Areas with annual average wind speeds around 6.5 meters per second and greater at 80-m height are suitable
>10.0
9.0-10.0
8.0-9.0
7.0-8.0
6.5-7.0
6.0-6.5
5.5-6.0
5.0-5.5
4.0-5.0
<4.0
CA AVERAGE PRECIPITATION (in)
- Average annual precipitation is 20-30 inches
Under 5
5-10
10-15
15-20
20-30
30-40
40-60
60-80
80-120
Above 120
CA DROUGHT REGIONS (2014)
- The state recently experienced record-breaking drought levels
- 41% of the state faced "exceptional drought"
Average
Moderate
Severe
Extreme
Exceptional
PROGRAM RELATIONSHIPS
MECH
OFFICES
IMMERSIVE EDUCATION
COURTYARD
STUDY
CLASSROOMS
RESEARCH LABS
5,300 FT
6,300 FT
7,200 FT
THESIS STATEMENT
Biomimicry, derived from the Greek words bios meaning "life" and mimesis meaning "imitate," is the study of nature in order to produce sophisticated solutions that are derived from the natural world.
The project will serve as an exploration of biomimetic architecture and energy harvesting in an effort to expand the possibilities of environmentally responsible design and to establish a relationship between biomimicry, architecture, and sustainablility.
PRECEDENTS
[ENR2]
LOCATION: UNIVERSITY OF ARIZONA, USA
ARCHITECT: RICHARD+BAUER
AREA: 150,954 SQ FT
YEAR: 2015
ENR2 contains a courtyard which mimics a desert slot canyon to harvest rainwater runoff which is continually reused to irrigate the native trees and plants that populate the desert ecosystem within the building.
[EASTGATE CENTER]
LOCATION: ZIMBABWE, AFRICA
ARCHITECT: MICK PEARCE
AREA: 333,000 SQ FT
YEAR: 1996
The Eastgate Centre imitates the self-cooling mounds of African termites to regulate the temperature within the building year round without the use of conventional air conditioning or heating systems.
CLIENT
Stanford University (SU) in Stanford, California is one of the world's leading research and teaching institutions in biological and environmental studies. The intervention will provide a facility for the students and faculty of SU.
SITE HISTORY
The 400-acre site is currently undeveloped land owned by the university, home to a 150 year old reservoir called Felt Lake. The lake was constructed by gold miner and lumber dealer Job Johnston Felt, who, wishing to build two water companies, diverted thousands of gallons of water from Los Trancos Creek and then constructed a large earthen dam to hold them.
By the mid-1880s, Felt abandoned the water company idea, selling the farm to Timothy Paige, who sold it to Leland Stanford Sr. in 1887. The university later added a larger dam to hold irrigation water for the growing campus.
PROGRAM
A 72,000 square foot energy research laboratory for the testing and production of biomimetic architectural skins.
EDUCATION:
Classrooms 10,000 sf
Research Laboratories 30,000 sf
Research Lab Support 4,000 sf
Testing Areas 5,500 sf
Conference Rooms 5,000 sf
ADMINISTRATION:
Offices 12,000 sf
Staff Support Areas 4,000 sf
SUPPORT:
Storage 1000 sf
Mechanical Space 200 sf
OUTDOOR:
Exhibition Courtyard
Parking
ARCH 641 THESIS RESEARCH SEMINAR
GABRIELLA SANTOSTEFANO
HASAN-UDDIN KHAN

GATE REVIEW (11-21-17)



GATE PRESENTATION



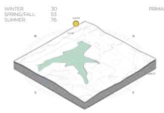


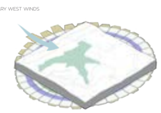
COMMENTS AT THE GATE REVIEW:

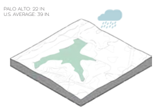
- Develop plans
- Develop circulation, access
- Develop elevations
- Develop landscape
- Develop bridge structure in the lateral direction
- Develop roof structure

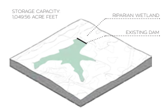
FINAL REVIEW (12-16-17)

FINAL PRESENTATION

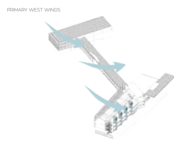

SOLAR STUDY (SUMMER/WINTER SOLSTICES)

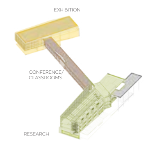

WIND STUDY


ANNUAL RAINFALL STUDY


CURRENT RESERVOIR/DAM REMOVAL

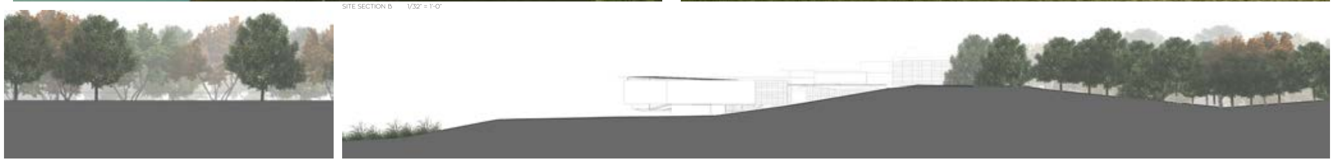

SOLAR ENERGY HARVESTING


WIND ENERGY HARVESTING


PROGRAM


CIRCULATION

SITE SECTION B 1/32" = 1'-0"



SUSTAINABLE STRATEGIES

1. habitat restoration
2. fish ladder
3. constructed wetlands
4. natural ventilation
5. evaporative cooling
6. fully daylit interiors
7. photovoltaics
8. deep overhangs for shading

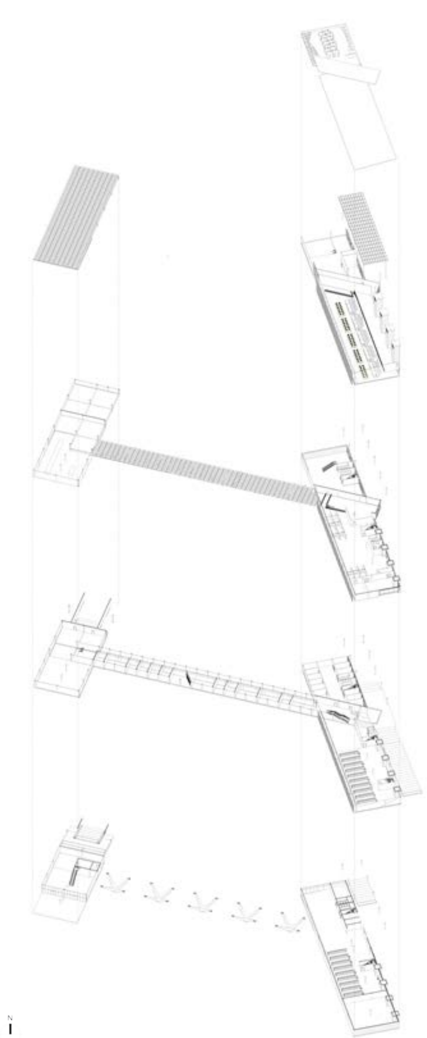
BIO-INSPIRATION

SECTION AA 1/16" = 1'-0"

SUSTAINABLE STRATEGIES

1. natural ventilation
2. evaporative cooling
3. louvered vent
4. wind harvesting
5. stack ventilation
6. fully daylit interiors
7. photovoltaics
8. shading device
9. rainwater harvesting
10. on-site cistern for water storage
11. sustainably harvested wood
12. thermal mass flooring

SECTION BB 1/16" = 1'-0"



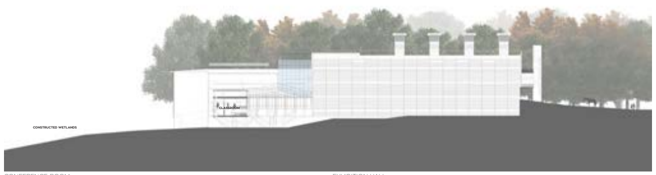
SECTION CC 1/16" = 1'-0"

Level 04
Library
Computer Lab
Greenhouse
Observatory

Level 03
Exhibition
Library
Innovation Studio
Workshop
Robotics Lab
3D Lab

Level 02
Lobby
Exhibition
Lecture Hall
Classroom
Conference
Office
Laboratory

Level 01
Exhibition
Cafe
Laboratory
Mechanical



RESEARCH GREENHOUSE

CONFERENCE ROOM

EXHIBITION HALL

LECTURE HALL

WETLANDS RESEARCH