WINNING PROJECT

Project Title:
Modular Sustainability

Students:
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Faculty Sponsor:
Gary P. Moshier, Carnegie Mellon University

While considering the program of the research campus, factors relating to sustainability and carbon footprints surfaced. From the outset, the team recognized that connecting the research campus to the local grid was not a proper solution. In our research, three naturally occurring forces have proven to be the means of viable solutions: prevailing winds, consistent solar exposure, and oceanic water. The resulting design solution would follow a net zero energy consumption with all its facility needs safely harvested and disposed.

The eastern prevailing winds became a driving force in the design of the campus' master plan. Natural cooling through wind creates a temperature differential enough to raise the comfort levels. With a larger eastern opening, created by the buildings' massing, and a narrower western choke, the campus creates a Venturi Effect that conditions the adjacent spaces. In addition, the orientation maximizes northern and southern exposure to take full advantage of solar power generation, while allowing for effective day lighting from north.

Consistent solar exposure upon the site gives reason for Photovoltaic thermal (PVT) arrays. These rooftop units provide all of the campus' energy, domestic hot water, and integrated systems. One of these systems includes the research laboratory's AC unit. The unit utilizes a heat pipe, which removes heat from the incoming air before the cooling coil and uses the same energy to reheat cold supply air. In addition, where a deep-sea water inlet is required for specimen tanks, a secondary inlet pipe wraps to a closed loop heat exchanger which transfers heat from the air conditioner's condenser unit to a continuous, open loop of seawater. The process eliminates the need to mechanically reheat the supply air. This system paired with a salt-water "Sea-O-Thermal" heat exchanger allows for a smaller, more efficient unit.

The potable water demands for all buildings are facilitated through rooftop rainwater collection. Once collected, the rainwater is diverted into one of two cisterns. The primary laboratory grade water tank is attached to a purification unit that consists of a carbon filter and a UV light sanitizer. Excess rainwater is deposited in a central cistern that runs a similar cleansing process to provide potable water to the entire campus. All wastewater from the campus is collected and processed on site in a passive, environmentally friendly way.

The "Marsh Machine" is the campus' black water filtration system and response to the island's poor septic system. The system uses naturally present ecology to bring wastewater near potable conditions without the use of hazardous chemicals or significant energy expenditures while presented as planted featured exhibits.

The combination of systems integration and natural remediation allows our campus to function with extreme efficiency and minimal environmental impact. The implementation of a seawater inlet as a heat exchanger in pair with a heat pipe energy recovery system allows for high performance air conditioning units. Similarly, the PVT arrays, the Energy Transfer Module, and the "Marsh Machine" work together to generate huge amounts of energy with minimal environmental disturbance.

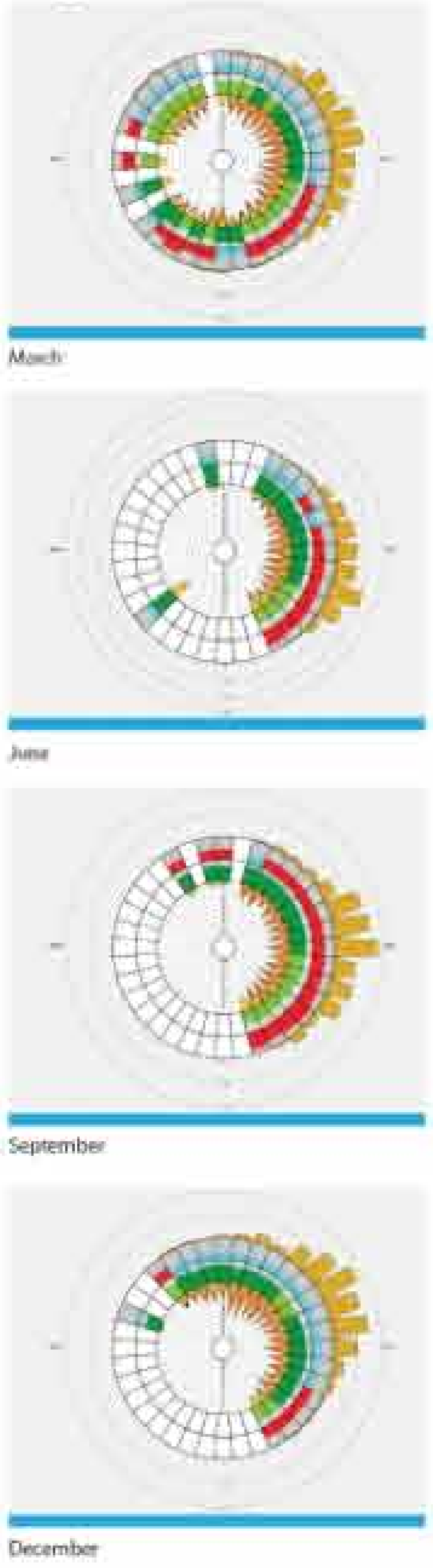
NATIONAL PROBLEMS:

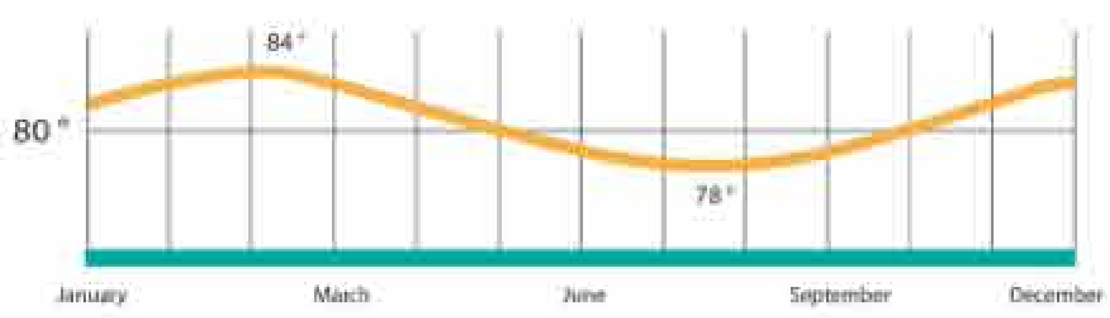
UNRELIABLE ENERGY GRID
UNRELIABLE SEPTIC SYSTEMS
DROUGHTS

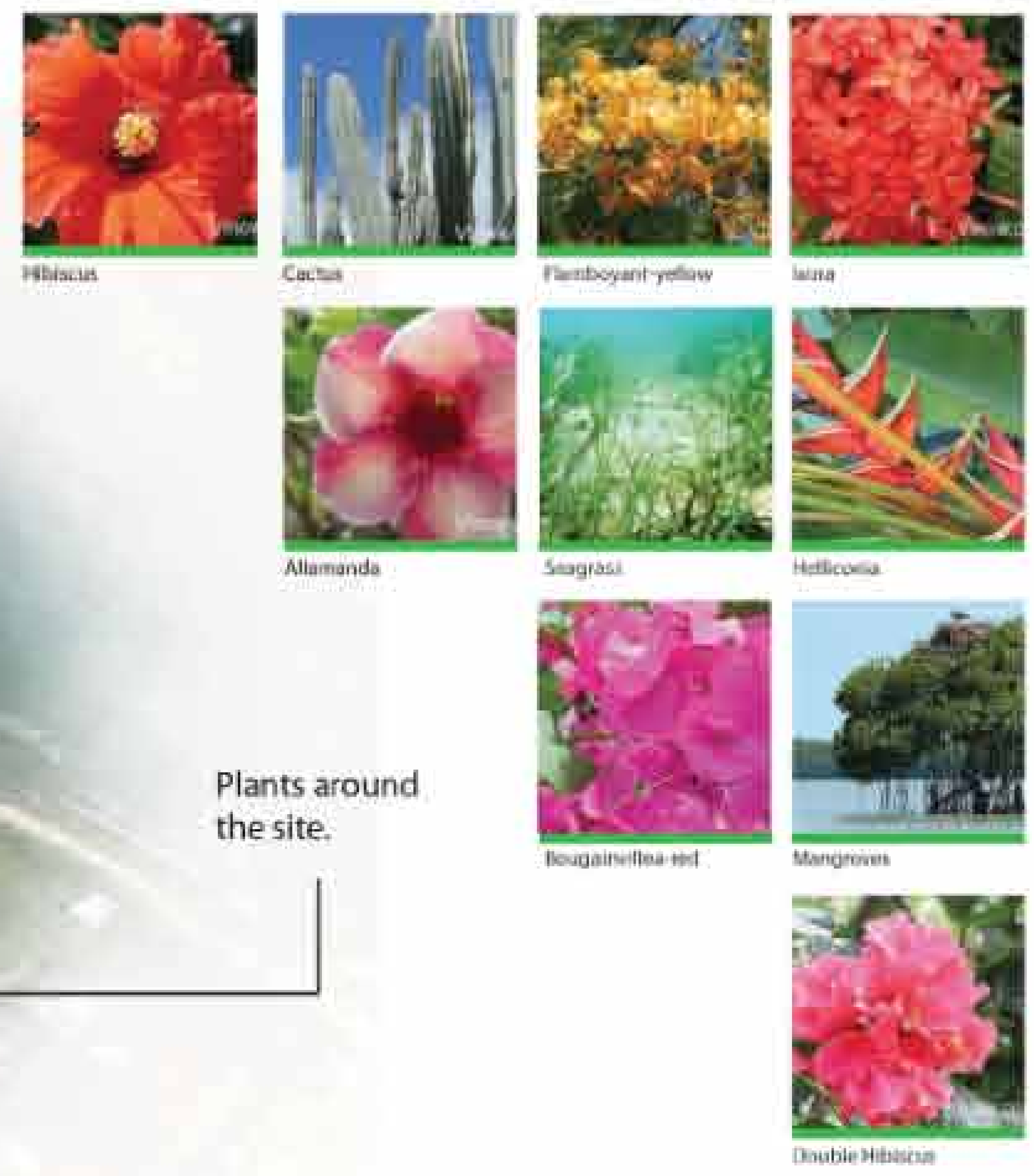
VIABLE SOLUTIONS:

SYSTEMS INTEGRATED PVT SYSTEM
CLOSED LOOP SEPTIC MARSH SYSTEM
DEEP SEA THERMAL SYSTEMS + RAIN HARVEST

ST. CROIX, VIRGIN ISLANDS







MARINE RESEARCH CAMPUS

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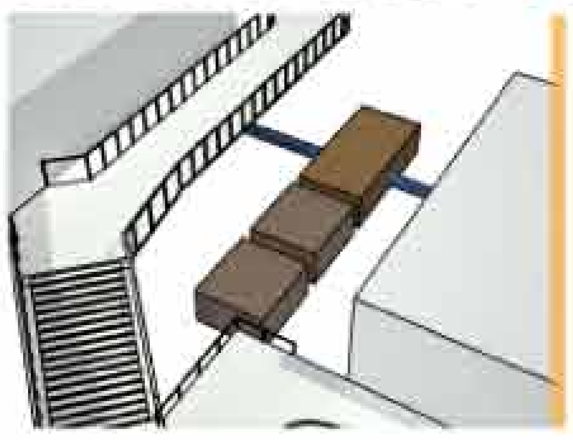
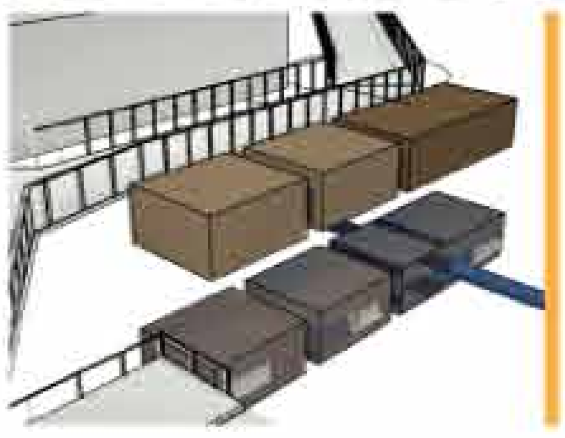
STEP One: Waste Collection



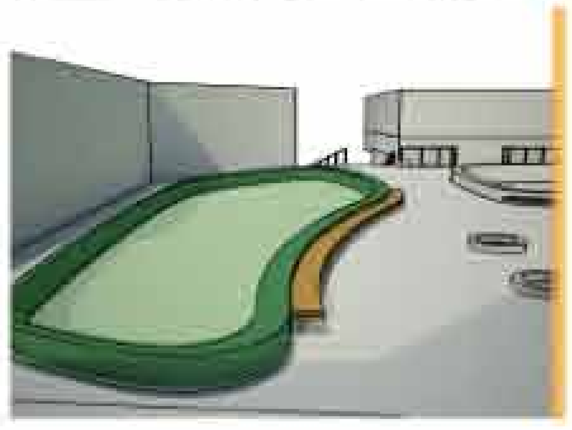
Waste water from the campus is piped into the first of three underground precast concrete holding tanks.

STEP Two: Pre-Treatment



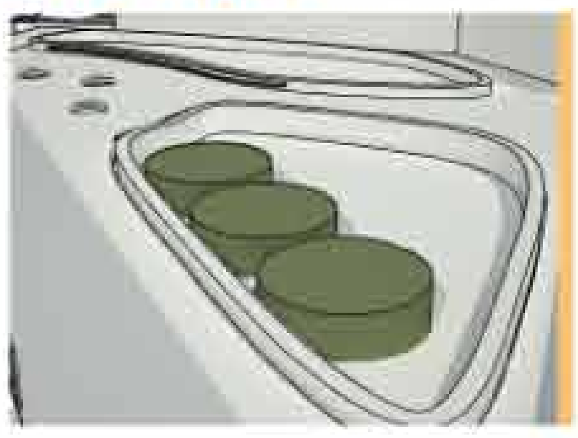
Solid materials start to settle while naturally present anaerobic bacteria begin to break down carbon and nitrogen- containing solids and liquids. This process converts organic nitrogen into ammonia. The remaining undigested solids are deposited in the bottom of the tank as sludge and the liquids are poured off. After this process is repeated in tank two it is passed through a bio-filter before entering tank three. The water is now ready for the Marsh Machine.

STEP Three: Marsh One



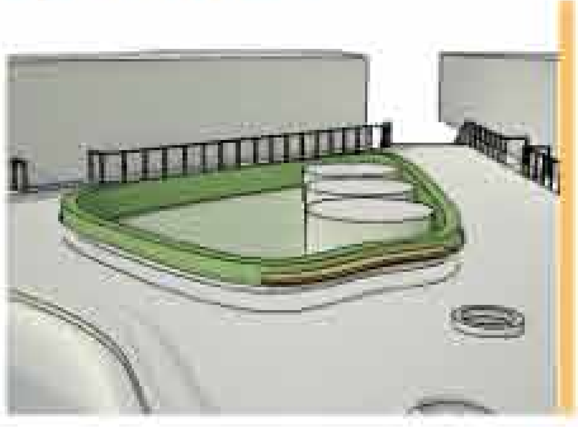
Water is now pumped into Marsh 1, which contains both aerobic and anaerobic bacterial environments. This is comprised of plants with a high tolerance to and capacity for contaminants (aerobic) and bacteria colonies know as bio films that attach to the root structure of the plants and aid in waste removal (anaerobic). A recirculating pump under the gravel moves water from bottom to top to increase dissolved oxygen, and stimulate nitrification and oxidation.

STEP Four: Aerobic Treatment Tanks



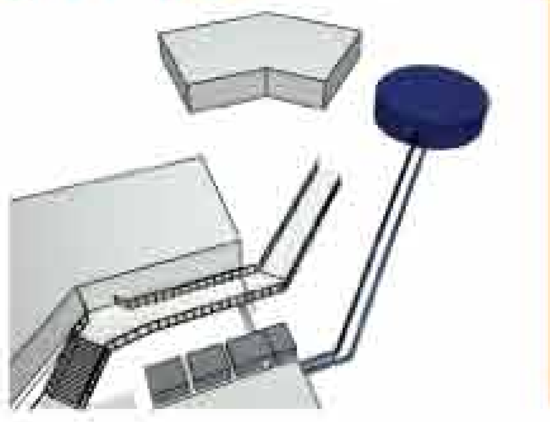
These three white tanks hold 550 gallons of water each and are highly aerobic environments, promoting bacterial floc formation and nitrification. The majority of the carbon is converted into bacterial biomass and the majority of the ammonia is converted to nitrate, some of which is consumed by the plants and algae.

STEP Five: Marsh Two



The same reactions occur as in Marsh 1, but this marsh is more anaerobic due to lack of recirculating pumps. The higher water level does not stimulate deep root growth, which would add oxygen to the marsh.

STEP Six: Final Filtration + Storage



After the nearly potable water has passed through Marsh 2 it is passed through a final carbon particulate and UV light filter before it is deposited in the final holding tank where it is ready to be redistributed to the campus to be used for toilet flushing in all restrooms.

Remediating Plants

Elephant-Ear (Colocasia)-
This plant is native to tropical Polynesia and South east Asia. It is a perennial plant with large Rhizome just below the surface with leaves that are 8-59 inches long. It has a high tolerance to pollution and is capable of consuming many of the heavy metals that traditional waste water treatment is unable to.

Canna-
This plant has large attractive foliage and can reach a height of 6 to 10 feet. This wetland plant can be used to extract many undesirable pollutants from waste water due to its high tolerance to contaminants.

Sedge (Cyperaceae)-
This wetland plant thrives in poor soil conditions making it an appropriate choice for St. Croix's soil type as a buffer plant to the Marsh Machine.

Cattail (Typha)-
Cattail is able to remove poisonous arsenic from water and has a high tolerance to pollution.

Water Hyacinth-
This free floating perennial aquatic plant is native to tropic and sub-tropic South American climates. It is one of the fastest growing plants in the word and is capable of doubling its population in two weeks. Fast growth and high tolerance to toxins make this flowering plant ideal for our application. It is extremely tolerant of, and has a high capacity for the consumption of heavy metals including Cadmium, Chromium, Cobalt, Nickel, and Mercury. It is also capable of removing cyanide and arsenic from water and enhances nitrification in waste water treatment. Their roots are ideal for biofilm communities necessary in the Marsh Machine.

Organisms

Anearobic Bacteria-
In the early stages of reclamation bacteria breaks down suspended solids, generates acids and ferments methane.

Photosynthetic Algae-
Fixes oxygen back into water and provide organic food for biological metabolism and respiration. Dead algae feeds microbial communities.

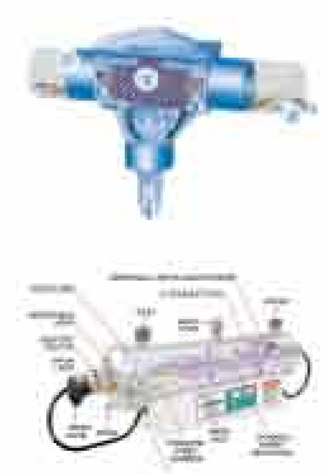
Bacteria-
Nitrosomonas and Nitrobacter bacteria work to nitrify ammonia from waste water, making nitrates for plant and microbial consumption.

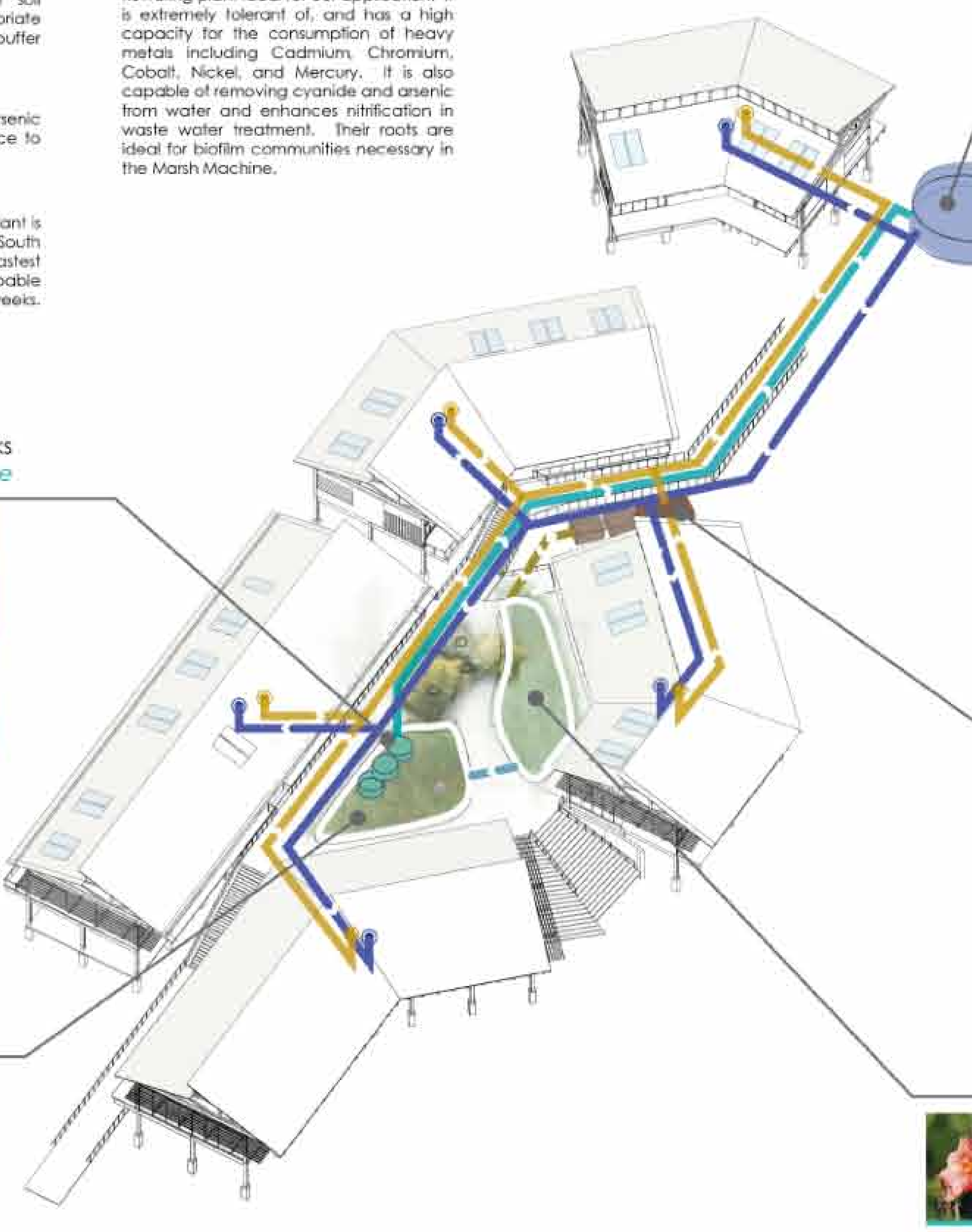
Plankton-
Zoo plankton feed on extremely small particles that traditional waste water treatment doesn't filter. Plankton can eat microbes and feed filtering feeding fish and mollusks. This food chain transfers biomass to higher trophic levels and increases the diversity in the Marsh Machine.

Snails -
Filter sludge and act as a diagnostic tool. When a toxic load is present the snails rise above the water level on the side of the tank alerting maintenance of an imbalance in the water quality.

Bio Film-
A colony of bacteria attached to the roots of the plants in the Marsh Machine that help breakdown contaminants.

STEP Six
Concrete Cistern (36,00 gal)
Particle Filter + UV Filtration



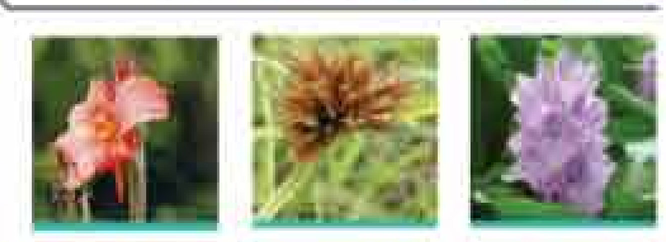


STEP Four
Aerobic Treatment Tanks
Snails + Plankton + Algae

STEP One + Two
Pre-Treatment Tanks
Bacteria

STEP Five
Marsh Two
Bacteria + Hyacinth
Sedge + Canna

STEP Three
Marsh One
Canna + Sedge + Hyacinth



MARSH MACHINE SYSTEM

- Transparent piping allow for occupants to observe the travel of rainwater through the system of the laboratory.
- These transparent 8" diameter pipes are fitted between the rafters, avoiding direct sunlight, so bacteria and algae do not form.
- All rainwater from the laboratory roofing is collected into a central cistern which is composed of two types of holding: treated water (carbon filtered and UV exposed) and overflow water (irrigation use).

ASSUME: 12 people + 20 gal/day (peak)

usage 87,000 gals/year >>> **AVG 7250 GAL/MONTH**

4.62 INCHES/MONTH - HIGH & 2.095 INCHES/MONTH - LOW

One tank with **A MONTH'S WORTH OF WATER**

DOWNSPOUT SIZING

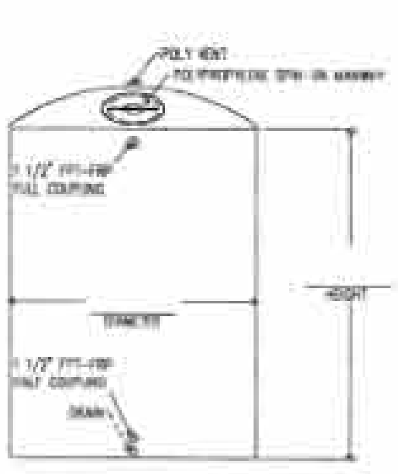
Rainfall Intensity (10yr) = 7.7 in./hr.
Rainfall Intensity (100yr) = 9.8 in./hr.
Drainable Area (10yr) = 160 sq. ft.
Drainable Area (100yr) = 120 sq. ft.
Year Setting = 100 yr.
Plan Area = 7680 sq. ft.
Gutter length = 320 ft.
Max Gutter Served by Each DS = 160 ft.

Design Area = 7680 sq. ft.
Minimum Number of DS = 2
Max Roof Area Served by Each DS = 3840 sq. ft.

Min. Gutter Width = 10 in.
Min. Gutter Depth = 10 in.

Min. DS Size = 8 in. diameter

TRANSPARENT DOWNSPOUT + PIPING



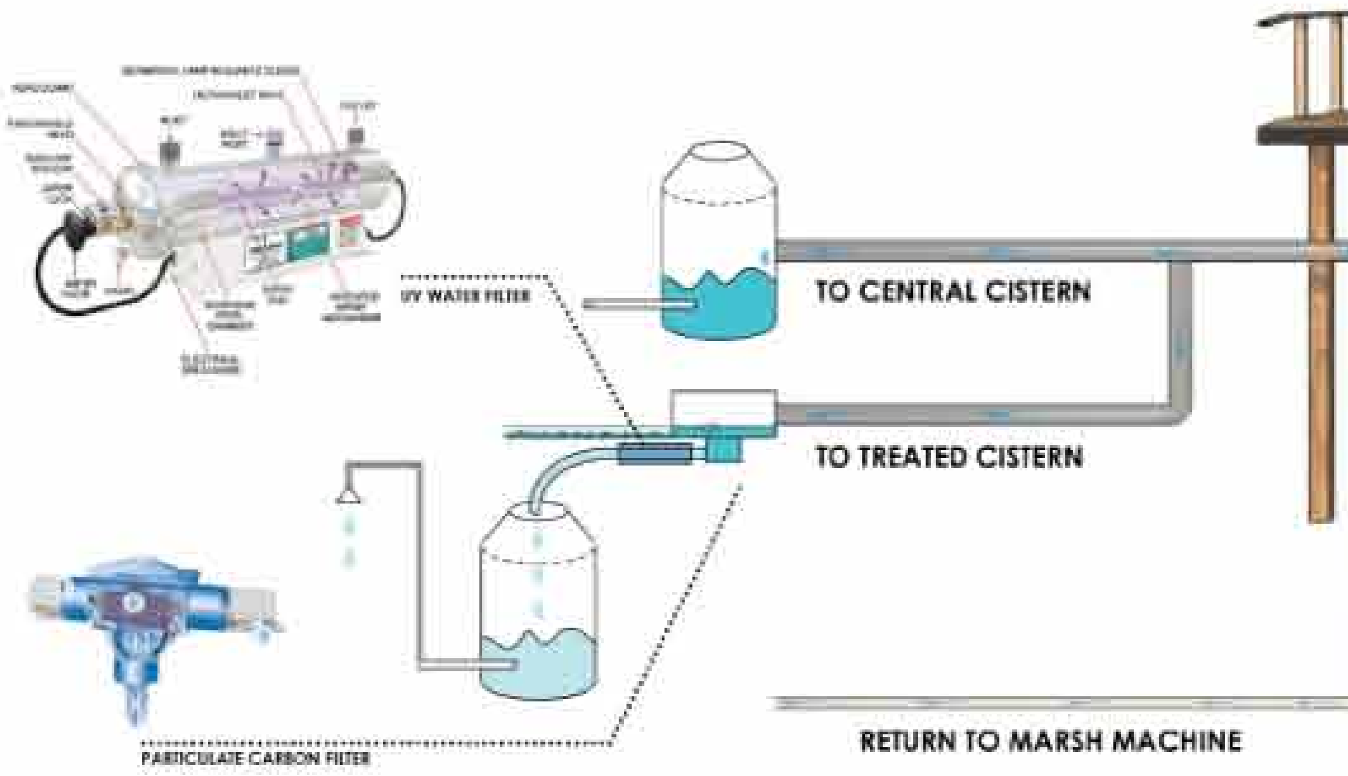
7,500 AUSTIN GAL FIBERGLASS TANK
SIZE: 12' D x 8' 10" H
ITEM # AUS7500

St. Croix Annual Rainfall = 40 inches/year
Rooftop Area of Collection = 9233 sqft

166,194 gals of rainwater / yearly collected / 12

>>> 13,900/ MONTH

G = GALLONS HARVESTED (YEARLY)
R= PRECIPITATION IN INCHES (YEARLY)
A= AREA OF ROOF IN SQUARE FEET
G = 0.4 * R * A



2 4 8 SCALE

LABORATORY WATER SYSTEMS

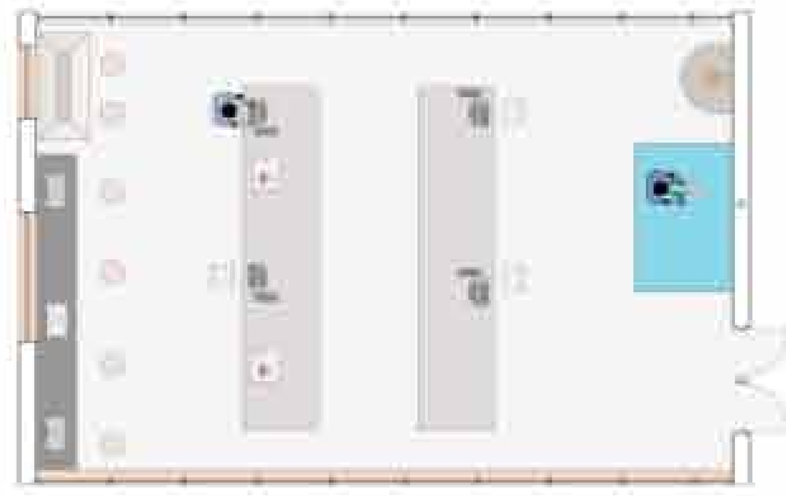
FOOTING PILES + FLOOR CONSTRUCTION

LABORATORY SPACES

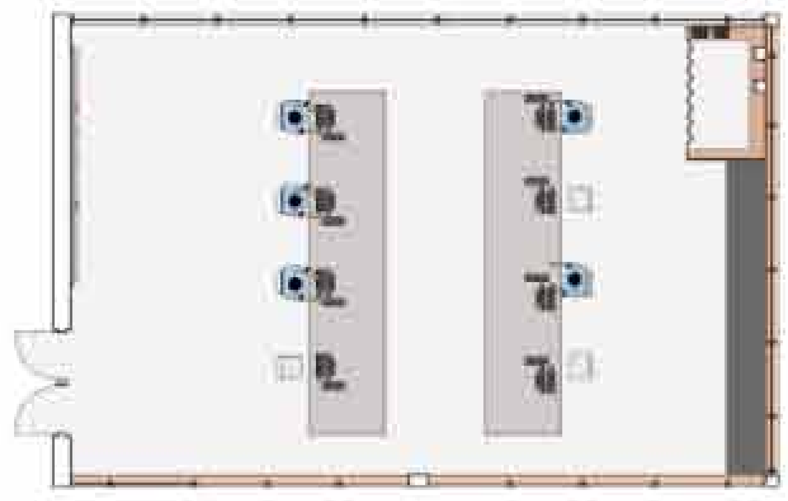
RECLAIMED CYPRESS TIMBER FRAMING

SOLAR PVT + SKYLIGHTS

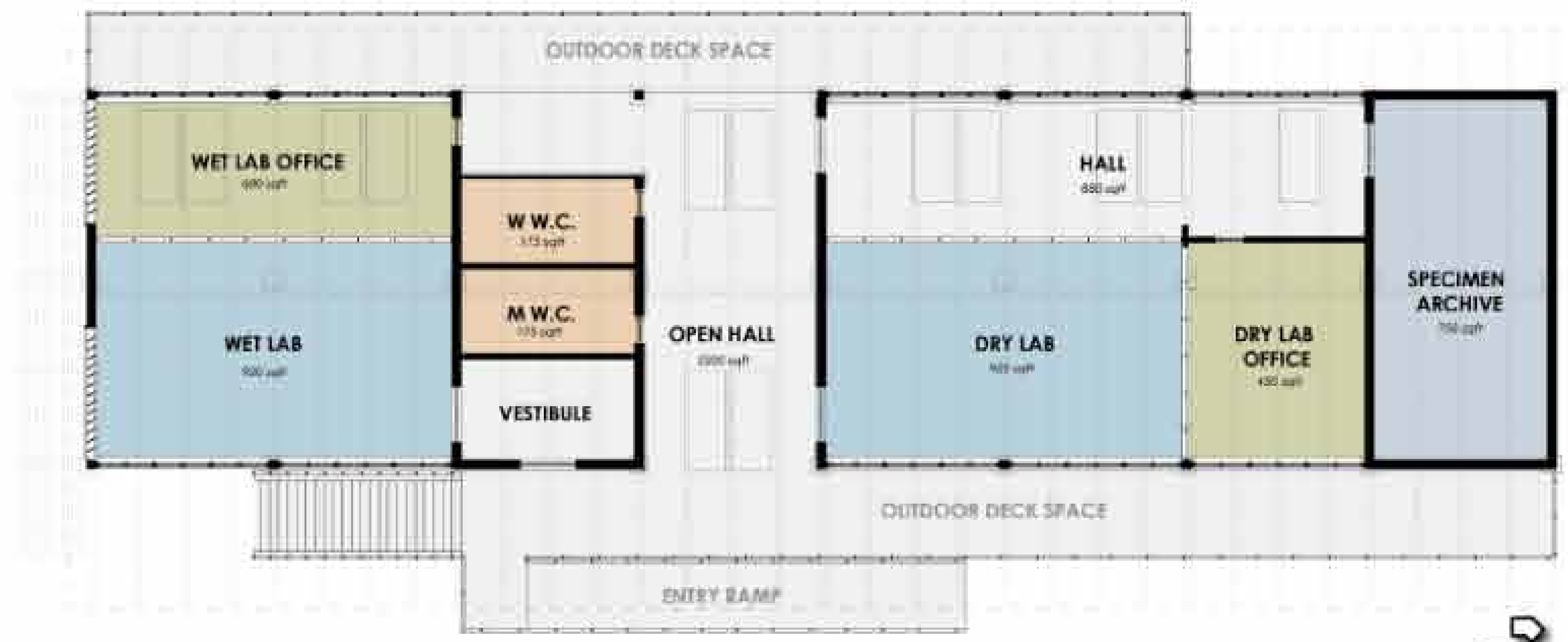
BUILDING AXONS



WET LAB DETAILED LAYOUT



DRY LAB DETAILED LAYOUT



SCALE: 1" = 8' - 0"
LABORATORY PROGRAMMING PLAN

48kW Array - 67,200kWh
Solar Module: 180 W
Number of Modules: 264
10 awg Output wiring
240 Vac output voltage
34.17lb/unit

• Designed to integrate standard PV modules along with Echo Thermal Module panel. The array creates a plenum underneath that channels thermal energy in the form of hot air.

• Air-based design eliminates the need for plumbing and water on the roof

PHOTO VOLTAIC

SOLAR THERMAL ARRAY

• Fumehoods are essential in any chemically oriented lab. Though few are used in marine biology settings, having at least one in the lab is still a major benefit. 14,000 kWh/year

• The fumehood vacuums at a safe rate of 150 fpm. This system is coupled with the laboratory's heat displacement system.

• As particulates and chemicals are exhausted through the hood, a chemical filter catches the harmful chemicals. The exhausted air is then pumped out of the laboratory building at safe levels.

PHOTO VOLTAIC + SOLAR THERMAL ARRAY

LABORATORY FUMEHOOD UNIT + EXHAUST SYSTEM

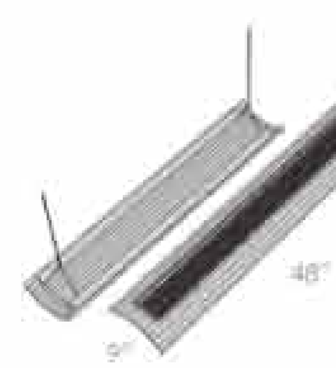
RETURN AIR EXHAUST

• Heats water and home with waste energy from solar module array

• Easily integrates with existing plumbing and HVAC systems

• Compact, simple to install and maintain design

ECHO ENERGY TRANSFER MODULE



• Suspended linear direct/indirect fluorescent with radial parabolic louver.

• Verve™ III offers variable distribution optics which include 70/30, 20/80, 10/90 and 100% direct illumination.

• Radial parabolic louver utilizes a high-quality low brightness aluminum that provides comfortable direct illumination.

•Optional Downlight Reflector Optic separates
center lamp for direct distribution and two outer lamps for indirect distribution on 3-lamp configurations.

DIRECT FLUORESCENT LUMINAIR

AIR CONDITIONING UNIT

PROCESS ORDER

1. COOL GAS FROM COIL GOES TO COMPRESSOR
2. COMPRESSOR HEATS THE REFRIGERANT
3. HOT REFRIGERANT IS SENT TO CONDENSER

DOAS AIR HANDLER UNIT

PROCESS ORDER

1. OUTDOOR AIR PASSES OVER PRECOOL SECTION OF HEAT PIPE.
2. AIR IS CHILLED BY COOLING COILS
3. AIR IS REHEATED BY HEAT PIPE

CISTERN (100 gal)

2 4 8
SCALE

SEA-O THERMAL SYSTEM

• Deep sea water ranges from 45 - 50 degrees Fahrenheit - a natural and renewal source of cooling.

• Heat exchanger coil pulls heat from refrigerant and dumps it into open loop sea water.

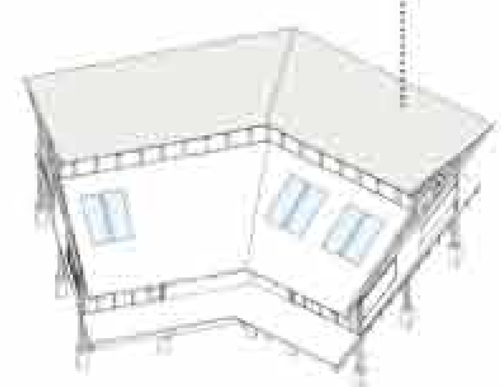
• Two air conditioners channel the chilled deep sea water into the air handler - despensed into conditioned laboratory space.

DEEP SEA WATER INLET PIPE

• The St. Croix Marine Biology Research Laboratory conducts extensive studies on the local specimens and sea life. Providing natural deep sea water is crucial in providing a suitable artificial habitat for specimens housed within the wet lab.

• Deep sea water is piped in from a mile off shore through an inlet pipe

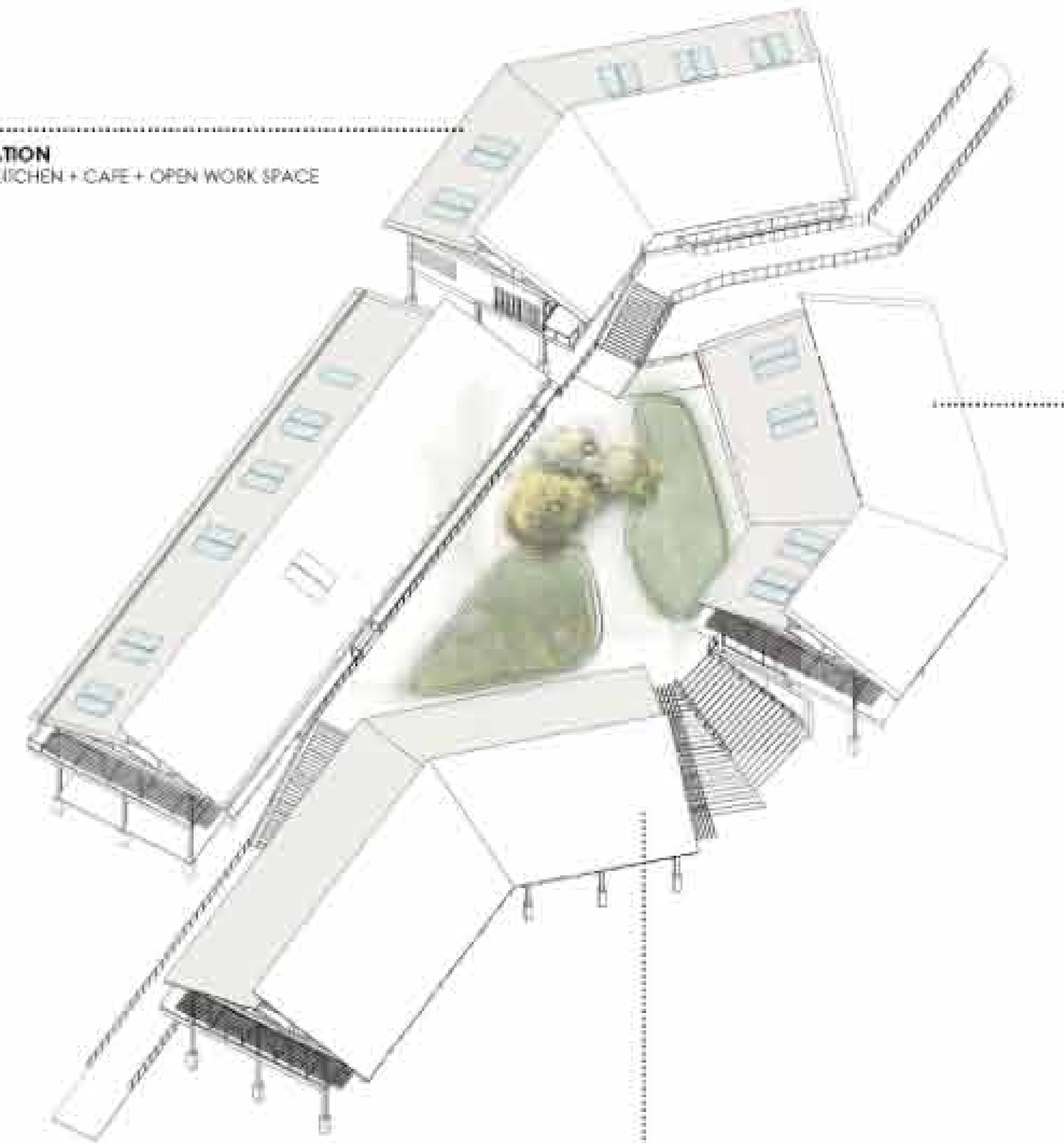
MARINE LABORATORY SYSTEMS



HOUSING CENTER
MENS | WOMENS BATHROOMS + STAFF QUARTERS + DINING

CAMPUS MASTER PLAN

OFFICE & ADMINISTRATION
CONFERENCE ROOMS + KITCHEN + CAFE + OPEN WORK SPACE



LEARNING CENTER
CLASS ROOMS + COMP. CLUSTER + TEACHIGN LAB

OUTLOOK @ LEARNING CENTER

OPERATIONS DOCK
BOAT DOCK + PREPARATION SPACE

OUTREACH CENTER
MARINE EXHIBIT + LECTURE HALL

MARSH COURTYARD

CAMPUS PROGRAMMING

ST. CROIX SUSTAINABLE LAB COMPLEX DATA SHEET

		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lab	[illegible]		[illegible]	[illegible]						[illegible]
	[illegible]		[illegible]							
	[illegible]		[illegible]							
	[illegible]									
	TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
Learning Center	[illegible]									
	[illegible]		[illegible]							[illegible]
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Administration	[illegible]						[illegible]			
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Outreach Center	[illegible]									[illegible]
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Housing Center	[illegible]									
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	TOTAL	[illegible]			[illegible]	[illegible]	[illegible]			
Cottages x 8	[illegible]									
	TOTAL				[illegible]					
	TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NET POWER 41,150 kWh/year
NET RAIN WATER 1,406 gal/month
NET GREY WATER 25,945 gal/month