compositive

"We are a *composite* of people working to leave a *positive* impact."

Team Institution	Virginia Tech
Team Name	Compositive
Project Name	Eco-Park Learning Center
Division	Office Building

VIRGINIA TECH

U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON

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Team Compositive
Eco-Park Learning Center

Project Summary

The management of society's waste, once overlooked as a burden to simply dump onto the Earth, has grown in public awareness during the last several decades as critical to sustainable planning. For the 2020 Solar Decathlon Design Competition, we are excited to work with a client that is setting the gold standard for contemporary waste management in our home state of Virginia. The Prince William County Landfill is currently designated as an Extraordinary Environmental Enterprise (E4) participant in the Virginia Environmental Excellence Program (VEEP), a title virtually unheard-of for active landfills. Their use of innovating recycling technology, landfill gas harvesting, and much more, attracts visitation from professionals around the globe. Their vision is to build the landfill as an Eco-Park, an important community resource. They desire a new center to house their administrative staff that doubles as a nexus for STEM education and community engagement. This is where we - team Compositive - propose the Eco-Park Learning Center.

Design Strategy

The design strategies approached within this project are inspired by the seven petals of the Living Building Challenge, which will establish the office building as the gold standard of Prince William County's environmental and community stewardship. Our goal is to seamlessly integrate the Eco-Park Learning Center with its ecological and cultural fabric. We employ a macro strategy that optimizes the building's relationship to sensitive ecological habitat, walking/biking trails, local schools, and cutting-edge landfill facilities. At the micro scale, we use responsible materials such as structural CLT panels and engineered wood beams/columns. Recycled glass appears as paver blocks, ground filter sand, and concrete aggregate. Efficient energy systems and a high-performance enclosure reduce the building's carbon footprint over its lifecycle. Our multi-tiered design team, spanning the domains of architecture, landscape, engineering, and construction, carefully evaluates the financial implications of our design through detailed budgeting and cost-benefit analyses.

Project Data

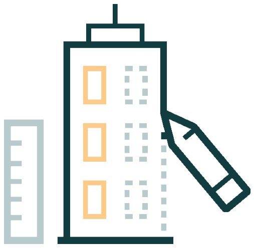
Location	Prince William County Virginia, USA
Climate Zone	4A
Lot Size	4 acres
Building Size	31,293 ft^2, 2 stories
Occupancy	90 people, 282 ft^2/person
Target Source EUI	70 kBtu/ft^2/year
Average Utility Cost	$4,500/month
Construction Cost	$330/ft^2

Technical Specifications

Enclosure (R)	Walls (33), Slab (10), Roof (40), Windows (4)
HVAC	Displacement Ventilation Four-Pipe Hydronic FCU's Radiant Flooring
Lighting	High Performance LEDs Smart Daylighting Occupancy Sensors
Renewables	110kW PV mounted over parking

Figure 1. 1: Visualization of the Eco-Park Learning Center.

Project Highlights



Architecture

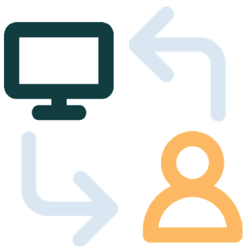
Biophilic Design.
Luminous Spaces.
Organic Materials.
Crafted Views.
Accessibility.
Public and Private.

Comfort & Environmental Quality

Glare Reduction.
Individual HVAC Controls.
Low Velocity Airflow.
Mechanical Noise Reduction.
Fresh Air Circulation.

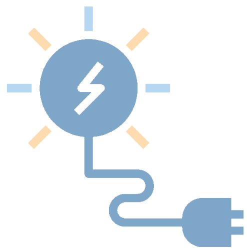
Engineering:

Occupancy Sensors.
Composting Toilets. Rainwater Harvesting.
4-Pipe Fan Coil Units.
Hydroponic Radiant Heating.
Displacement Ventilation.



Operations:

Building Management System.
Dormant Energy Reduction.
Smartwall.



Energy Performance:

105% PV Energy Generation.
iTree Analysis.
Plug Load Controls.

Resilience:

Net - Positive Water.
Net - Positive Energy.
Natural Flood Mitigation.Food Harvesting.

Financial Feasibility & Affordability:

Minimize Operation Costs.
Material Selection.
Potential Income.

Market Potential:

Municipal Space Expansion.
E4 Participant.
Startup Space.
University & Research Partnerships.

Innovation:

Low Embodied Energy Materials.
Flood Plane Preservation.
Displacement System.

Team Information

Institution Profile

As a land-grant university, Virginia Tech strives to fulfill its mission in transforming knowledge to practice through technological leadership and by fueling economic growth and job creation locally, regionally, and across Virginia. The College of Architecture and Urban Studies has the most direct impact on moving towards a more sustainable future for buildings. It is home to the School of Architecture+Design, which offers undergraduate and graduate degrees in a broad array of design fields, and the Myers-Lawson School of Construction, which offers degrees in Building Construction, Construction Engineering Management, and Environmental Design and Planning. Within the Building Construction program a Sustainable Building Performance track is offered, which places an emphasis on applied building sciences. Additionally, students from the Colleges of Business, Engineering, and Science all contribute to our project in innovative ways as the university seeks solutions to the current environmental crisis through a more holistic approach.

Industry Partners

Prince William County: As the client for this project, Prince William County plays a primary role by providing access to the site and county resources which function to support and evaluate our design decisions. Progress reports and meetings with the county allow for an open dialogue that facilitates decision making based on real needs for the county's intended use of the building.

DPR & Hourigan Construction: DPR is one of the nation's leading commercial contractors and has built four different International Living Future Institute (ILFI) net-zero certified projects. Hourigan Construction has built one of ILFI's fully Living Building Challenge certified buildings; the Brock Environmental Center in Virginia Beach, VA. Both DPR and Hourigan play a key role in supporting the project by providing feedback in terms of real world implications of design decisions as well as cost specific data to the challenges related to high-performance buildings.

Team Members

Student Team Lead: Dominick DeLeone*

Marketing	Landscape	Engineering	Real Estate	Architecture	Faculty
Chiravi Patel	**Alex Arshadi**	**Mitch Peck**	**Justin Gravatt**	**Lucas Kretzing***	Dr. Georg Reichard
LeAnna Jackson-Gilmer	Caitlín Adams	Carlos Amaral	Laney Hull	Adam Alford	Robert Dunay, FAIA
Cat Piper	Alaina Bessette	Patricia Asiatico		Yoni Comhaire	James Wood
Christian Schroeder	Melissa Novy*	Zach Greene		Joshua Delaney*	
Hayley Stout	Samantha Snyder	Leigh Kadlec		Anna Dubyk	
	Joseph Troia	Alsaleh Sugati*		Blake Massie*	
				MJ Steven	
				Lelan Yung	

* Graduate Standing

com ______________.
comfort
community
communication
complexity
compassion
comprehensive
compositive.

Team Overview

In order to provide a holistic design approach, our team is composed of a variety of backgrounds, ranging from architecture and building construction to macromolecular science and civil engineering. As a team, we intend to positively impact the surrounding community with our design. Developing a community within our team is crucial to our success. Team members participated in various design charrettes, as well as individual research, which allowed our comprehensive design for the Eco-Park Learning Center to integrate all aspects of life and community.

Vision Statement

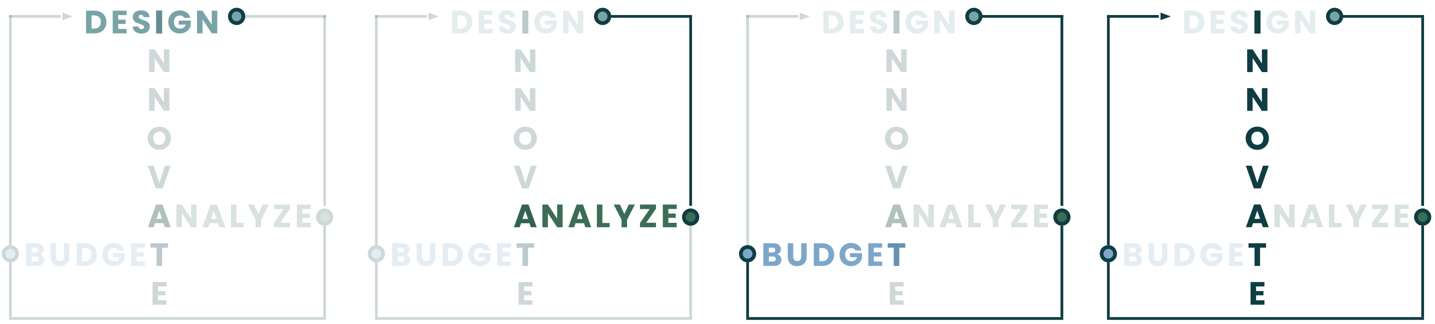
"Finding strength in diversity, Compositive pools the talents of an interdisciplinary team with the goal of positively changing the future of the built environment."

Team Experience

What makes Virginia Tech such a special experience is a strong emphasis on hands-on learning. All students are encouraged to participate in study abroad and/or internship opportunities. Having the opportunity to apply what is learned in the classroom is incredibly valuable to our team members. With a diverse group of roughly 30 students, we collectively pool our experiences with over 20 companies and many study abroads. This shared knowledge allows our team to work in vibrant collaboration, ensuring a comprehensive design for The Eco-Park Learning Center.

3M • Clune • **Cushman & Wakefield | Thalhimer** • Dodson • **FKB** • Gilbane
Hidden Lane • Hugh Lofting • **IMERYS** • JE DUNN • **Kirlin** • LUX ET VERITAS
Mills Group • NIST • **Park Properties Management** • Quantum Spatial
SFCS • SOM • **Thomas Jefferson Monticello** • Whiting-Turner

Designing the Eco-Park Learning Center



The ***design*** phase of our cycle is continuously informed by budget, energy modelling, and client/occupant feedback. Our client's aspirations for The Eco Learning Center push us to investigate cost-effective solutions that can make their vision a reality. For example, we are repurposing a custom CNC wood screen into beautiful landscape structures after realizing it was infeasible for a building application – a solution appreciated by the client.

Our ***analysis*** process uses OpenStudio to test the performance impacts of design options like insulation thicknesses, window to wall ratios, and/or different MEP systems. Plotting the changes in EUI vs. budget data helps communicate our decisions to Prince William County. For example, we show how reducing windows around the building's courtyard can improve energy performance and reduce cost while keeping a "seamless" transition desired by the client.

Budgeting began with a construction breakdown based on the Uniformat II standard. This included traditional commercial construction assemblies and systems for the first architectural draft. This provided a comparison to traditional construction practices to inform future investigations. Data from our energy model will inform cost-benefit analysis for each scenario which will support cost-considerate decisions.

Innovation is the product of our design → analyze → budget work process. We aim to craft unique design solutions that push the current bounds of construction practice but are financially and physically achievable. An example is our pursuit of a more environmentally responsible CLT wall system that can be high-enough performing to achieve net-positive goals.

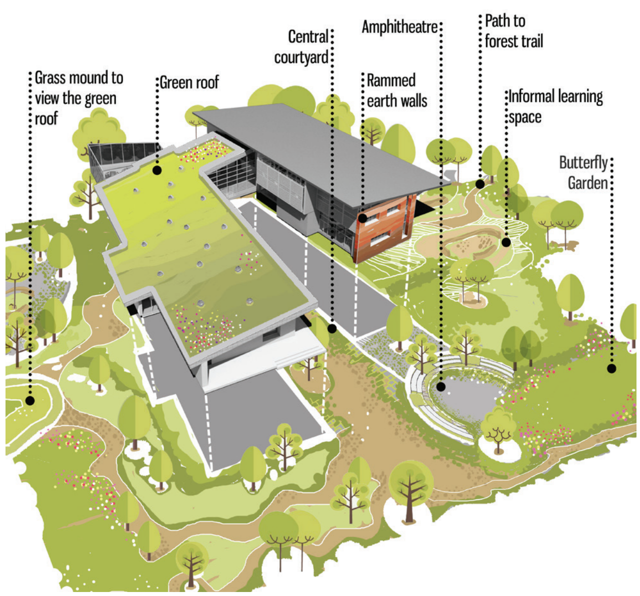


Figure 1. 2: Preliminary site concept

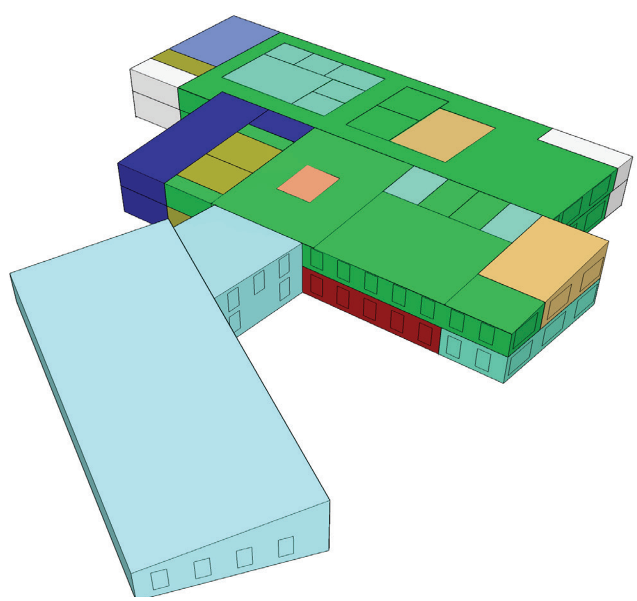


Figure 1. 3: OpenStudio energy model of thermal zones

Design Constraints

Site Design

The roughly 4-acre lot is located partially within the woodland buffer of the Prince William County Landfill. The property includes an easement that leads to an existing parking lot near a ballfield. Improving and sharing this parking lot reduces impervious cover and achieves criteria for the "Human Scale + Human Places" imperative of the LBC. Sun exposure is greatest at the parking lot, presenting an opportunity to merge our solar strategy with sustainable parking design.

Located in the Coastal Plain region of Virginia, our site experiences hot and humid summers which influence the building's climate control strategy. On average, Prince William County receives 43 inches of rainfall per year which offers an excellent volume for rainwater harvesting systems.

Pedestrian oriented mobility is encouraged by the 5-minute walk from the parking lot to The Eco-Park Learning Center, a value shared by the "Human Powered Living" imperative of the LBC. Further design explorations for this imperative include a bike network that serves tours of the landfill and provides an incentive to preserve 9,000 ft. of stream that bisects the landfill property.

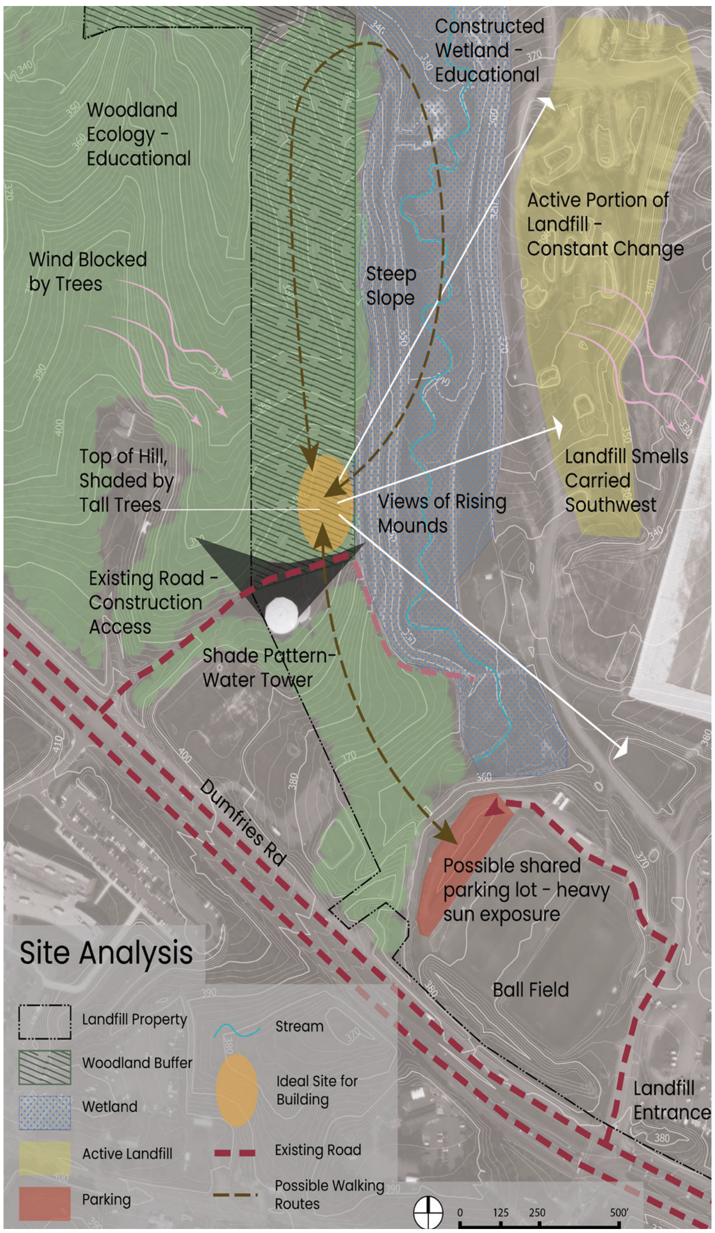


Figure 1. 4: Analysis and location of building site

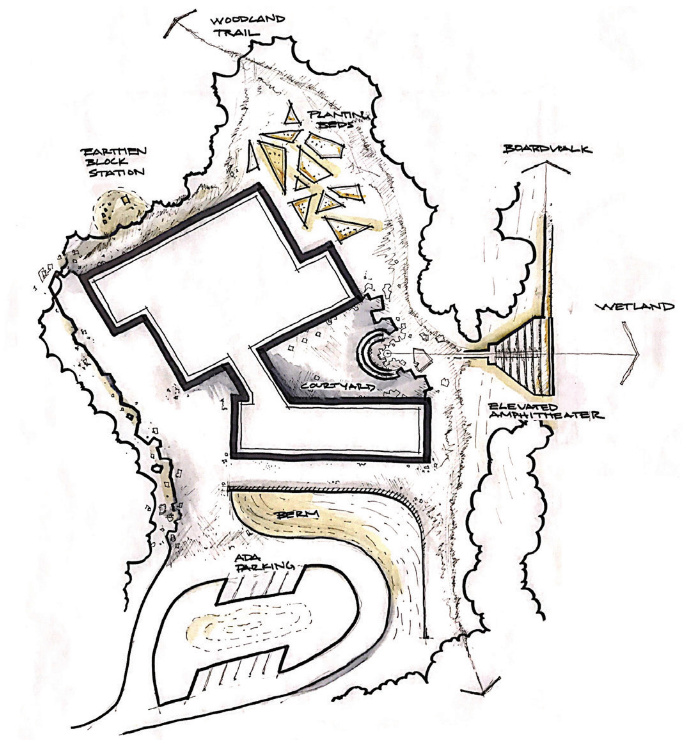


Figure 1. 5: Preliminary sketch of the site plan

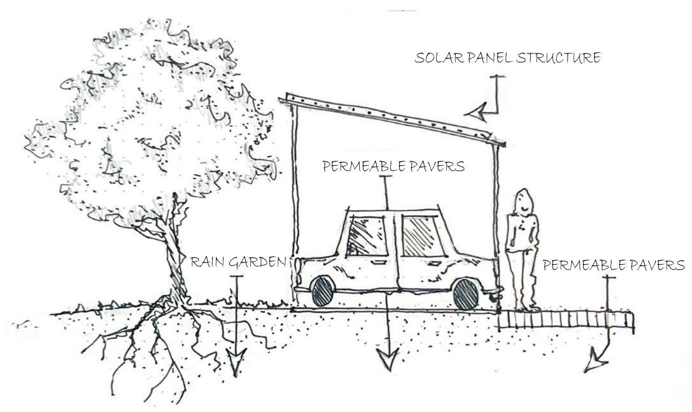


Figure 1. 6: Sketch of solar parking concept

Occupancy Characteristics

The Eco-Park Learning Center consists of around 4,600 sq. ft. of flexible office space and 2,000 sq. ft. of community educational space. The office portion of the building is designed for up to 85 occupants. The building will house local administrators, the Prince William County Landfill researchers, and a community engagement center. The local municipality will be occupying the majority of the space while the remainder of space will be leased in short term periods to individual entities. Additionally, this flex space will have the ability to be absorbed by the community as an educational sustainable landmark. Potential end users will be attracted to the adjacent award-winning Prince William County Landfill where the county deploys a team of researchers exploring pathways of innovative sustainability for both building and site.

The administrators and research team will be occupying the northern wing comprised of a laboratory, closed offices, and a portion of open office space for easy collaboration. Aside from the outdoor instruction zones, local students will be able to use the multipurpose rooms and gallery extension to engage with the learning materials. The beauty of The Eco-Park Learning Center is that the building is designed for flexible program use, so the occupants can truly use the building to their imagination.

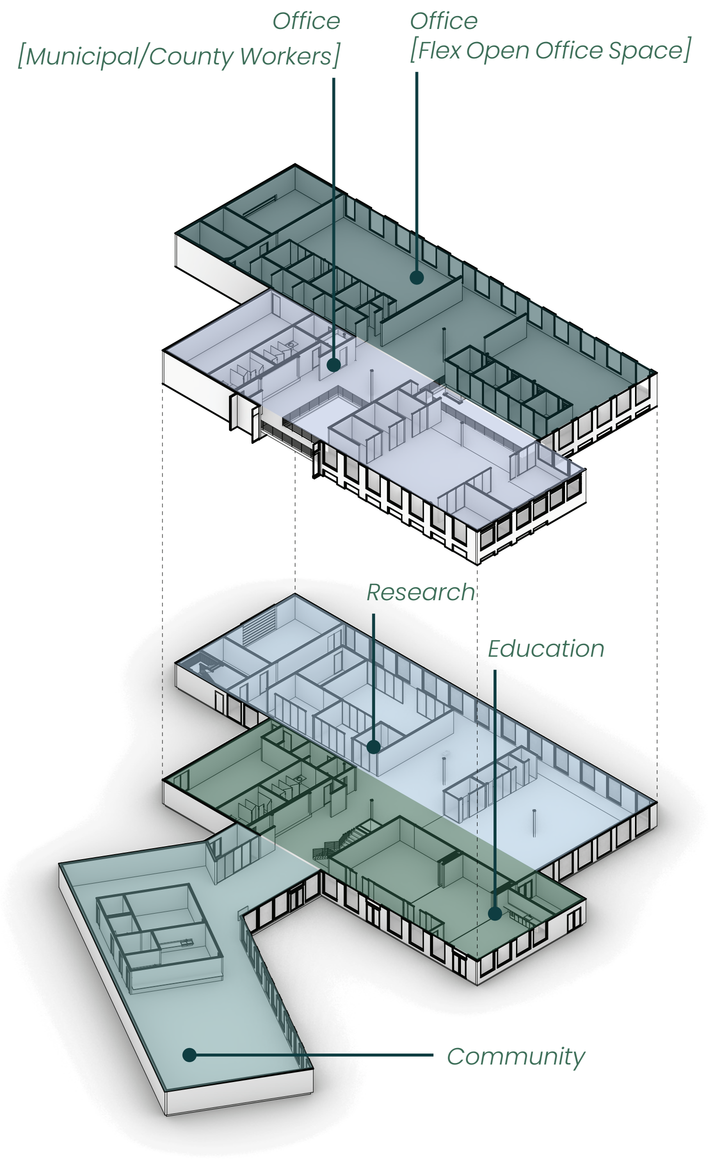


Figure 1. 7: Occupancy categories

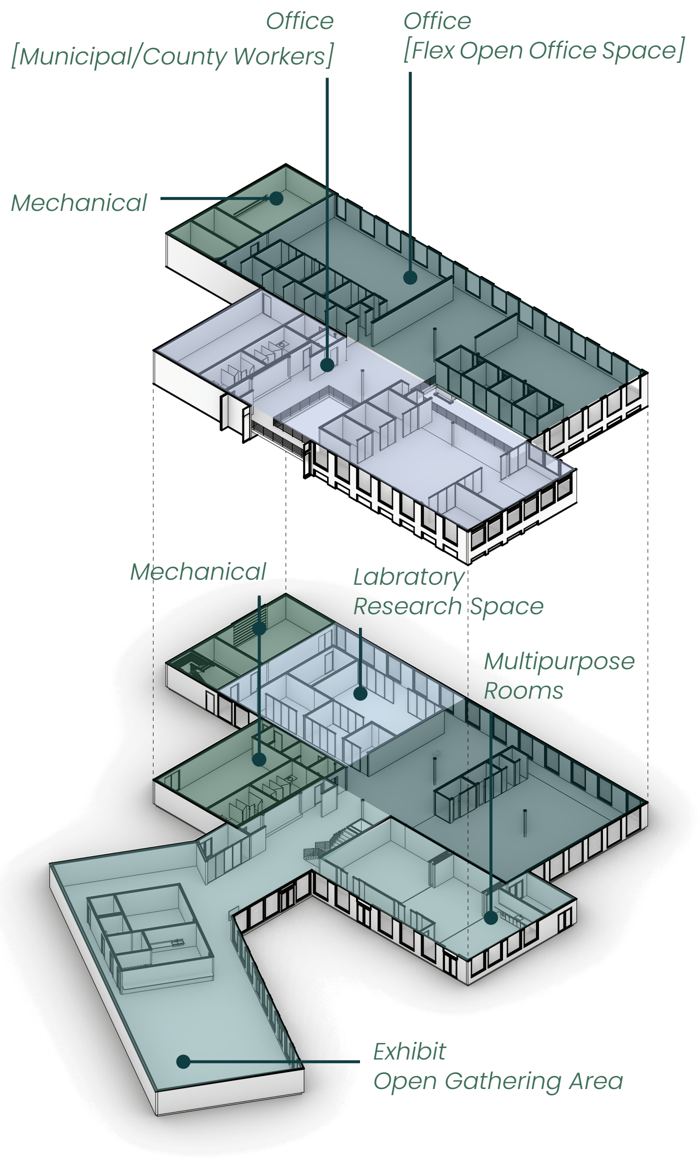


Figure 1. 8: Space breakdowns

Living Building Inspiration

As part of the design process, our team has been studying buildings that exemplify the values we wish to guide our design strategy. Many of these buildings have achieved petals of the Living Building Challenge. Inspired by these projects, we identified specific systems that are crucially important for achieving our ambitious sustainability goals. The figures below highlight the major systems that drive our project towards a more complete LBC Petal Certified building.

Sacred Heart Stevens Library
Atherton, CA

Showcasing key sustainability features to K-12 students, the ***Sacred Heart Stevens Library*** uses displacement ventilation with a sensor based building management system to reduce energy demand based on building innovative materials,

Co|Lab - HITT
Falls Church, VA

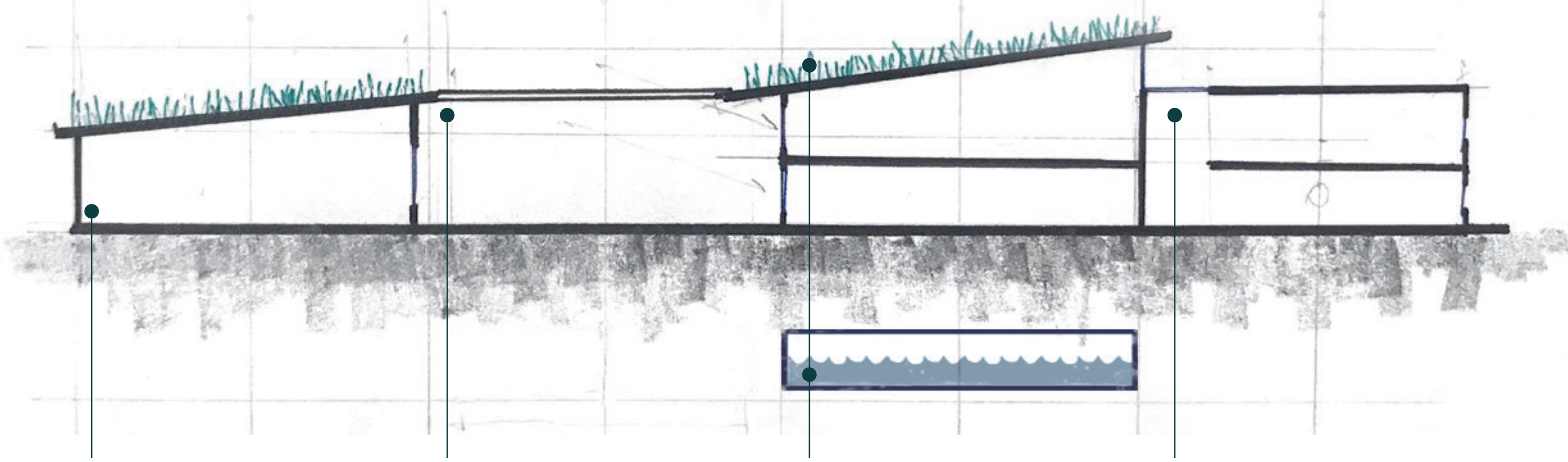
Co|Lab for HITT Construction is prototyping systems that will allow for a more sustainable construction industry, combing natural materials and ample glazing with inspirational interior design.

Brock Environmental Center
Virginia Beach, VA

The donated and re-purposed materials used in the ***Brock Environmental Center*** allows students to further understand the complexities of the living systems located in the Chesapeake Bay.

Rocky Mountain Institute HQ
Basalt, CO

Integrating the natural world, the ***Rocky Mountain Institute HQ*** introduces wood furnishings to replicate the surrounding landscape. Also influencing our implementation of daylighting.



HVAC: In the open gathering area, we will be using a displacement system to cool the space and a radiant floor system to heat up the space.

Innovative Materials: The structure of the building is comprised of Cross Laminated Timber Panels, Glulam beams, and stabilized earth block.

Green Roof & Rainwater Harvesting: The implementation of a green roof and rainwater harvesting cistern manges the sites stormwater.

Daylighting: A double height atrium provides natural light to central office space and multipurpose rooms.

Design Goals

Conservation

Preserve Existing Ecology

Use of Reclaimed Materials

iTree Analysis

Community

Showcase to School Groups

Encourage Green Communities

Locally Sourced Green Roof

Scenic Walk/Bike Paths

Comfort

Individual Thermal Zones

Low Velocity HVAC

Radiant Floors

Natural Daylighting

Material Selection

Cost Awareness

Intelligent Constructability

Financially Attainable

Low Operational Costs

Living Building Challenge: Core Imperatives

C1 | Ecology of Place • C2 | Human Scaled Living • C3 | Responsible Water Use

C4 | Energy & Carbon Reduction • C5 | Healthy Interior Environment

C6 | Responsible Materials • C7 | Universal Access • C8 | Inclusion

C9 | Beauty and Biophilia • C10 | Education and Inspiration

Figure 1. 9: Bird's-eye view of the Eco-Park Learning Center

Comprehensive Master Planning

The line that marks our building lot does not determine the extent of our capacity to dream. It is vitally important to the success of the Learning Center that the land planning and outdoor programming is designed to fit architecture to place. This belief pushed us to design outside the bounds and provide Prince William County with a holistic master plan that engages the totality of the landfill and offers direct path connections to local elementary, middle, and high schools. Naturalistic trails and boardwalks wind through different types of native ecosystems, through valleys and over hilltops, forest and wetlands. Stopping points feature learning nooks with place-based exhibits, a cutting-edge recycling facility, a landfill gas cogeneration plant, an aviary, and more. We think that this landfill, following the example of many projects around the globe, can continue to serve the community after the last garbage truck has unloaded and the last mound is capped. The trails and places identified in our plan can help form the backbone of a future parkland, extending the mission of the Learning Center far beyond its initial conception.

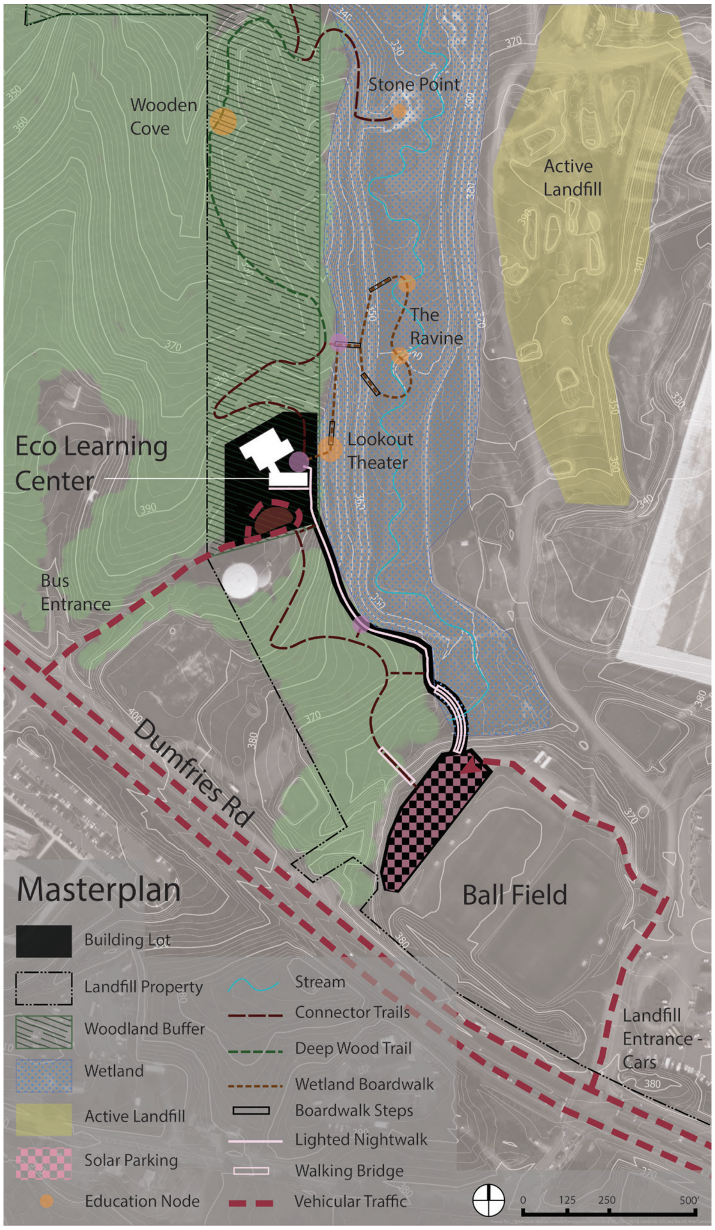


Figure 2. 1: Masterplan of the Eco-Park

Figure 2. 2: Visualization of outdoor learning nook

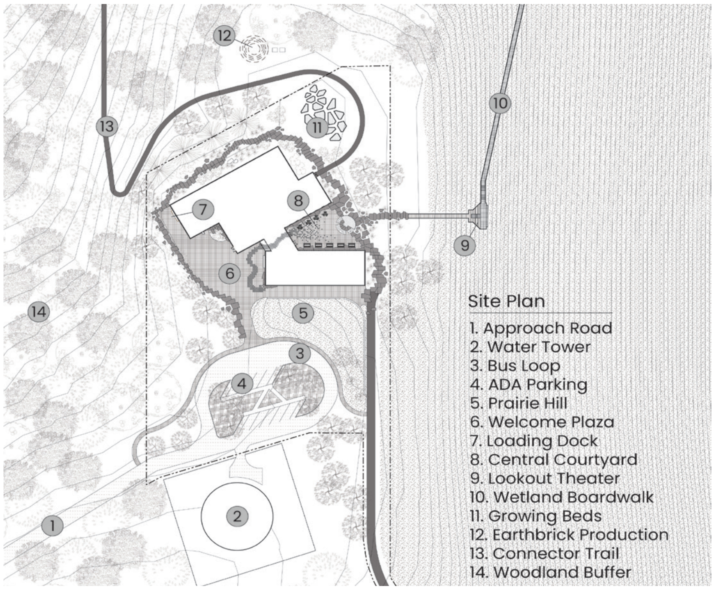


Figure 2. 3: Site plan of the Learning Center

Site Design

Solar Parking

The solar parking canopy design takes advantage of the abundance of square footage present at the neighboring public sports complex by creating an improved parking lot that uses the industry leading, SunPower Maxeon Gen 5 solar cells to create energy for the site. A system of customized 400-watt solar panels stretching across 13,200 square feet of area located above the parking spaces provides a desirable climate for vehicles by shading, cooling and regulating car temperature. An overhead solar parking structure protects vehicles and pedestrians from different weather side effects such as sun, rain, and snow. These attributes of solar parking structures inspire the promotion of smarter environmental practices within the community through the act reducing carbon footprint.

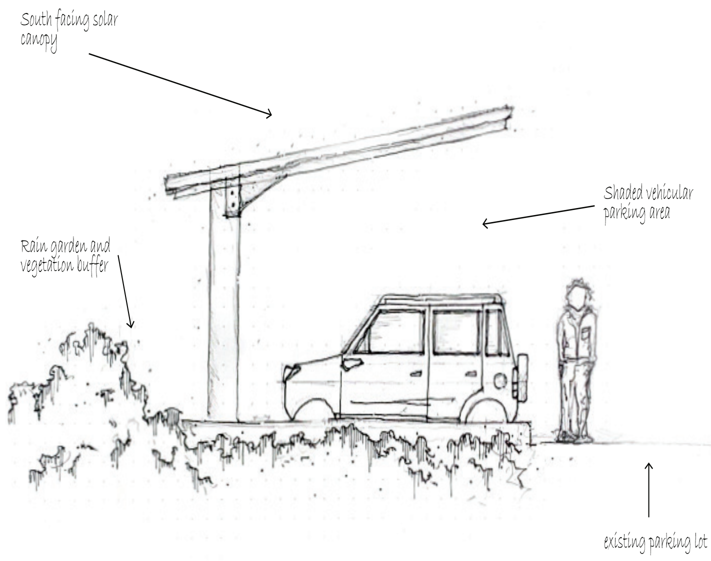


Figure 2. 4: Site plan of the Learning Center

Boardwalk

In the expansion of the Prince William County Landfill, an existing stream was relocated and transformed into five acres of a new constructed wetland. Respecting the Place Petal of the LBC, the building's close proximity to the wetland is allowed if it is used for ecological education. We propose an educational wetland boardwalk that extends from the building's courtyard. The boardwalk itself is constructed with locally sourced, recycled and treated wood using minimally intrusive practices as outlined by the USDA's guide to Wetland Trail Design and Construction. Young visitors can engage the wetland at water testing stations, wildlife observation platforms, and interactive exhibits.

Living Building Challenge: Place Petal

The building's close proximity to the wetland is allowed if it is used for ecological education. As part of the networks of paths spanning our site, we hope the Eco-Park leads to a reduced emmision community.

Figure 2. 5: View from Boardwalk, as it emerges from the site

Site Design

Courtyard

A river of recycled glass that forms near the entrance of the Eco-Park Learning Center guides visitors through the building and eventually to the heart of the Eco-Park Learning Center - the courtyard. This space opens out to views of the landfill and serves as the primary vantage point to watch the landfill grow over the coming decades. Events in the banquet hall can easily spill out into the courtyard through generous side doors. In addition, recycled and reclaimed materials are incorporated into every detail of this space. Permeable pavement allows water to infiltrate and be directed to an underground cistern as a major source of harvested rainwater.

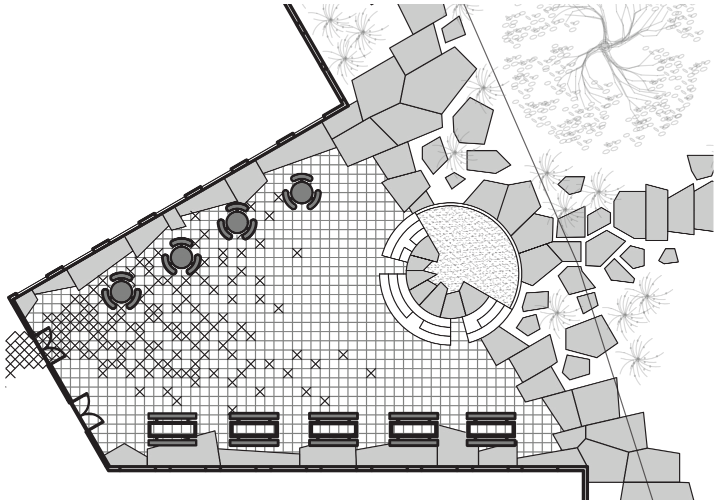


***Figure 2. 6*:** The central courtyard

Path Connections

Surrounding the property are compacted-earth walking and biking trails that wind through the woods and connect at various points, such as: the local schools, a tributary of Powells Creek, and the Prince William County Landfill. The trails would accommodate low-carbon landfill tours and outdoor educational activities, featuring interactive exhibits and nature-based games. For the Living Building Challenge, these bike trails allow us to meet criteria for the Place Petal by contributing to a more pedestrian-oriented community.

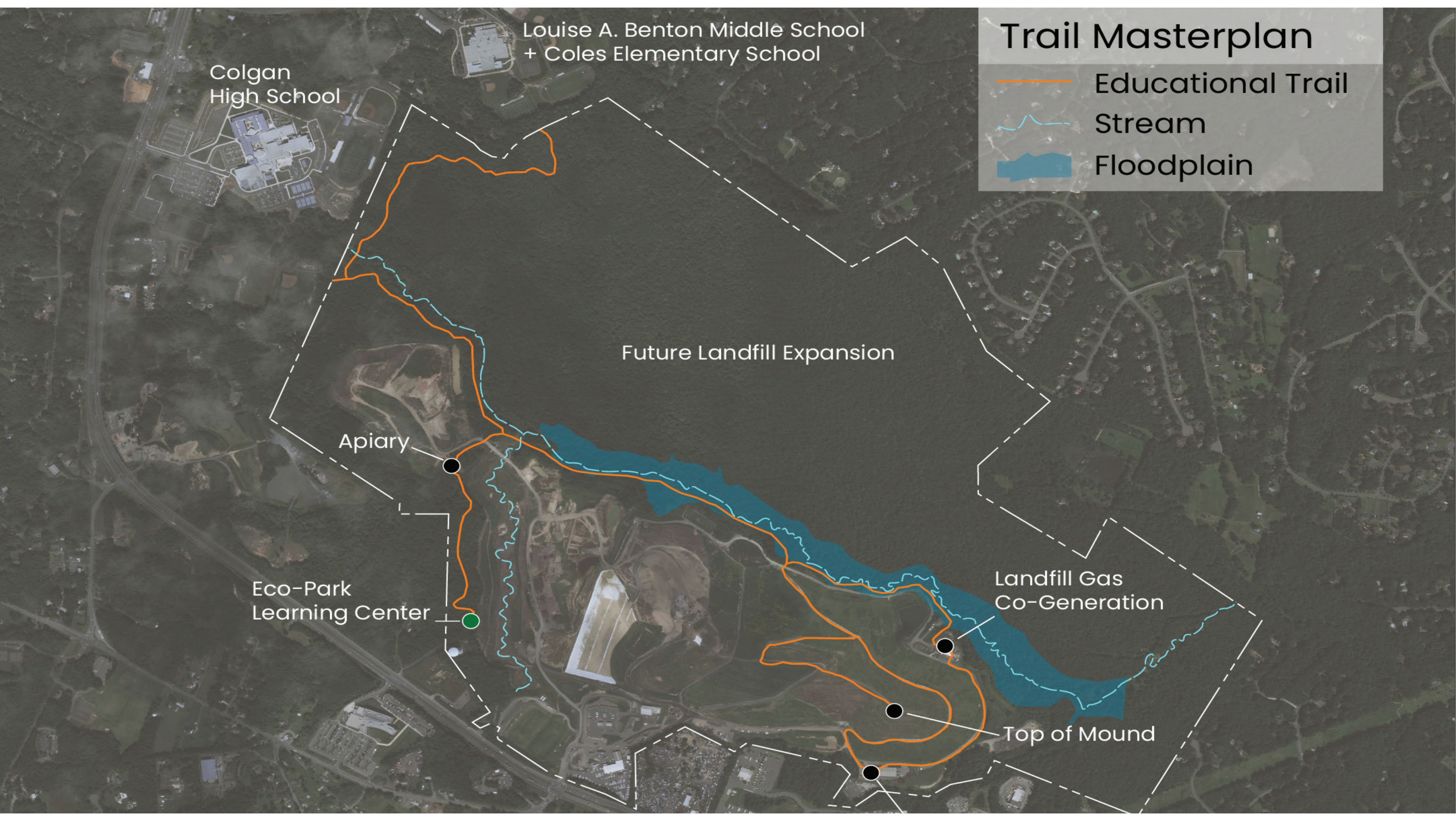


Figure 2. 7: Masterplan of trails linking educational sites

Form Development

The arrival sequence begins with a densely wooded approach road, where upon meeting with the bus loop visitors are greeted with a building that "isn't there." A large sloping green roof appears to blend into a grassy hill, hiding the structure underneath. A meandering path turns the corner to reveal the welcome plaza, where outdoor educational and technological exhibits can excite and inspire. A meandering river of recycled glass pavers guides visitors to the main entrance, which, through glass panels, frames a view of the central courtyard. The courtyard is framed on three sides by the building and one end opens toward the wetlands, with a prime view of the rising landfill in the distance. The juxtaposition of these elements creates a reflective, ever-changing view. The form of the building is molded to create a sequence of discovery and a strong visual relationship between the Eco-Park Learning Center and the landfill.

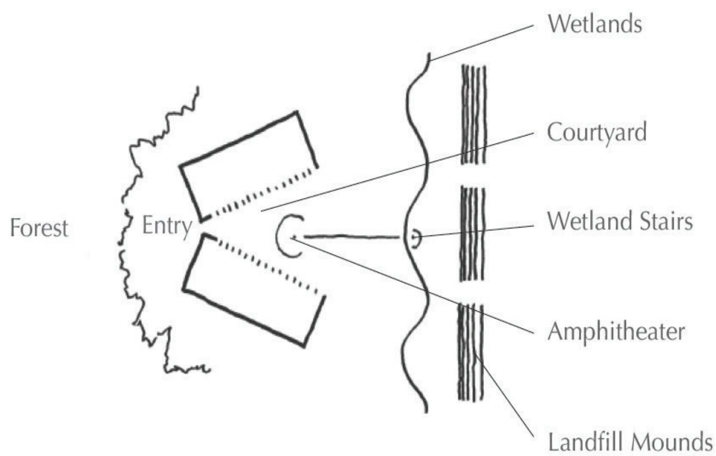


Figure 2. 8: Analysis and location of building site

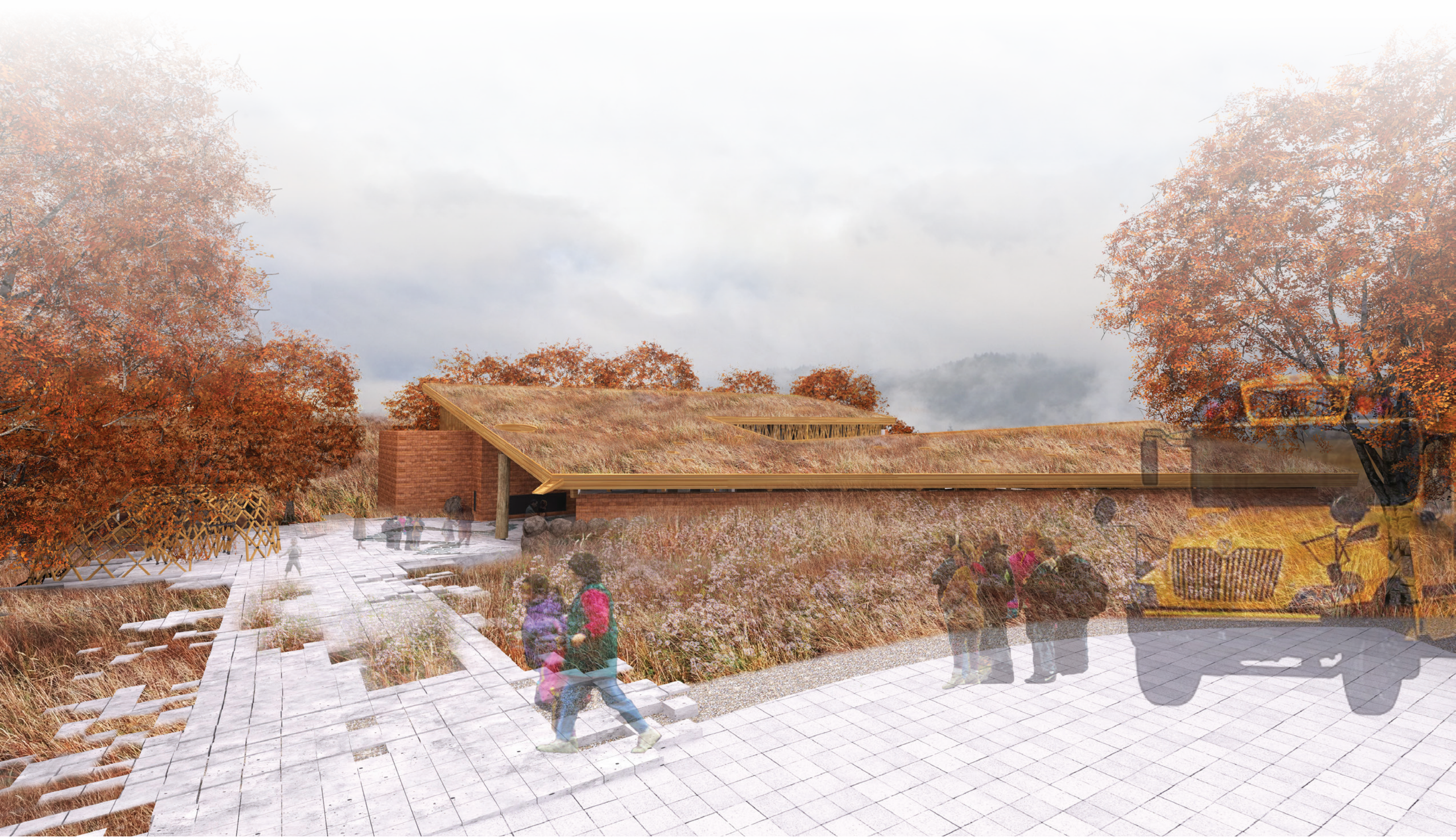


Figure 2. 9: The Eco-Park Learning Center emerges from the topography

Living Building Challenge: Health & Happiness Petal

Architectural design seeks the Health and Happiness Petal through occupant control of climatic conditions, generous daylighting, and biophilic design. Further, connecting architecture to place is achieved with comprehensive master planning and biomimicry.

Community	5,950 SF
Research Lab	920 SF
Education	2,200 SF
Office	
Phone Booths/Breakout Rooms	650 SF
Closed Office	820 SF
Conference Area	1,000 SF
Kitchen/Break Area	1,700 SF
Facilities	1,100 SF
Open Office	4,200 SF
Circulation	8,500 SF

Community

The central courtyard provides a welcoming space for communal gathering and is accessible to all walks of life. With three multipurpose rooms and indoor/outdoor gathering spaces, the facility easily accommodates community visitation outside of its primary office tenants. The indoor event space located in the south wing is fitted with a kitchen/bar that supports gatherings ranging in scale from private events to professional conferences, and overlooks the site and central courtyard.

Research Lab

The research lab space, located on the first floor of the facility, provides general lab equipment for a variety of research types. The growing beds located off the northeast part of the building present opportunities to integrate horticultural/ecological studies. Prince William County has a working relationship with George Mason University and plans to expand their university outreach with live-in residence programs. With the research lab, Prince William can attract research initiatives that reflect the ideals of the Eco-Park and contribute to the forward-thinking culture of the Learning Center.

Education

Multipurpose classroom spaces on the first floor of the facility offer visitors a place for engagement and education. With a focus on STEM, the Eco-Park Learning Center can use the high-tech landfill as an educational resource. The size of these rooms can be adjusted according to demand by retracting the operable glass partition walls. The rooms overlook the landfill and central courtyard, allowing the opportunity to draw immediate relationships with the site. Students also have the opportunity to observe the activities of the research lab, located within feet of the multipurpose rooms.The courtyard, adjacent to the multipurpose rooms, is the heart of our outdoor learning environment which offers a gathering circle and accessible connections to the wetland, woodland buffer, and growing beds.

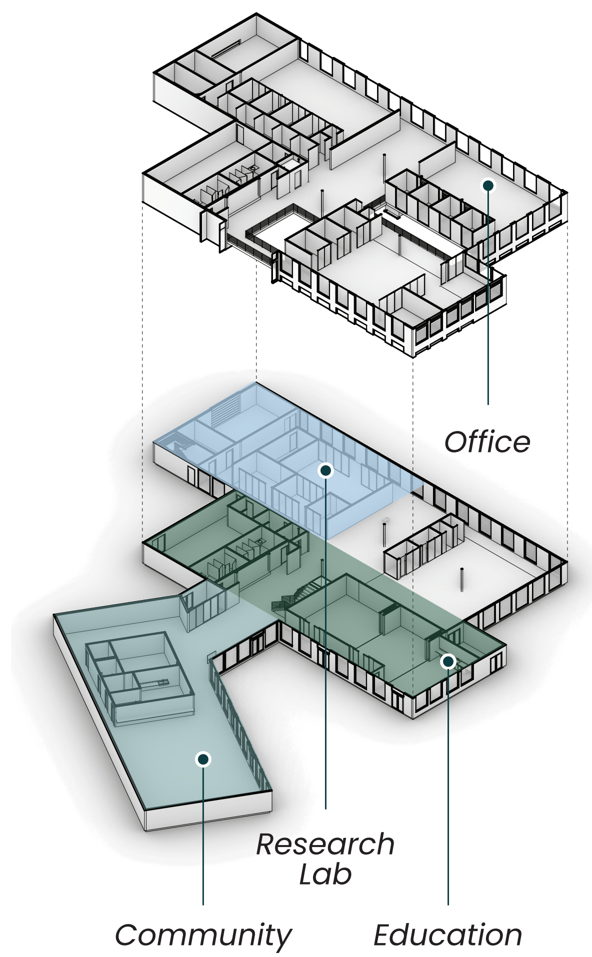


Figure 2. 10: Building Programing

Space Breakdown

Offices

The office space is divided into two components: closed office space for the municipal workers and administration, located on the second story of the facility, and rentable open office space. The open office space is divided amongst the first and second floors of the north wing to mitigate disruptions often faced with coworking spaces, such as increased noise levels, overcrowding, and lack of privacy. The office areas are equipped with:

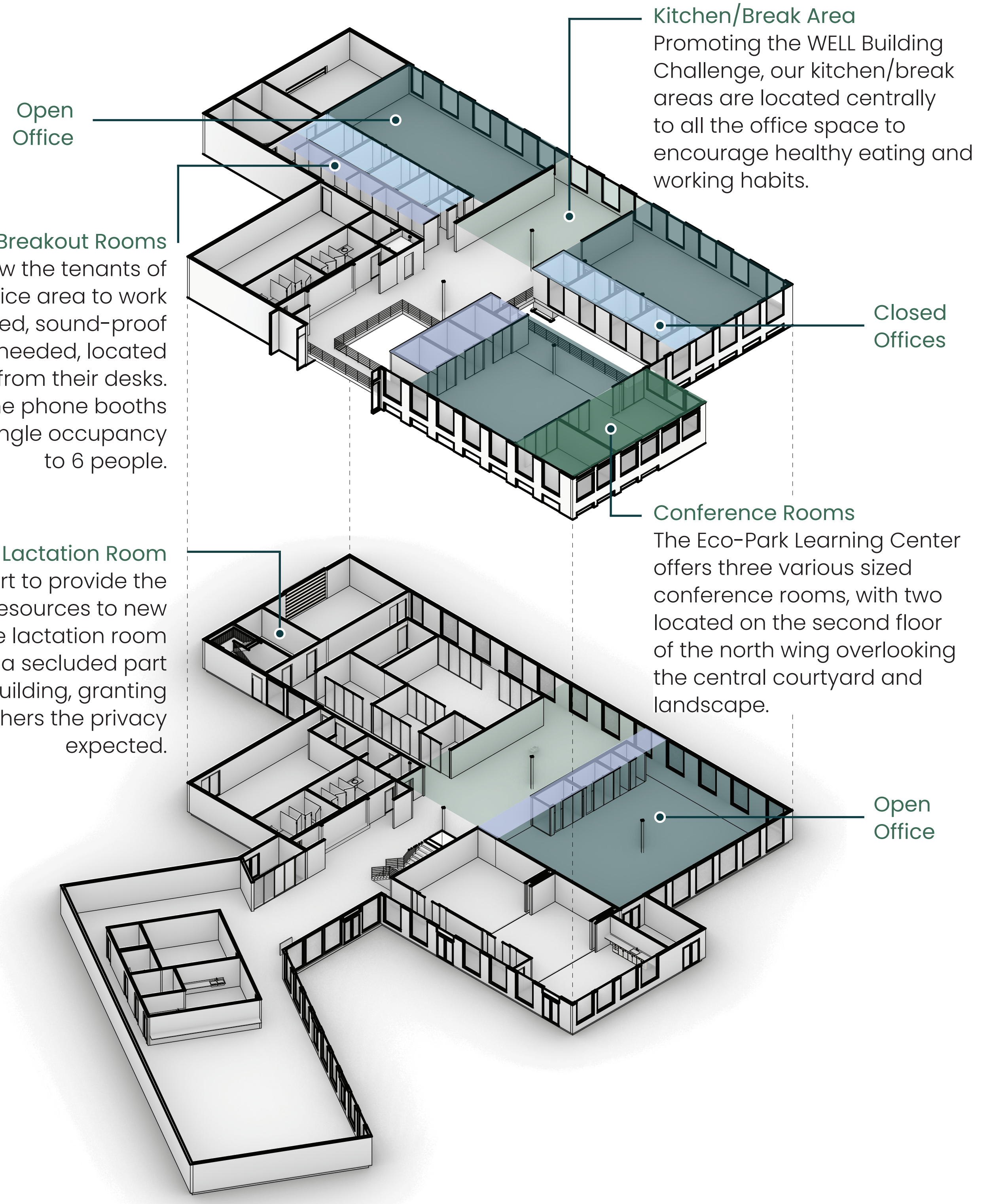


Figure 2. 11: Breakdown of office areas and amenities of the floorplan

Material Selections

When performing the material selection for Eco-Park we looked to the surrounding landscape to identify characteristic textures and colors of the locality. We selected materials that resonate with the building's environment and also met self-imposed criteria such as environmentally friendly, locally sourced, and either reclaimed or recycled if possible. We determined that trying to achieve the strict Materials Petal of the Living Building Challenge would dramatically inflate the cost of the building, so we decided to simply take inspiration from the LBC mission and use responsible materials wherever feasible. These responsible materials form a major component of the building's didactic value, serve as talking points on tours, and tie the narrative of waste management into the Learning Center's physical presence.

Figure 2. 12: View of entry way from North Wing of the Eco-Park Learning Center

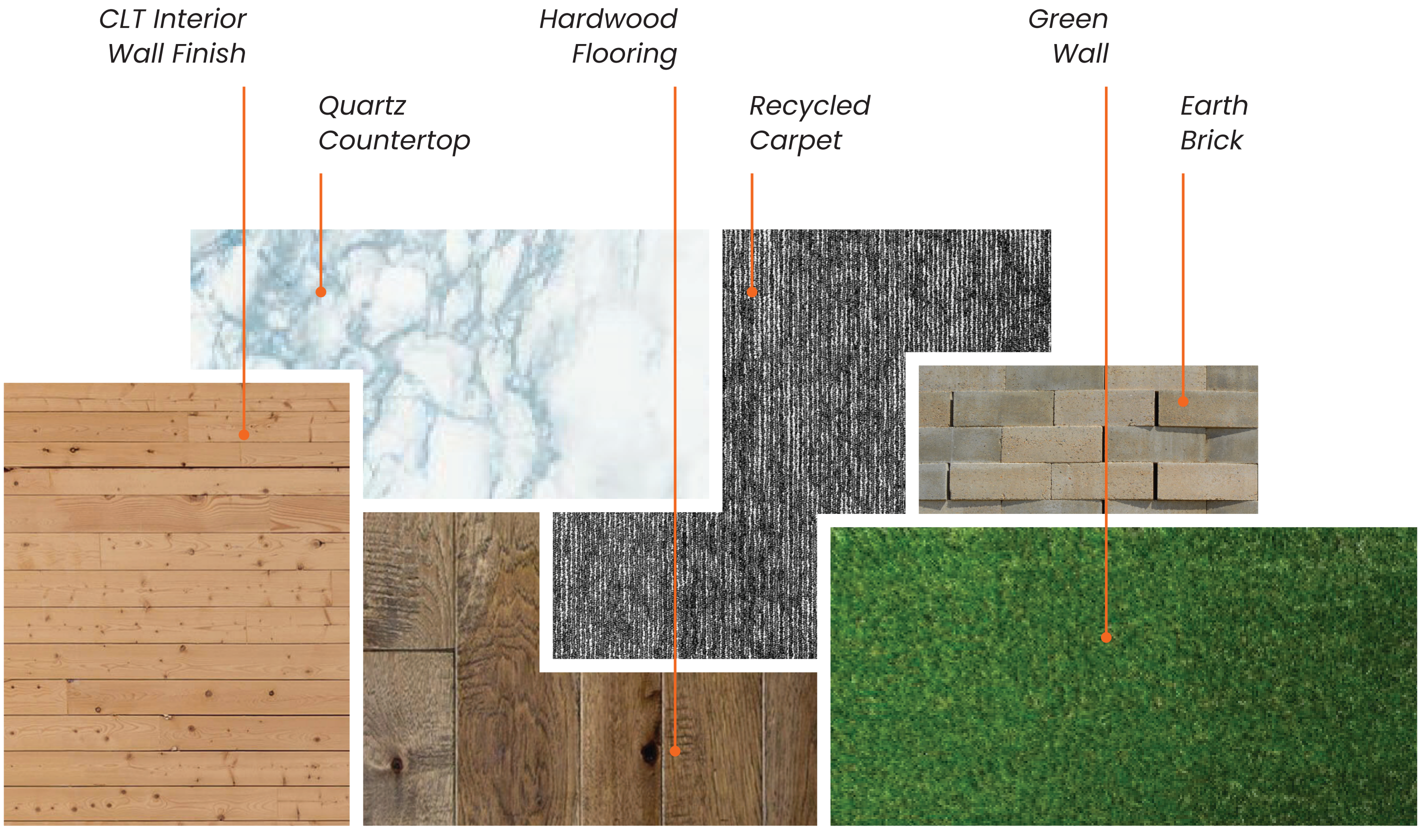


Figure 2. 13: Complementary, biophilic material choices

Lighting

Natural Lighting

Our design strategy follows the principle of working with environmental forces to optimize our design strategies. One important consideration is the sun path in our location. To achieve a balance of function and aesthetics, natural lighting was studied to achieve the optimum solution that considers daylight amount/timing, glare control, heat gain and visibility to the outside. To make efficient use of our daylight, the spaces are divided into two types: task based, and non-task based. Task based spaces are brightly lit and pleasant for workers by providing an appropriate access to sunlight and views to nature.

This strategy helped determine the size and shape of each window, which provided an excellent daylight factor of 2.5%. In addition, this strategy helped us avoid window placement in areas that cause glare to users during working hours and allowed us to bring daylight from the northern side to ensure a high indoor quality. Further, the design of an open floor plan helps maintain adequate daylighting for the whole building. The combination of these techniques decreases the need for artificial lighting as much as possible, which increases the efficiency of the building.

Interior Lighting

Ensuring adequate light while saving the most energy for the building is our approach to using artificial lighting. First, we evaluated different types of artificial light (LED / fluorescent) as candidates for different types of spaces looking primarily at the variables of cost, power density, and luminance. Several experiments Acuity's 3D-modeling software allowed us to make informed decisions about the ideal light types. To increase efficiency, motion sensors are added to activate artificial lighting only when people currently occupy a space. With this strategy, lighting quality will be offered to suit the space, save energy and reduce the cost of building operations.

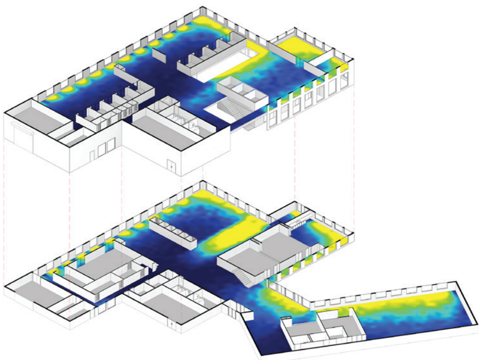


Figure 3. 1: Daylighting model

Figure 3. 2: Visualization: open floor plan allows for generous daylighting

4-Pipe Flexibility

In addition to reducing mechanical noise and ensuring air quality, we are providing tenants thermal control as a key feature for individual comfort. A 4-pipe hydronic system incorporates simultaneous heating and cooling to any thermal space in the building. In addition, the 4-pipe layout allows flexibility for future use of the building with easy changes available to the FCU layout. Occupants may adjust the thermostat to their preference or let the integrated building management system suggest the ideal temperature for energy savings.

Acoustic Quality

Surveying office workers from the Brock Center in Virginia Beach on their working conditions revealed one of the leading complaints to be acoustic discomfort. To prevent acoustic problems for Eco-Park occupants, QRD wood sound diffusers are incorporated into the ceiling paneling that will help absorb noise from mechanical operations. In addition, acoustic partitions divide the open office spaces to provide a suitable environment for phone calls and conversations. At the Eco-Park Learning Center, the displacement ventilation system located in the south wing operates on a low velocity, low elevation duct, supplying conditioned air lower than 10 dBs at floor level within the room. To heat the assembly area, subfloor hydronic heating loops are installed, enabling uniform heating of the space with absolutely zero noise.

Air Quality

Another common complaint from office workers concerns a lack of fresh air circulated in office buildings. Occupants complain of headaches and "stale" air in their offices. Operating in parallel with our 4-pipe FCU system is an MAU that cycles pre-conditioned fresh air from the roof through all thermal zones of the building, and removes exhaust at strategic points of the building to control building pressurization across the different seasons. A strategic design of the mechanical system allows Eco-Park to provide its occupants with fresh air while saving energy with an enthalpy controlled energy recovery system in the MAU and an economizer for the assembly wing air handler that feeds the displacement system. The economizer detects indoor and outdoor climatic conditions to determine when to switch from conditioning return air to utilizing exterior air, which can help save energy through the shoulder seasons.

Figure 3. 3: Visualization: second floor kitchen and break area

Structural Design

During the design process, we evaluated two structural systems: a standard steel structure vs. a mass timber structural system. An important factor to us is calculating the embodied energy of either system. Steel was found to have an embodied energy a little over 2 times that of Glulam. We chose Glulam to provide our building with a structure that was lighter with a smaller carbon footprint, compared to steel, pound-for-pound.

Plumbing Design

The plumbing system is designed to satisfy occupant needs by the use of low energy equipment and an efficient layout. There are two main tanks that store the rainwater, with one dedicated to supplying the purification system while the other is reserved for green roof irrigation. A 25,000 gallon tank provides water to the RainFlo system which can generate 18 gallons of purified and disinfected water per minute and is stored in a third tank that supplies Eco-Park's domestic water system.

Hot Water Heater

Eco-Park's hot water is supplied by a heat pump hot water heater located in the main mechanical room. This main heater supplies hot water to bathrooms and kitchens strategically placed in the building to reduce long runs, reducing the chances of wasted energy through heat loss. Additionally, there is a smaller hot water heater located in the south wing that services the catering kitchen for large events. This system operates independently to run on an as-needed basis during catering events to reduce energy demand.

Composting Toilets

One of the major reasons we are able to achieve LBC water petal certification is the employment of composting toilets. Implementing this system removes the water demand for flushing and saves roughly 50,000 gallons of water annually. Located on both floors, the bathrooms are slightly offset from each other to allow for both sets of toilets to have the proper chutes and exhausts. The composting chambers are located within a partial basement which can also provide access for maintenance work. The only plumbing required for this system is a minor misting supply to the catch basin in the basement that fuels decomposition.

Living Building Challenge: Water Petal

All water needs are supplied by our rainwater harvesting system and treated with a RainFlo purification package.

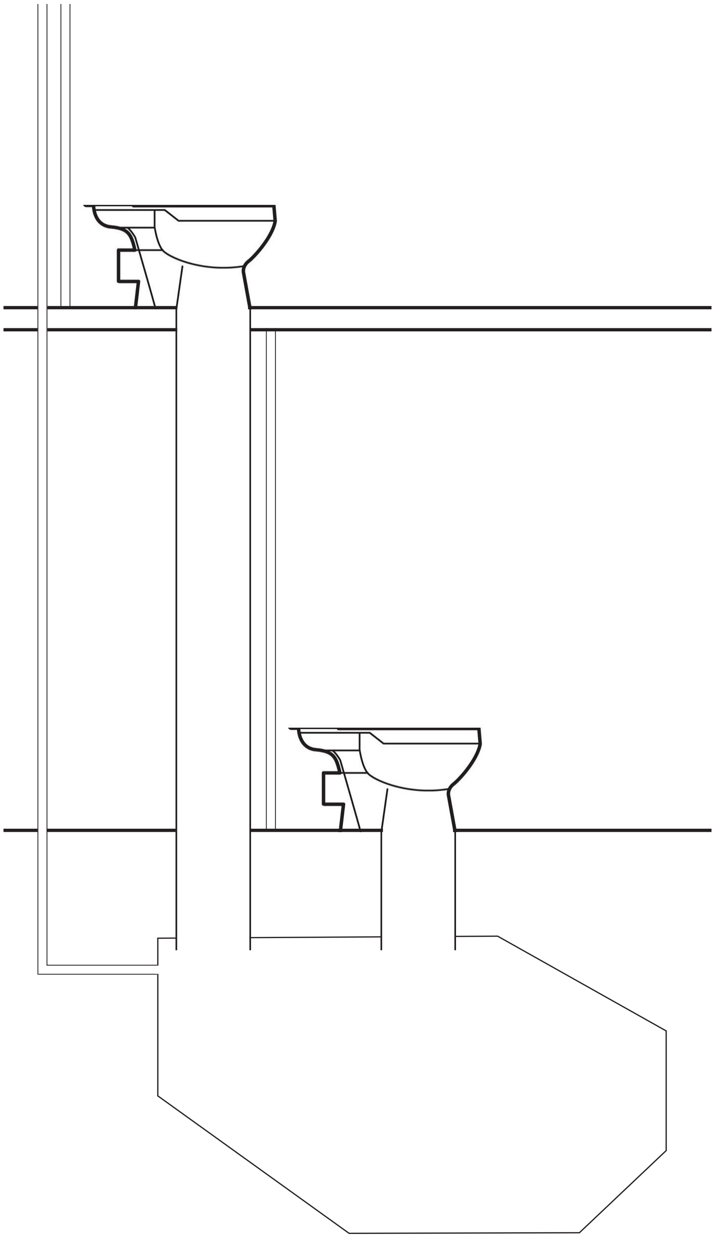


Figure 4. 1: Composting toilet system

Building Enclosure Design

Green roof

Providing our client, Prince William County, with a building that both operates at net-zero and displays the methods of achieving net-zero is important for their mission to showcase sustainable design to its own community. As workers and visitors approach the building, they will be met by a building capped with the very grasses that can be seen growing down in the wetland behind Eco-Park. Functionally, the green roof operates as a thermal mass material. Throughout the day, the soil layer will store heat from the sun and release the heat through the night, regulating interior temperature of the building and reducing the energy load on the HVAC system.

Stabilized Earth Block

A portion of the building features an enclosure system with an outermost layer of stabilized earth blocks. Stabilized earth blocks have a significantly lower embodied energy, 180 BTU/lbs, as compared to the alternative traditional brick which measures 1,075 BTU/lbs. In addition to being thermally efficient, the stabilized earth blocks can be produced locally, and visitors can engage in the process to create earth blocks that form landscape gathering spaces along the woodland trails. Local production reduces transportation cost and maintains a lower construction cost.

CLT Integration

In order to use CLT as a structural element within our perimeter wall, our wall section had to be revamped to properly insulate the building. CLT incorporates innovative design strategies to maintain an R-33 wall enclosure. As shown in figure 4.3, insulation is installed on the exterior of the CLT to provide a continuous layer, unbroken by interior wall intersections or floors. Also, by providing a continuous layer of insulation on the exterior, the CLT layers are protected from the most extreme outdoor temperatures, preventing expansion and contraction. Keeping the CLT as close as possible to the interior layer of the building prevents moisture accumulation in extreme temperatures. During our design studies, we considered Rockwool insulation, XPS insulation, and Batt insulation. For proper performance of the CLT, a rigid insulation is specified for mounting on the exterior, which quickly eliminates Batt. Ultimately, rockwool holds an embodied energy of about 3 times less than XPS, bringing our overall building EE down in addition to saving more money.

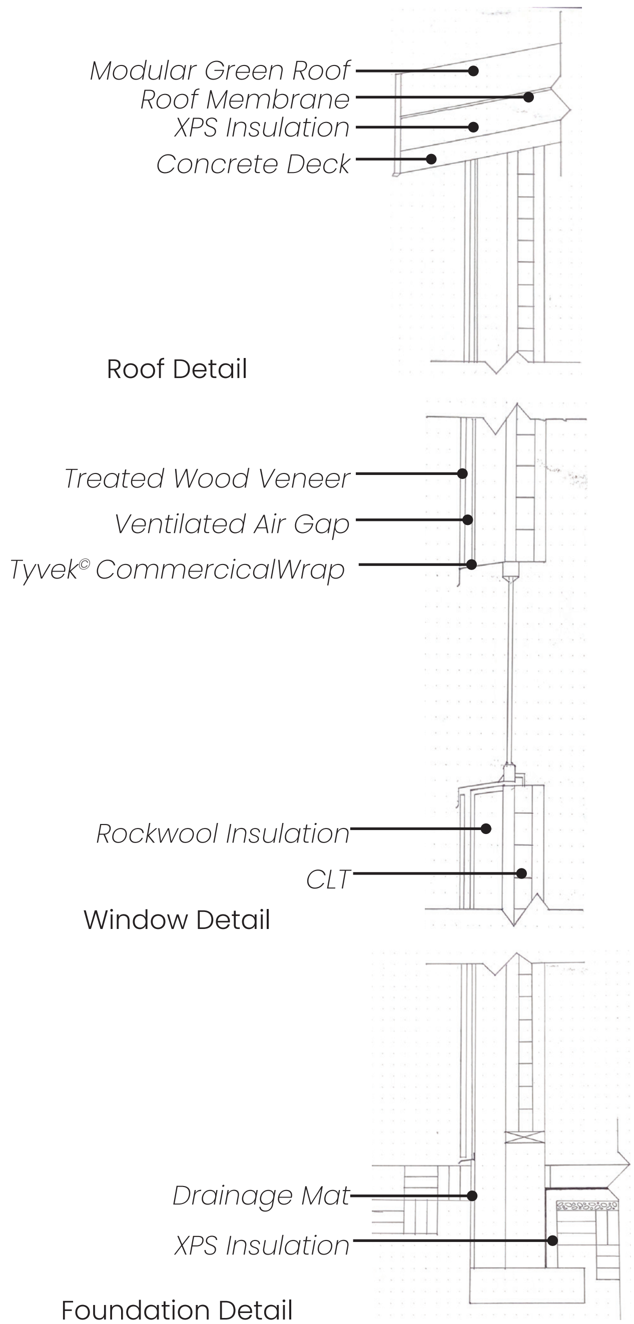


Figure 4. 2: Wall section

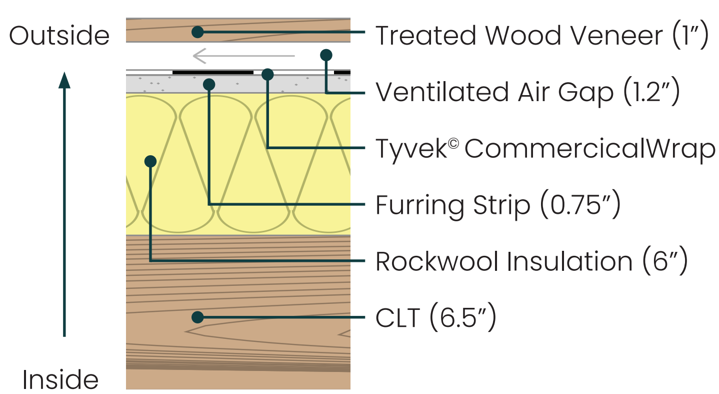


Figure 4. 3: Condensation risk analysis of CLT Wall Section, using Ubakus.

Mechanical Systems

Eco-Park maximizes mechanical energy savings with the use of two different energy conserving strategies. The north wing utilizes a DOAS with ERV, while the south wing utilizes a displacement system with an economizer tied into the air handler with fresh-air access. The economizer is installed to automatically turn the air handler off and instead use outside air. If outside conditions such as temperature and humidity are favorable for the interior climate, the air handler operates in economy mode rather than spending the energy to condition return air for redistribution. Eco-Park operates on one air handler that services the displacement ventilation system in the south wing and a DOAS (or MAU) serves the zones which are conditioned by FCUs. Operating these systems independently enables Eco-Park to function at peak efficiency, serving highly populated areas with consistent conditioning while minimizing the volume of space needing to be conditioned.

Displacement Ventilation

Located in the south wing of the Eco-Park office building is a general assembly area designed for conferences, educational presentations or social events. With such a large open space and a maximum ceiling height of nearly 22', there is a lot of volume to be conditioned. By implementing a displacement ventilation system, we effectively cut the volume to be conditioned nearly in half, along with the energy demand to do so. Running on AHU-2 located in the south wing mechanical room, the displacement system supplies conditioned, cooled air at baseboard level at a low velocity for maximum comfort. Return ducts are located just above head height along the same wall to create a shift zone, separating conditioned from unconditioned space above and thus reducing energy demand.

Hydronic Radiant Heating

Servicing the FCUs, MAUs, and the radiant heating system in the south wing, our 4-pipe hydronic system implements heat transfer technology to reduce energy losses along supply routes, beginning in the mechanical room. For the forced air systems (FCUs and displacement), heat is efficiently transferred to and from supply air within individual zones. A 4 pipe system supplies hot and chilled water at any time to any fan coil unit in the building, meaning one office can heat while the adjacent office can cool. This allows for greater flexibility across localized spaces and the entire building, such as cooling a zone hit by solar radiation, while heating a zone along the northern perimeter of the building. The MAUs are also provided with hydronic supply to pre-condition outside air before it supplies specific zones.

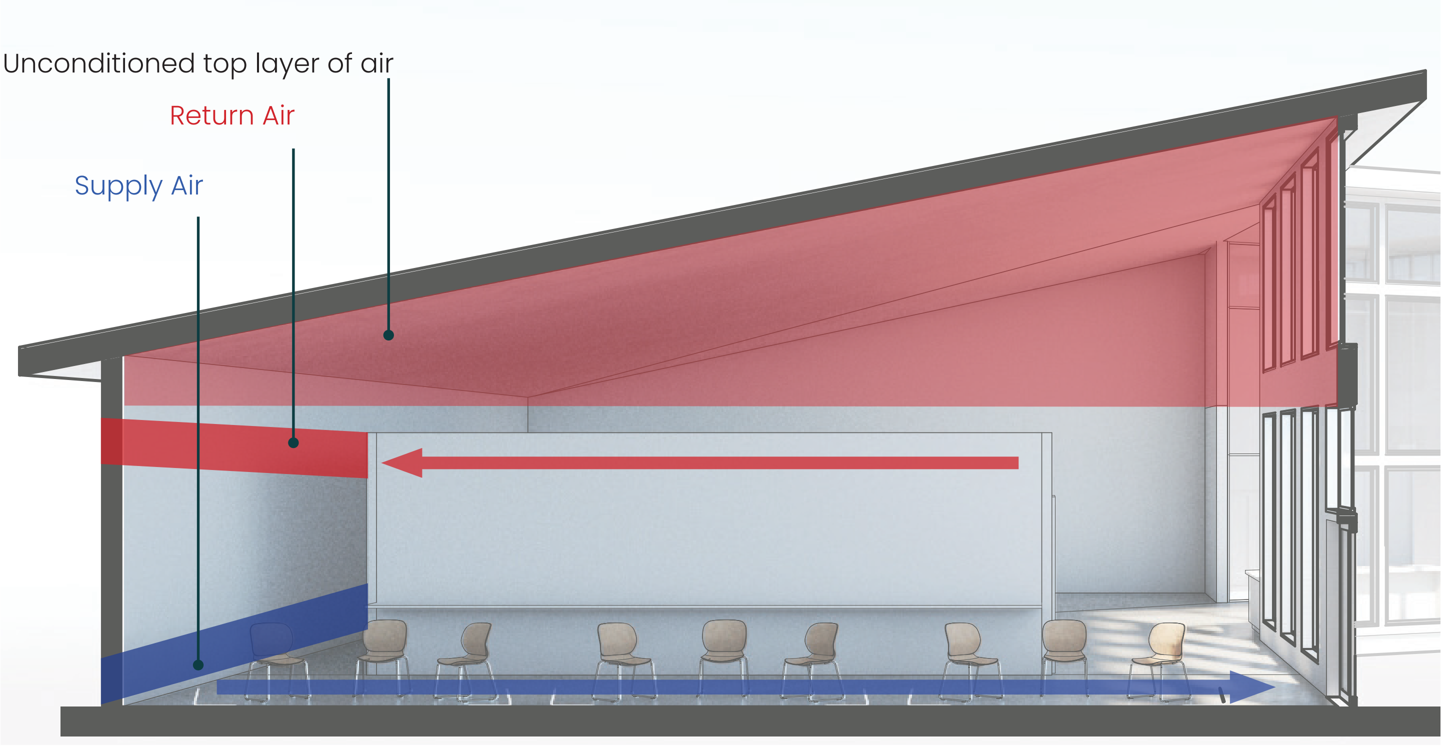


Figure 4. 4: Section visualizing air flow pattern of the Displacement System

Mechanical Systems

Hydronic Four Pipe

Servicing the FCUs, MAUs, and the radiant heating system in the south wing, our 4-pipe hydronic system implements heat transfer technology to reduce energy losses along supply routes, beginning in the mechanical room. For the forced air systems (FCUs and displacement), heat is efficiently transferred to and from supply air within individual zones. A 4 pipe system supplies hot and chilled water at any time to any fan coil unit in the building, meaning one office can heat while the adjacent office can cool. This allows for greater flexibility across localized spaces and the entire building, such as cooling a zone hit by solar radiation, while heating a zone along the northern perimeter of the building. The MAUs are also provided with hydronic supply to pre-condition outside air before it supplies specific zones.

Fan Coil Unit (FCU)

Located throughout most of the north wing are the main office spaces within Eco-Park. In order to provide occupants with the most control, FCUs supply the office space with heating and cooling solutions. Running on the 4-pipe hydronic system, each unit can be controlled with a thermostat specific to 1 of 17 total thermal zones. This provides an incredible amount of flexibility across adjacent spaces, able to heat one office while cooling another. Energy usage is managed within this system by strategically placing supply and return diffusers that divide the building into those thermal zones.

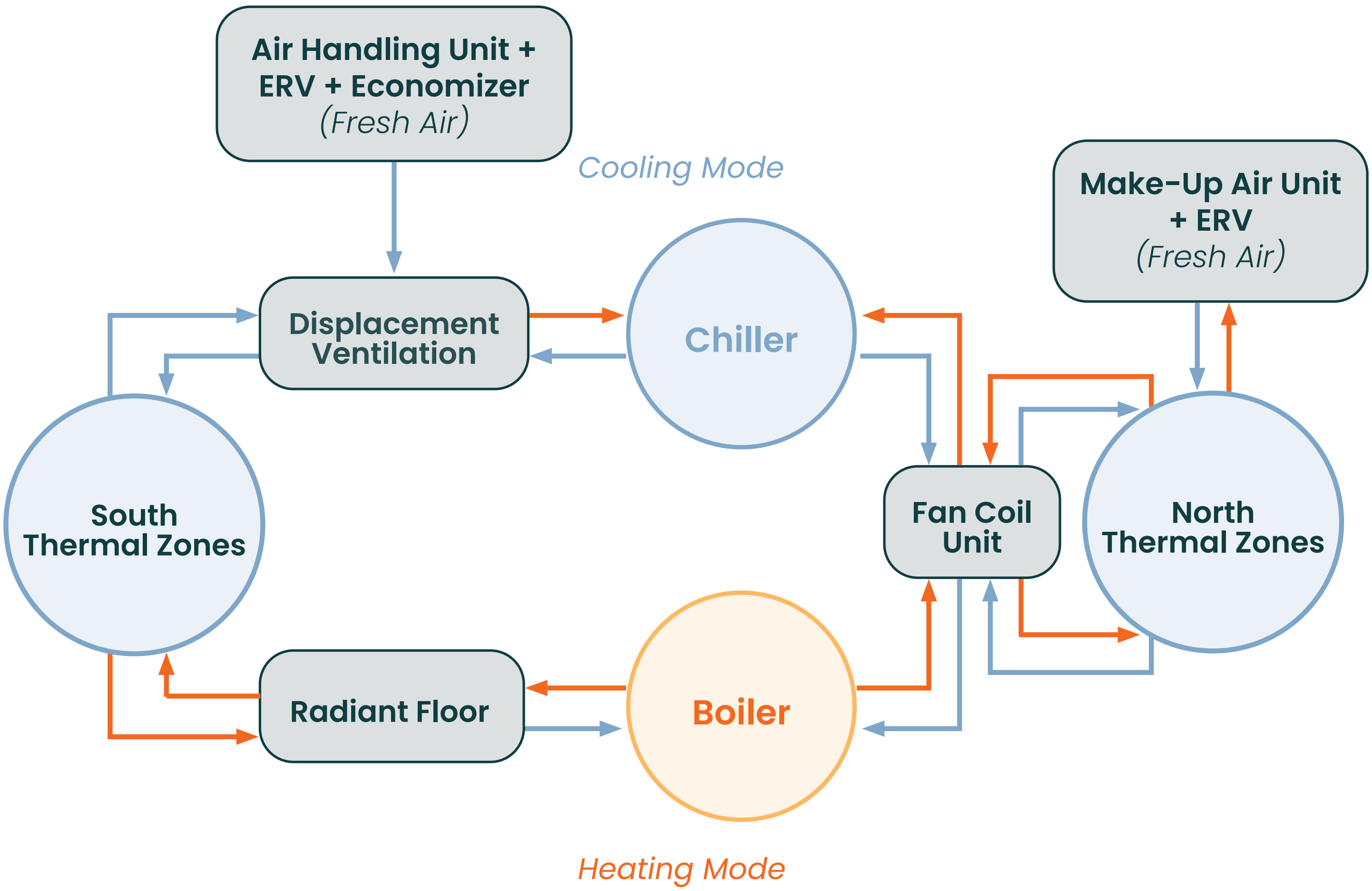


Figure 4. 5: Mechanical systems flow diagram

Dormant Energy Reduction

When offices empty at the end of a work day, many plugs remain active and draw unnecessary energy from the building for equipment that is not being used. To help the Eco-Park Learning Center remain net-positive, Wattstopper Plug Load Controllers are installed to save energy for high demand hours of the day. First, by utilizing occupancy sensors, the system automatically enables or disables power to areas of the building that are either occupied or vacant, respectively. Additionally, timers are placed on power outlets that cut-off power to pieces of equipment that have been vacant for a set amount of time. Based on the average power demand of office buildings and the expected occupancy of Eco-Park, Wattstopper could save over 10% of annual energy through the management of dormant plugs and lights. .

Smartwall

One of Prince William County's goals for the Eco-Park learning center is to use the site as a teaching tool about sustainable energy systems. Located in the lobby of the building, the Smartwall allows tenants and visitors to visualize the performance of all the systems implemented within the building management system. The smart wall includes data as miniscule as the temperature sensor readings in various rooms and as broad as the energy production of the solar PV array. Not just for the visitors, the program running the smart wall can also track and display historical data such as weekly, monthly, and annual energy usage to provide Prince William County with data on building use.

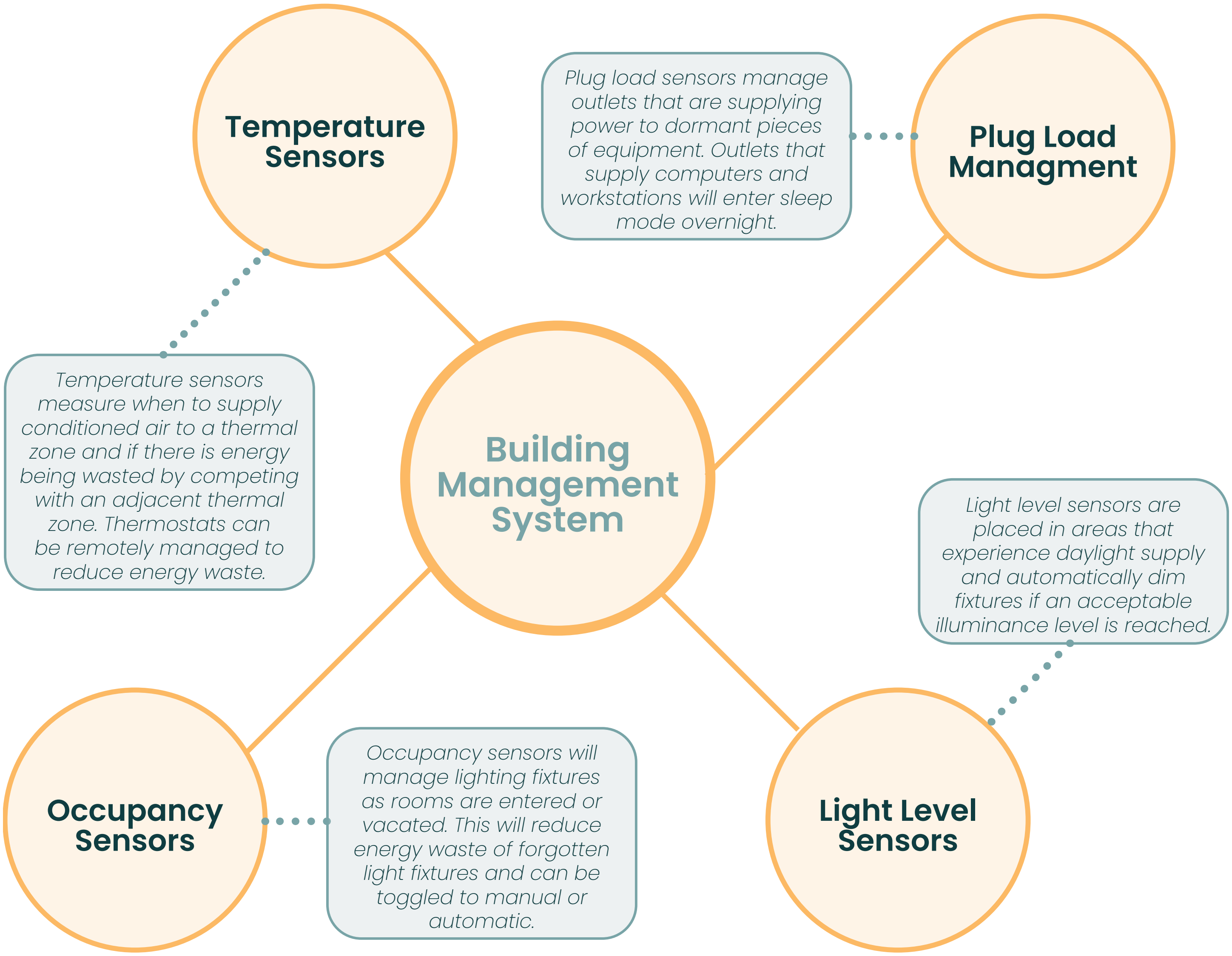


Figure 5. 1: Bulding operations system

Electrical Design

In order to achieve our net positive energy goals for the building, the Eco-Park Learning Center utilizes a 110 kW PV array. This array also doubles as an overhead cover for the majority of the spaces in our parking lot. When selecting a product, we chose SUNPOWER's Maxeon Gen 5 commercial solar panels. In addition to leading the industry in cell efficiency and power density, their panels feature a durable design that reduces damage and improves resilience. This feature combination is something we identified as important early on due to the array being so close to an active landfill that can produce excess dust and debris.

In order to size the array we utilized NREL's PV Watts tool to determine that a 110 kW array would generate 152,000 kWh/year. Based on our OpenStudio model, the Eco-Park Learning Center needs to produce over 151,000 kWh/year to meet our 105% energy production target set by the Living Building Challenge's Energy Petal.

Living Building Challenge: Energy Petal

By reducing our demand with natural shading, using native tree species, the Eco-Park Learning Center is able to produce 105% energy production.

Figure 6. 1: Comparison of UNPOWER's Maxeon Gen 5 commercial solar panel vs. standard solar panel

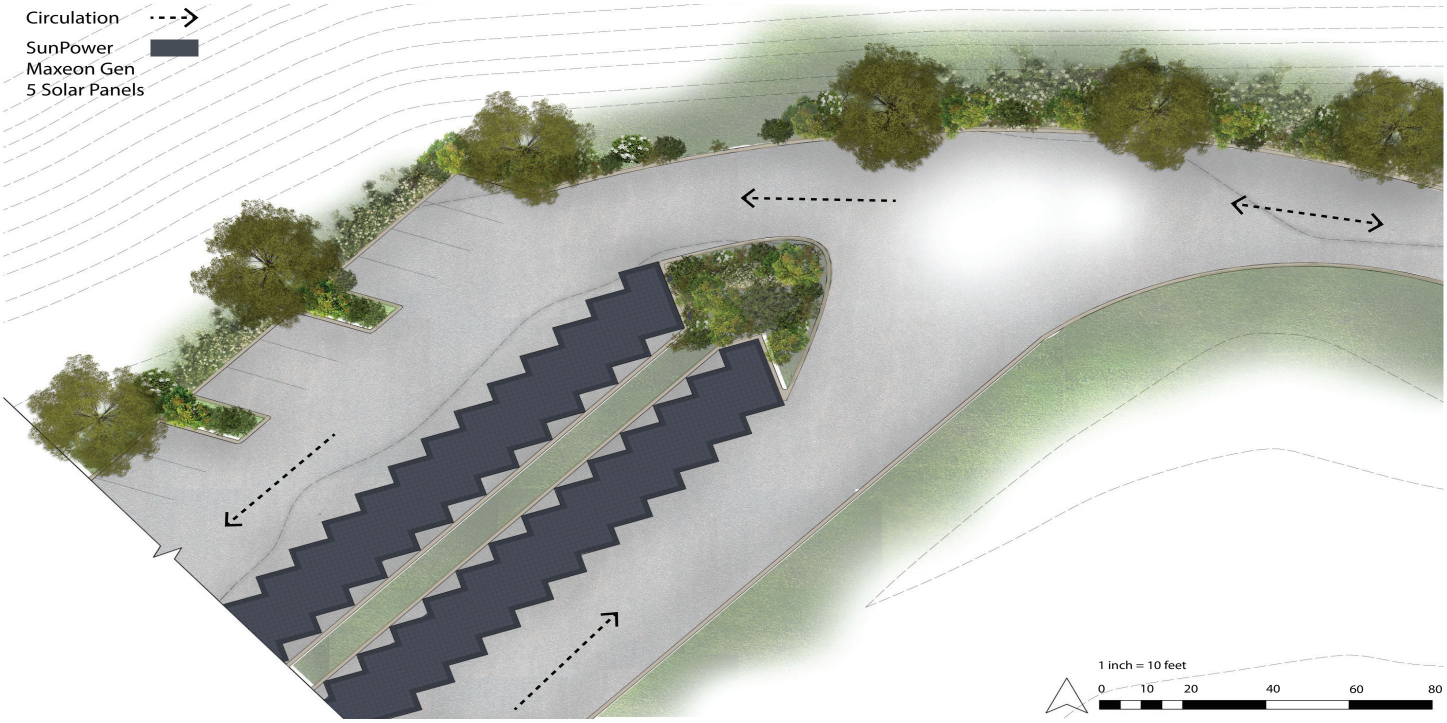


Figure 6. 2: Plan view of solar parking lot

i-Tree Analysis

Our building's efficiency goals are partially met with passive strategies that capitalize on the wooded location of the site. We quantified these benefits with an online modeling software called i-Tree Design. Based on research by the USDA Forest Service, i-Tree Design estimates benefits provided by individual trees including stormwater interception, energy savings, and air quality improvements. Deciduous trees shade the building in summer and let light sunlight pass through in winter. Locations of existing trees near the future building were modeled to help determine which trees should be preserved during construction. It is important to us to use native trees (boxelder, tulip popar, etc) wherever planting or re-planting is necessary. The optimized tree placement model predicted yearly energy savings of 7,180 kW-hr and heat savings of 830 therms. Additionally, the modelled trees would intercept 22,200 gal of stormwater and sequester 26,500 lbs of CO2 each year. The yearly net total benefit from preserving these trees on the site would be $2,321.

iTree Average Annual Benefits (First Year)

Stormwater Services
$26
Air Quality Benefits
$43
Carbon Dioxide Sequestration
$564
Summer Energy Savings
$344
Winter Energy Savings
$1343

Total Energy Savings
$1687

Net Benefits
$2321

Figure 6. 3: iTree analysis graphic with preserved and planted trees

OpenStudio Analysis

The first iteration of our model, which consisted of 10 thermal zones with ideal air loads was based on ASHRAE 189.1-2009 standard construction sets, load profiles, and schedules, which resulted in a source EUI of 92.5 kBtu/ft2. This first iteration represents a standard, code compliant building and acts as our baseline model. The iterations following the baseline used various measures that were applied to this baseline to reduce energy consumption to achieve a source EUI target of less than 75 kBtu/ft2. The second iteration applied an efficient HVAC system to our model which consisted of 17 thermal zones and used a four pipe fan coil system as the HVAC system. Net zero energy design load profiles, and schedules were used in this iteration which resulted in a source EUI of 41.3 kBtu/ft2, which is about a 44.6% reduction from the baseline. Our next and final iteration focused on building envelope improvements. We increased the standard ASHRAE 189.1-2009 performances to an R-33 wall and R-40 roof system as well as increased the slab to an R-10. This reduced our site energy demand by 18.8% and brought our source EUI to 39.5 kBtu/ft2.

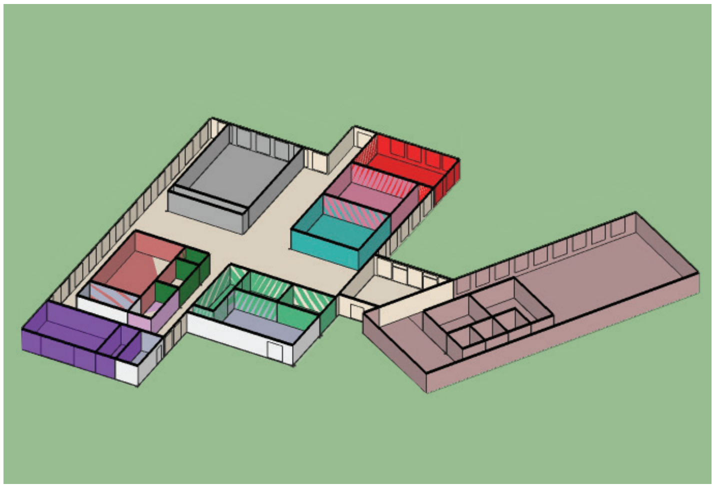


Figure 6. 4: OpenStudio Energy Analysis: 1st Floor Space Types

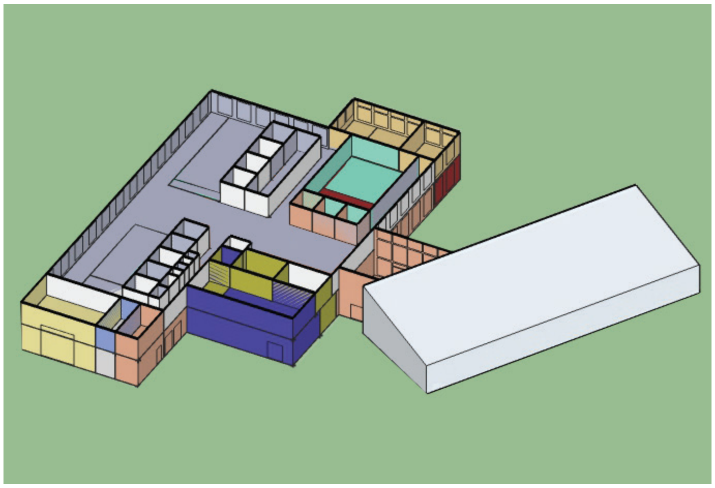


Figure 6. 5: OpenStudio Energy Analysis: 2nd Floor Space Types

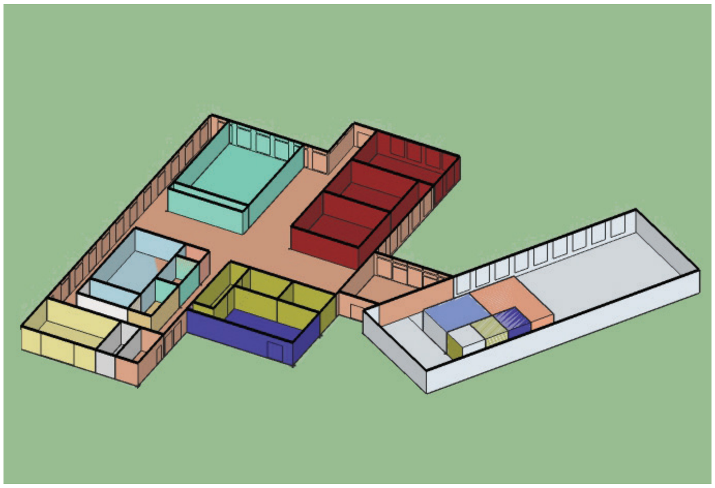


Figure 6. 6: OpenStudio Energy Analysis: 1st Floor Thermal Zones

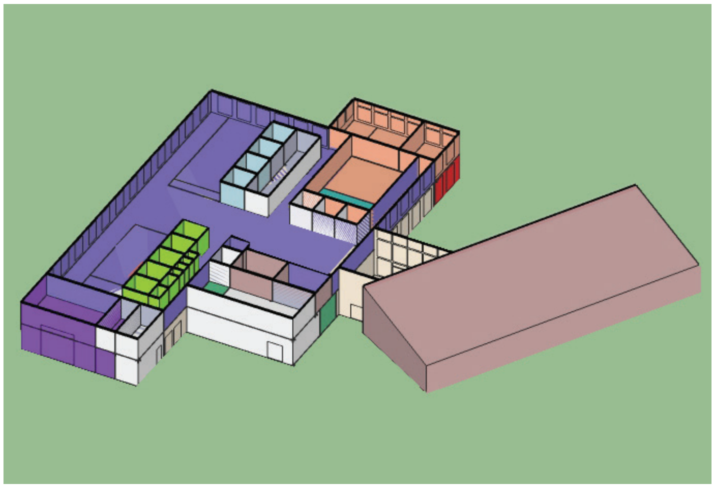


Figure 6. 7: OpenStudio Energy Analysis: 2nd Floor Thermal Zones

Building Envelope

WuFi Analysis

In order to evaluate the moisture durability of the Eco-Park Learning Center's envelope, we first used a german code compliance tool called Ubakus to test out several different construction options and look for condensation issues between the various layers. After deciding on an envelope in tandem with our budget and energy model, we translated that information into WUFI for a more detailed analysis of the moisture content within the envelope over time. We were able to see that although our wall builds up some moisture in the winter months, it dries out every summer and the moisture does not consistently build up on a year to year basis.

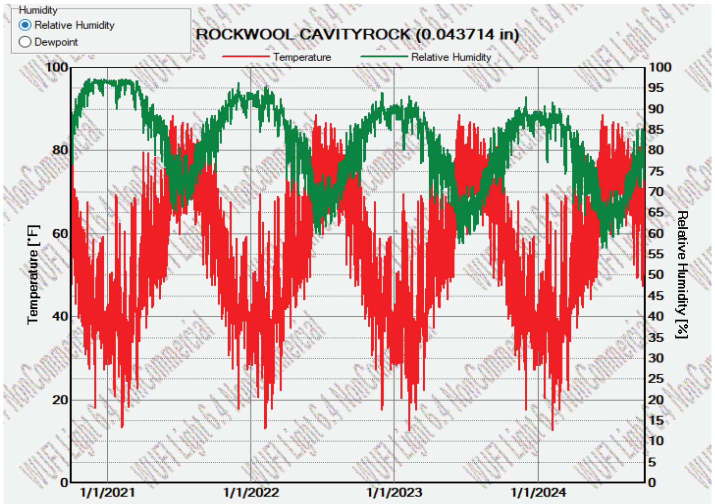


Figure 7. 1: WuFi® Analysis of Relative Humidity within Rockwool Insulation within CLT Wall Section

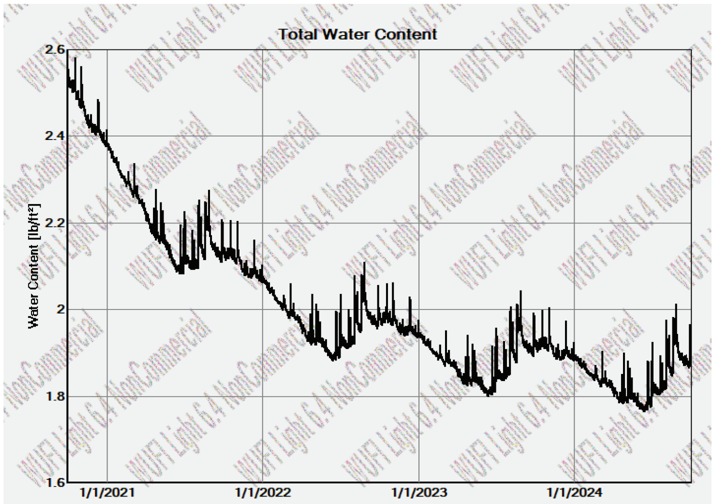


Figure 7. 2: WuFi® Analysis of total water content over a 4 year span within Rockwool Insulation within CLT Wall Section

Site Resiliency

In the expansion of the Prince William County Landfill, an existing stream was relocated and transformed into five acres of a newly constructed wetland. This wetland features 3,800 feet of new stream and serves important hydrologic functions. The placement of our building on top of a hill near the wetland ensures that flooding is unlikely to pose a threat to the building, even during a 500-year storm.

Figure 7. 3: Visualization of Boardwalk within the Wetlands

Food Production & Harvesting

Local food production is essential for communities in the event of a supply chain disruption, so our resiliency strategy within the context of a landfill includes a consideration of the relationship between food and waste. Outside the building sits over 1,000 sq. ft. of growing beds which are fertilized with compost produced by the building's composting toilets. These provide young students an early exposure to small scale agriculture and closed resource loops. The beds can supplement the food consumed by the building's employees with healthy options and surplus food can be readily donated to local schools. According to Rutgers New Jersey Agricultural Experiment Station, an expectable average of 0.5lb of produce per sq. ft. of bed space yields over 500lbs of vegetables and greens annually. Further, a core imperative of the Place Petal of the Living Building Challenge concerns the incorporation of urban agriculture.

Living Building Challenge: Place Petal

The Living Building Challenge expects projects to incorporate urban agriculture into their design. As we have seen during the recent COVID-19 crisis, the availability of local food becomes important in the event of a supply chain disruption, highlighting the importance of this resiliency strategy.

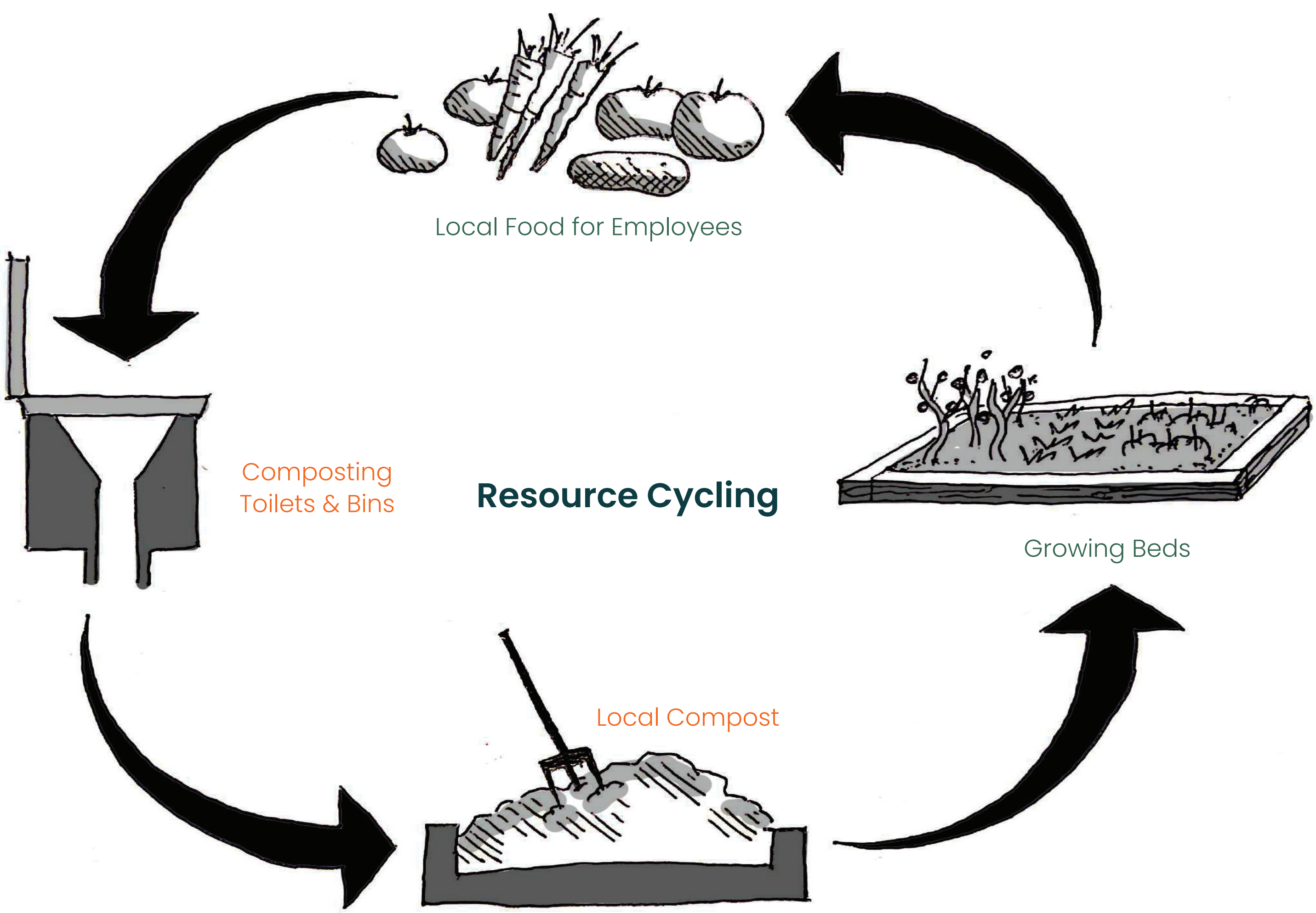


Figure 7. 4: Cyclic process of food production

Rainwater Harvesting

Inspired by the water petal within the Living Building Challenge, our building provides its own potable water strictly from rainwater harvesting which supplies the occupants year round. Each year, we are able to capture over 220,000 gallons from the bare section of our roof and around 96,000 gallons through permeable pavement in the courtyard, totaling 316,000 gallons of rainwater per year. The two main water uses of the Eco-Park Learning Center, serviced by rainwater collection, are potable water for domestic use and irrigation for the Green Roof.

Green Roof

The largest water demand for the Eco-Park Learning Center is irrigating the Green Roof. Storage for this water supply is provided by a 50,000 gallon water tank that is filled directly by harvested rainwater From the months of June through September, the green roof would require approximately 196,000 gallons of water (not accounting for seasonal summer rainfall). The water tank will have enough volume to supplement this summer season demand by holding spring rain water and collecting during summer storms. The leftover rainwater, roughly 125,000 gallons, can be diverted to supply the building.

Potable Water

The potable water tank can store up to 25,000 gallons of water at a time and connects to the RainFlo filtration system for treatment. Without toilets tied into the plumbing system, domestic water demand can function on this smaller storage tank. Annually, about 125,000 gallons of water will be available for domestic potable use.

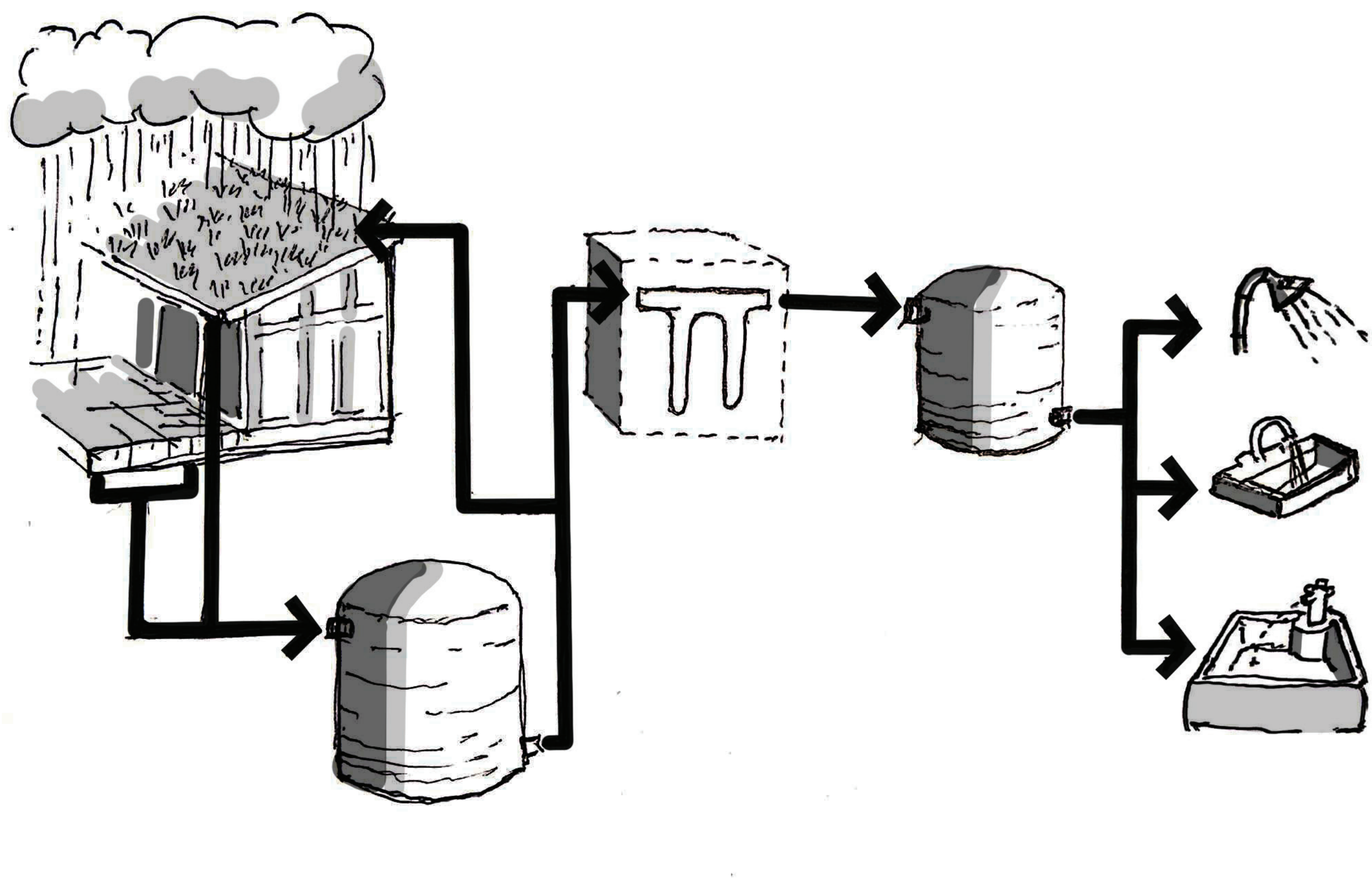


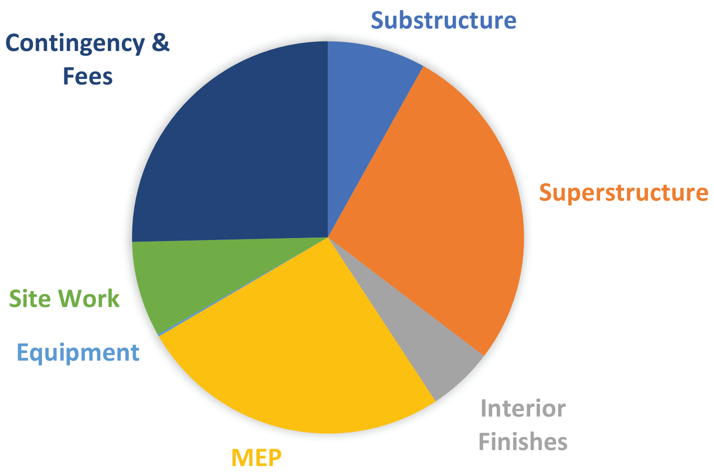
Figure 7. 5: Rainwater Harvesting System

Potential Income

With the additional rentable desks incorporated into our design, we are able to generate income to help offset the cost of capital needed to finance, operate, and maintain this property. This space can be utilised by other municipalities, sustainable tech startups, waste management entities, and research companies or universities. We performed a pro forma analysis and determined that maintaining 80% occupancy of the rentable desks, we can cover 45% of our costs. A detailed cost analysis can be found in our supplemental documents.

Cost Estimate

We created a cost estimate as a part of our iterative design process. During this process we compared the costs of various systems and weighed them with their benefits to determine what we would utilize in our building. One of the major components we analysed was the structural system. Even though a Glulam structural system is more costly, it has significantly less embodied carbon.



	Total Price	*Price/SF*
Substructure	$ 843,572	$ 27
Superstructure	$ 2,844,771	$ 91
Interior Finishes	$ 564,137	$ 18
MEP	$ 2,694,510	$ 86
Equipment	$ 18,487	$ 0.6
Site Work	$ 821,407	-
Contingency (20%)	$ 1,557,377	$ 50
Fees (14%)	$ 1,090,164	$ 35
Total:	**$ 10,434,423**	**$ 333**

Figure 8. 1: Cost breakdown of project

While designing the Eco-Park building we performed multiple cost-benefit analysis that continually informed the design. Several of the building systems and components used in the design, although more costly than traditional methods, help drastically reduce the overall operation and maintenance costs for the building. Some of these strategies include our mechanical systems used to condition the building as well as our glazing and shading systems.

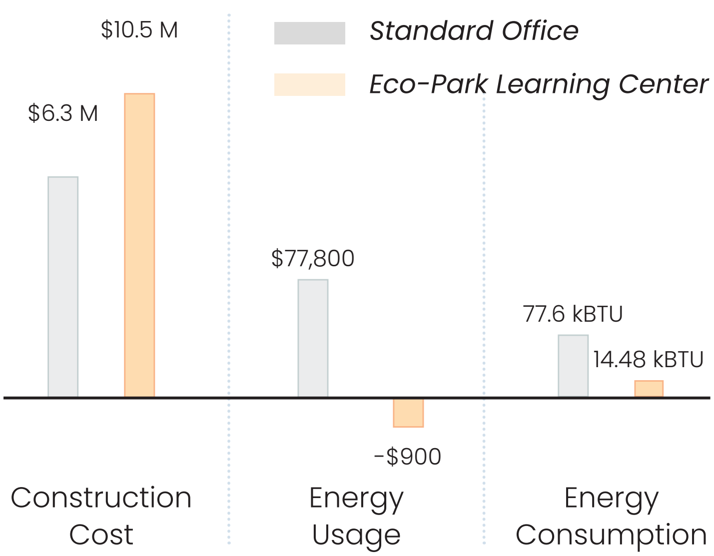


Figure 8. 2: Cost comparisons between standard office building vs. ours

This project originated from Prince William County's expressed desire to relocate the landfill staff and expand its municipal space. The county approached us with an idea to marry the functions of an office building with a community center that serves educational purposes. We spun this idea to create the Eco-Park Learning Center. In addition to the municipality's needs, we added extra office and lab space that will operate as rentable coworking space. With the project being located in a state of the art building as well as its association with an Extraordinary Environmental Enterprise, the opportunities are fit to attract other municipalities, sustainable tech startups, waste management entities, and research universities. Additionally, there are opportunities for universities and research entities to secure residency in the space to perform research and experimentation. To make this project work, we have partnered with a local waste management company to co-lead and help facilitate an educational program. Office space is available by the desk, and tenants will have access to the amenities provided by the building as well as the site.

Many design strategies found in the Eco-Park Learning Center are easily replicable in office buildings in various geographic locations and can be slightly modified to respond to various climates. The exterior CLT wall system panels, as well as the majority of our mechanical systems can be assembled off-site to ensure superior quality, productivity, as well as cost and labor efficiency.

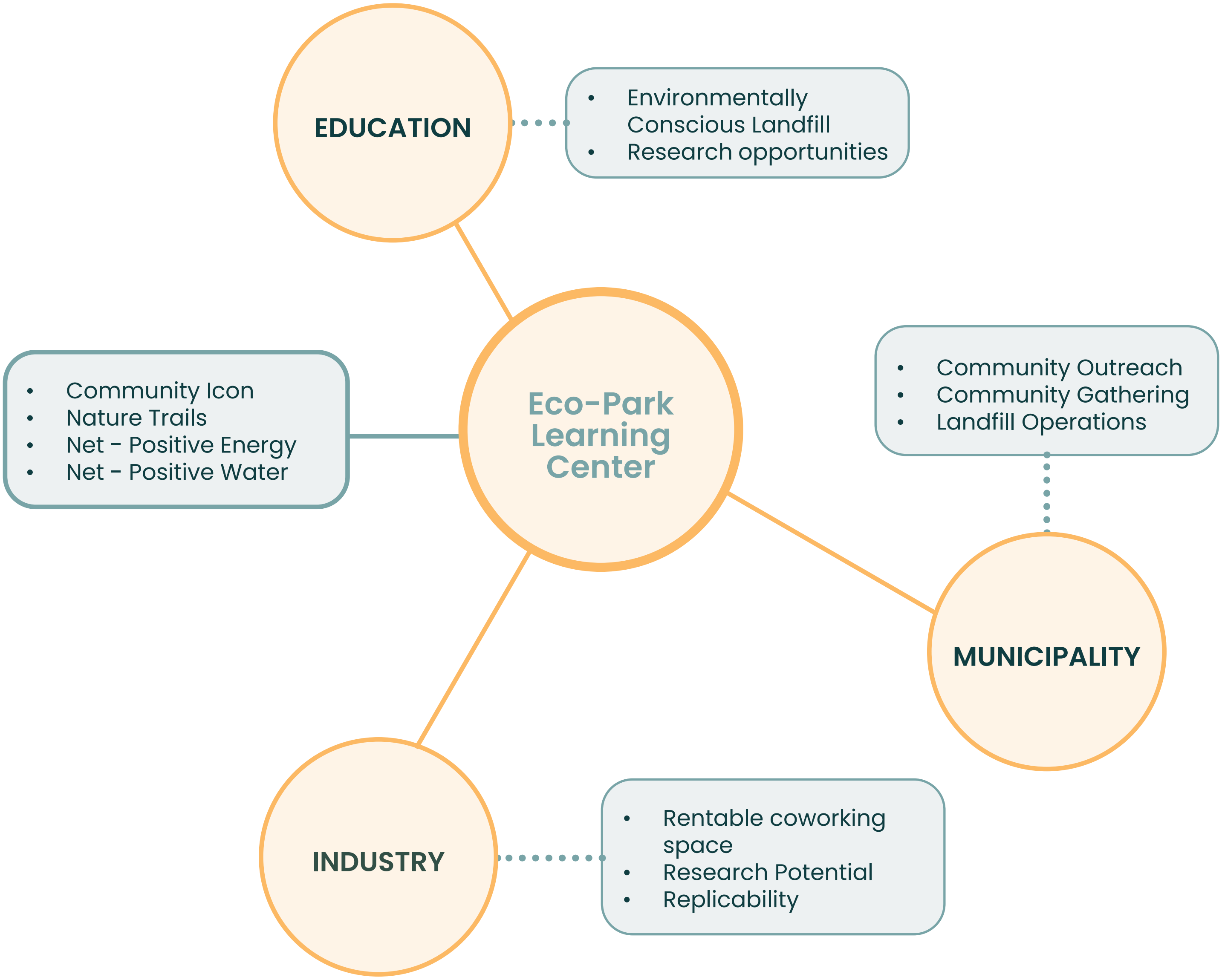


Figure 9. 1: Principle stakeholders in the Eco-Park Learning Center

Embodied Energy

Increasing the number of recycled and repurposed materials brings our total embodied energy down.
Average construction materials can take a long process to manufacture and get delivered to the job site, often leaving a large carbon footprint that is overlooked in the construction industry. To minimize Eco-Park's total carbon footprint, our team considered the materials that would normally be used and compared them to some greener alternatives. The comparison took into account a cost analysis, material performance such as structural criteria, and more than anything, cradle to grave embodied energy. Cradle to grave encompasses the embodied energy from harvesting to its end use in the building. The result of this analysis was a decision to revamp some major material decisions within the building. Major areas that were redesigned were structural elements (glu-lam vs steel), insulation (XPS vs rockwool), exterior finishes (earthblock vs ceramic brick) and interior finishes (polyester vs traditional).

Figure 10. 2: Embodied energy assesment

Smartwall

One of our driving missions for Eco-Park is to include education as a piece of the design to showcase a net-zero building and, critically, how it is achieved. To keep occupants engaged and educated in the process, we introduce an interactive "smart wall" to feature current energy production and use around the building. Data tracking and live updates allows users to compare daily, weekly, monthly and annual energy data to any time period in the building's lifetime. In addition to educating the public on net-zero strategies, the smart wall is beneficial to the building occupants in displaying their real time energy use. If the building happens to dip below net-zero, the occupants can adapt accordingly to adjust for the energy demand.

Figure 10. 3: Visualizing the Building Management System on the Smartwall, allowing occupants to understand the systems integration

Landscape Materials

Material choice is critical for our design expression, didactic pursuits and sustainability measures. Inspired by the Living Building Challenge core imperative of Responsible Materials, we have strived for sustainable and healthy material choices for each design detail. Recycled concrete chunks express the fractal aesthetic in pathways and courtyard spaces. Excavated soil from construction will be stored on-site to engage school children in the production of compressed earth blocks. The blocks can be engraved with student names and built into seating spaces along the woodland trails. We also plan to partner with the landfill to collect recycled glass through their new PurLandple Bin program and incorporate it into concrete aggregate, as an artificial sand material, and melted/formed into glass pavers. We can use recycled scaffolding to fashion a "fractal" screen along the sides of our boardwalk. This process can be automated with a CNC machine to produce an adequate screen density while maintaining a randomized organic structure. We believe that recycled and reclaimed materials can be incorporated into any project and can significantly reduce the embodied carbon in the finished product.

Figure 10. 4: Tying design to place with landscape materials

Saving a Stream

The tributary of Powells Creek is currently considered for piping by Prince William County in order to eliminate the floodplain and provide more space for landfilling. We know that floodplain soils sequester significant amounts of carbon, so the proposal of a bike trail along this stream provides an incentive to preserve it. Far in the future, this stream corridor could form the beautiful heart of a public park after the landfill reaches the end of its operational life. For the Living Building Challenge, It may be possible to achieve the Habitat Exchange imperative of the Place Petal by preserving this floodplain in agreement with the Institute's Living Habitat Exchange Program.

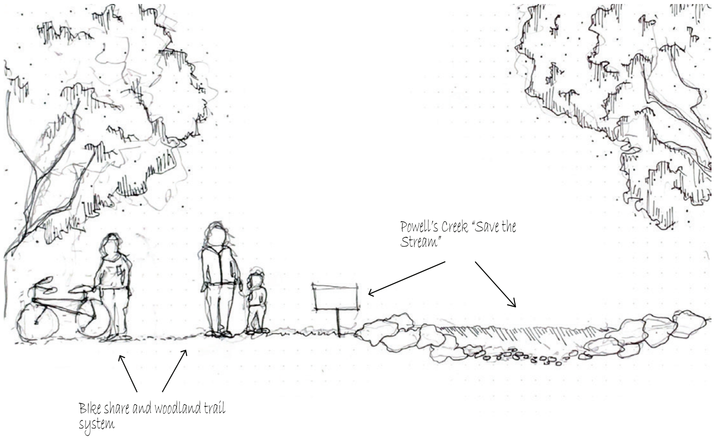
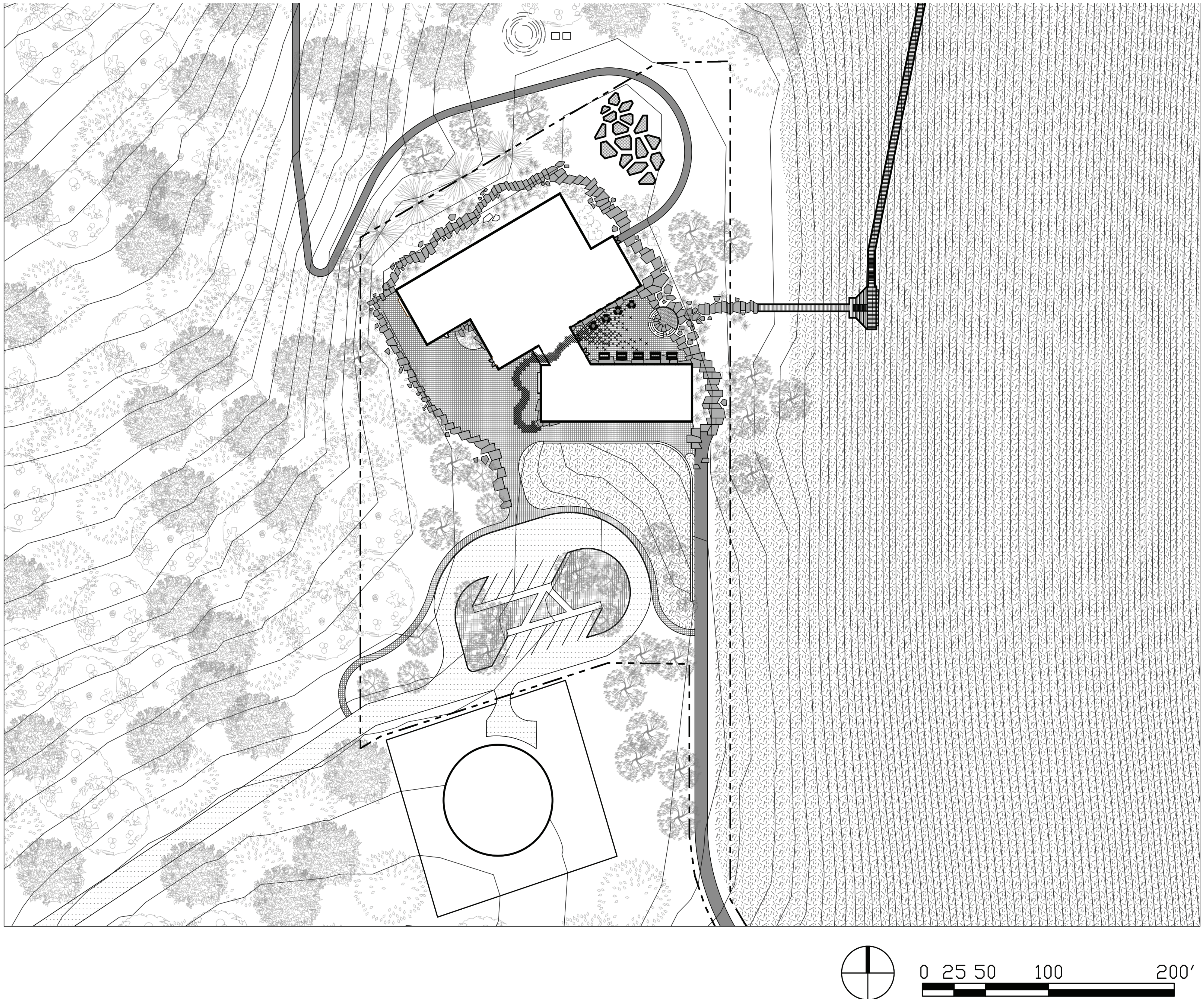
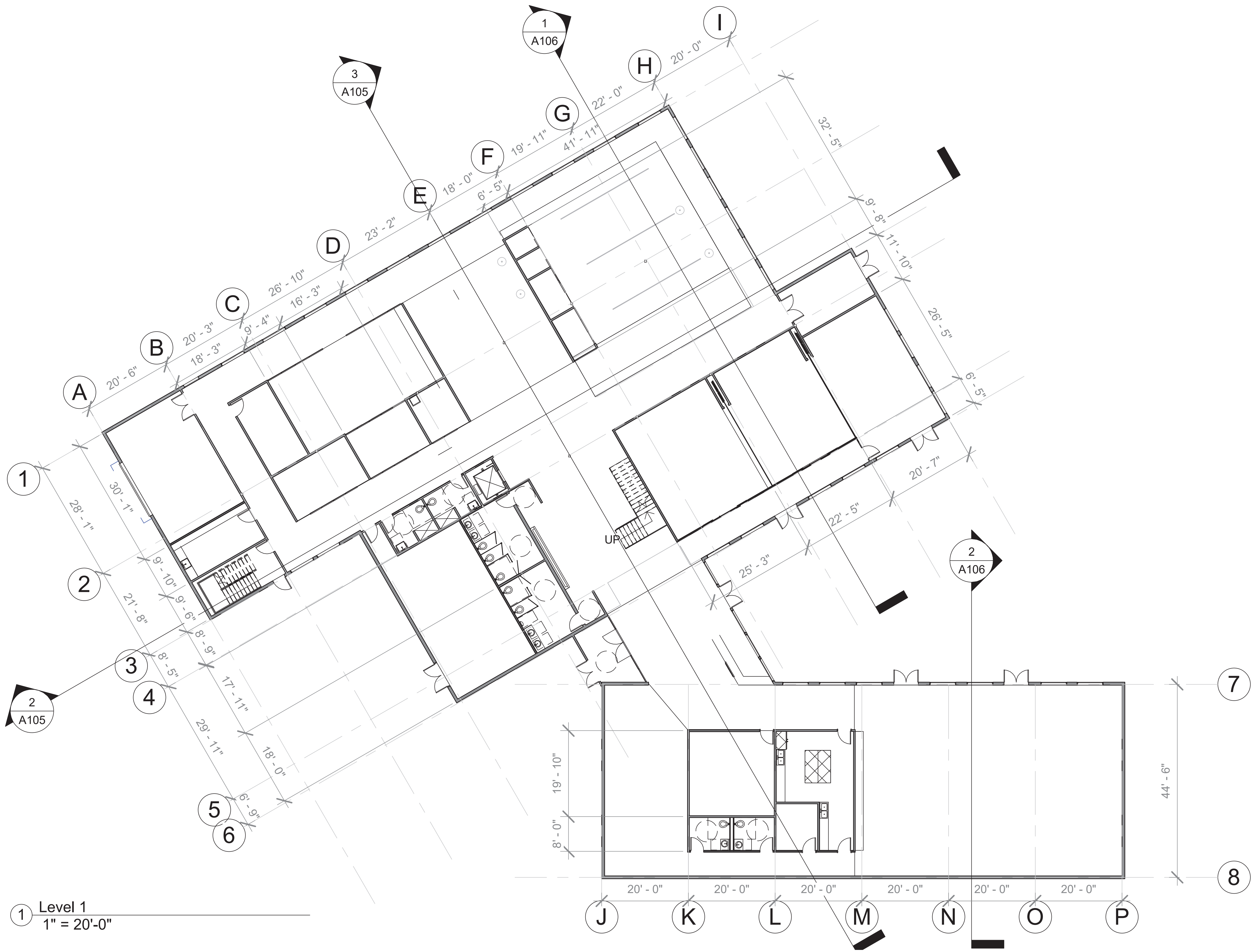


Figure 10. 5: Incentive to preserve tributary Powell's Creek

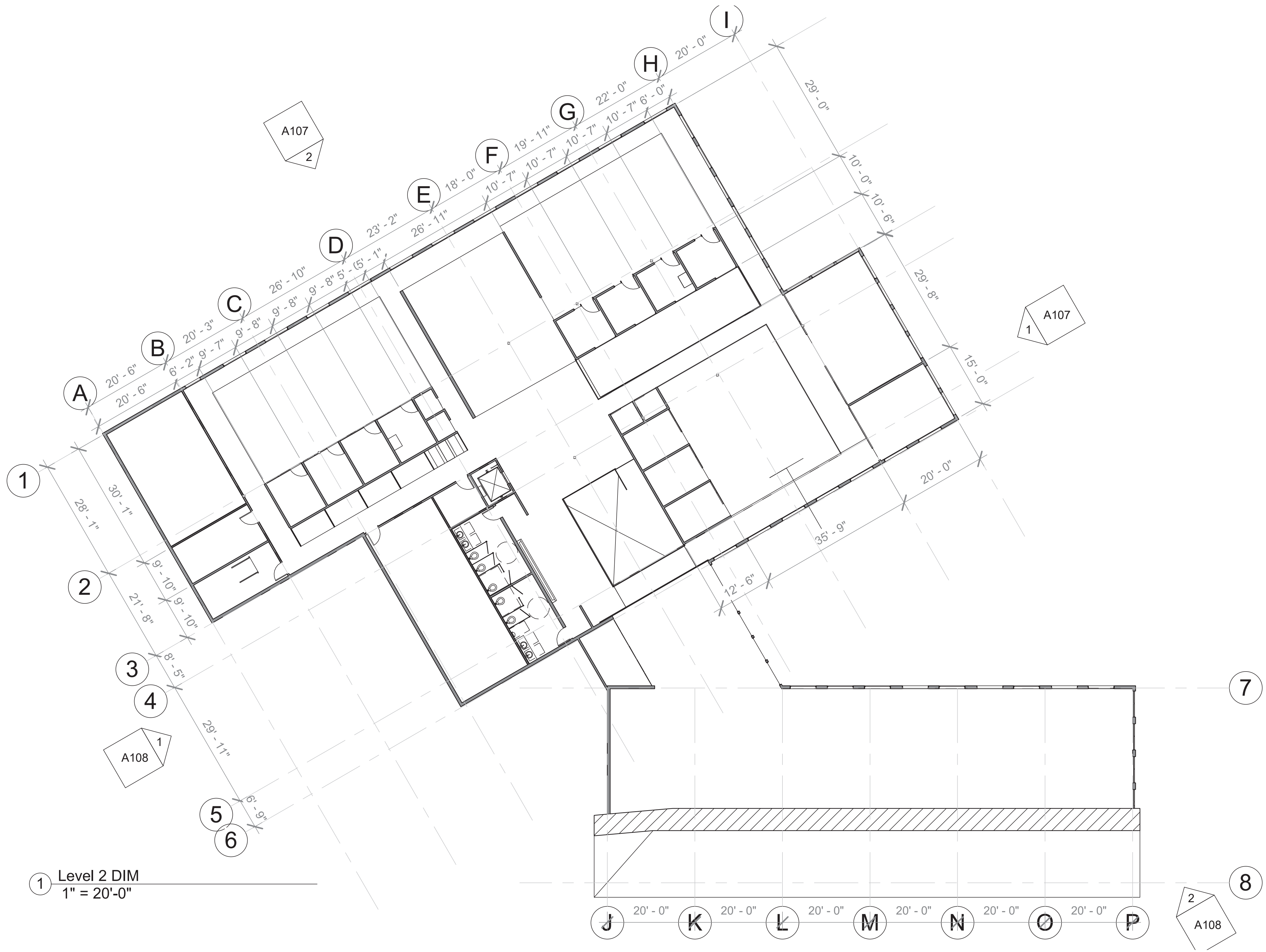


Site Plan

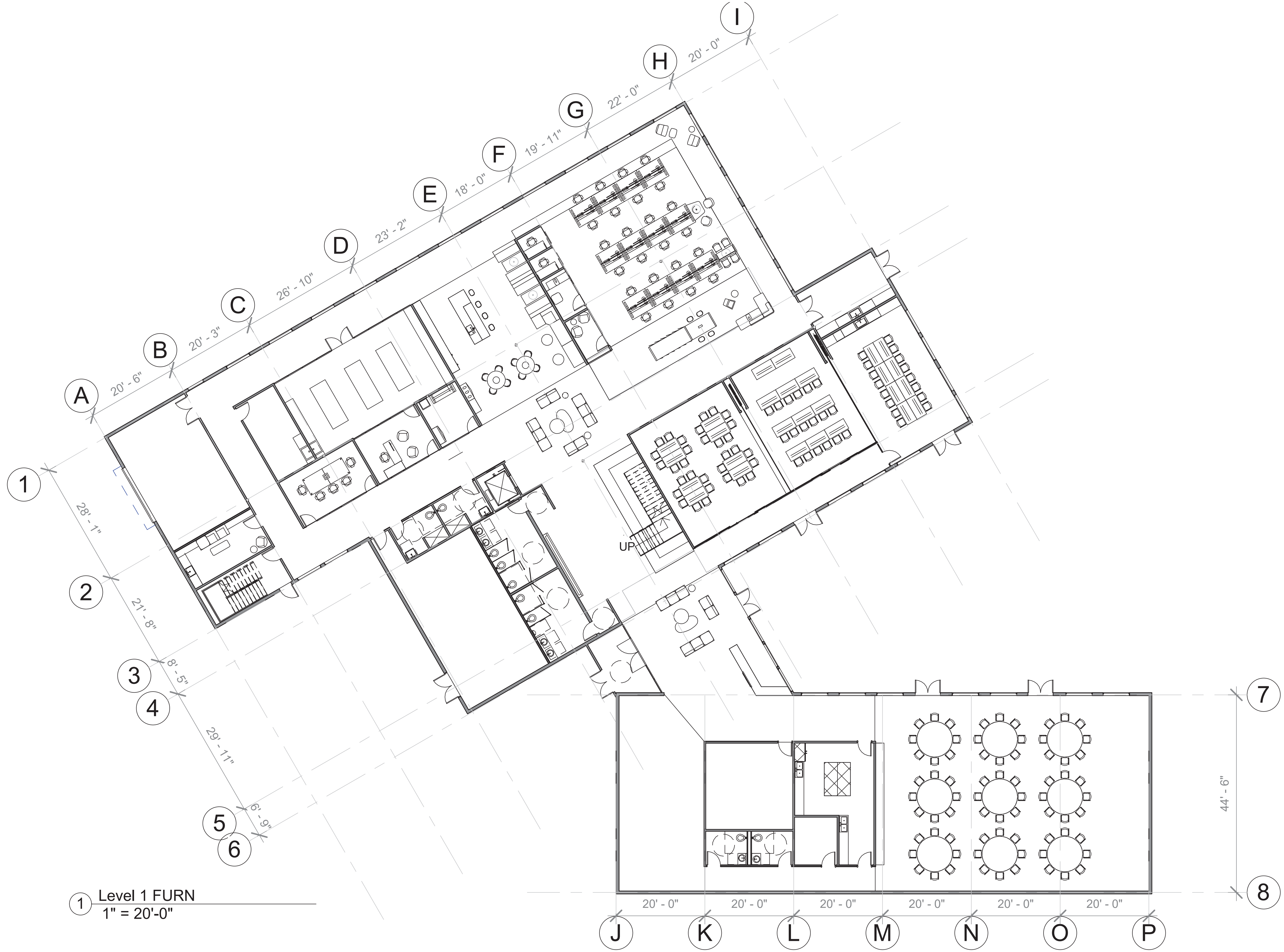


1 Level 1
1" = 20'-0"

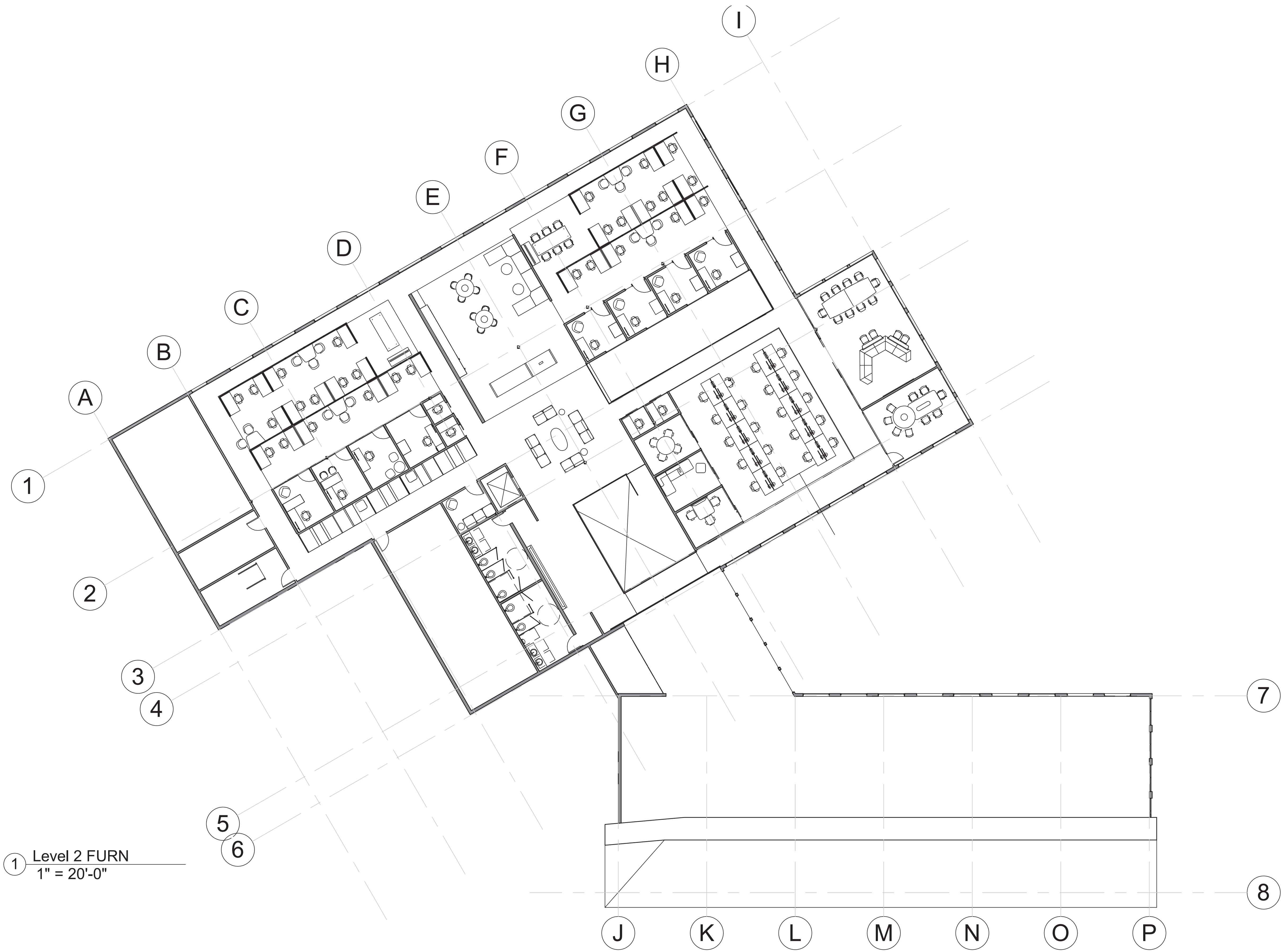
Level 1



Level 2

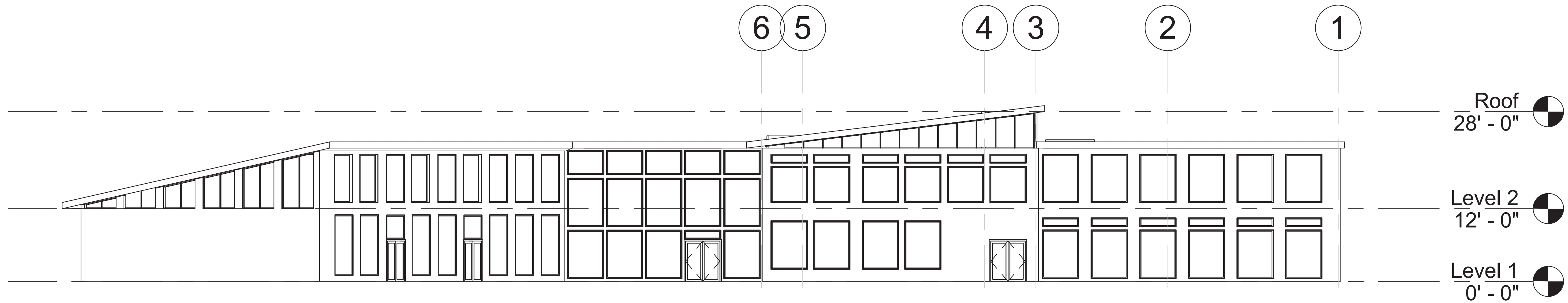


Level 1 w/ Furnishings

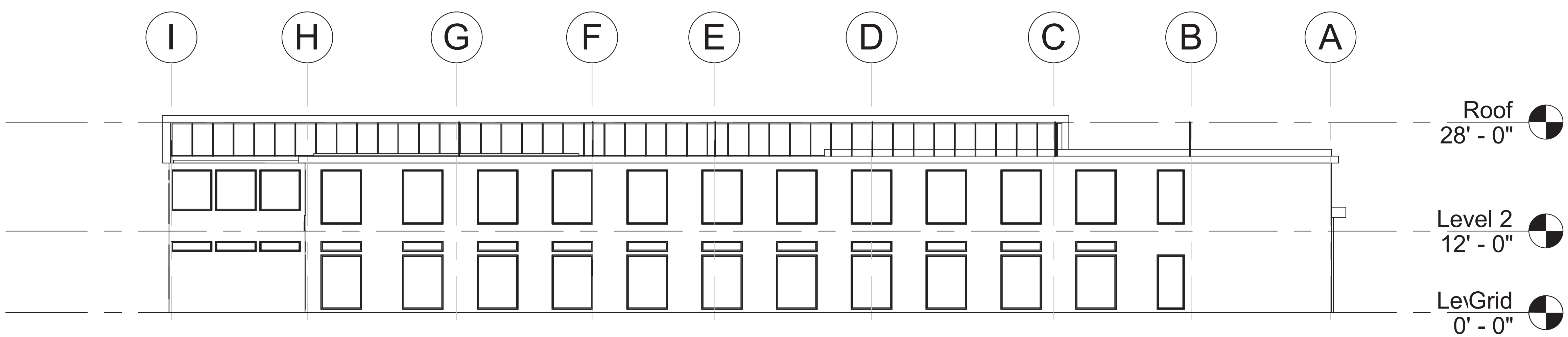


1 Level 2 FURN
1" = 20'-0"

Level 2 w/ Furnishings

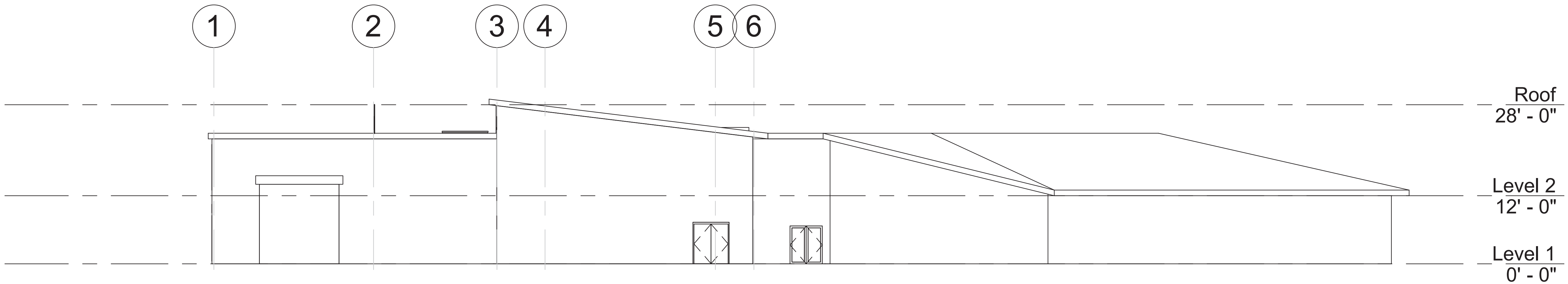


1 East Elevation
1" = 20'-0"



2 North Elevation
1" = 20'-0"

Elevations



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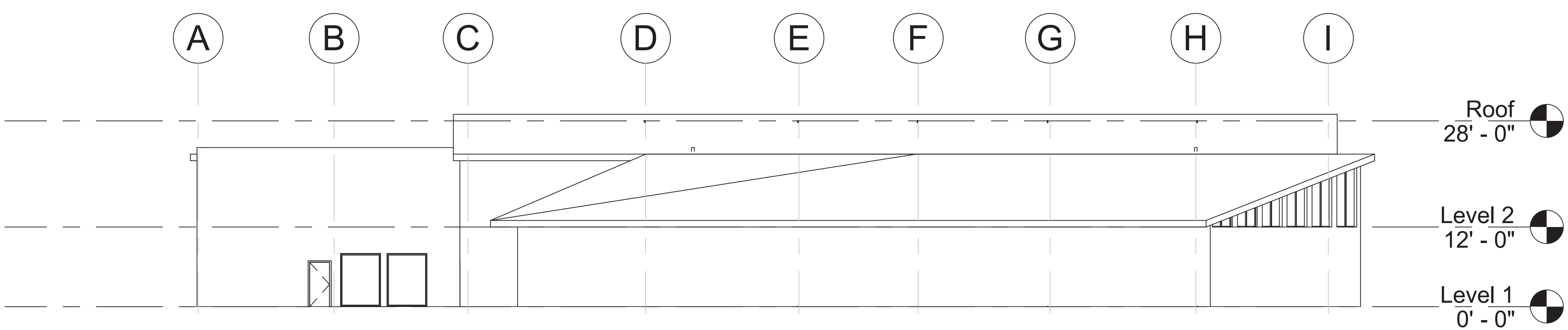
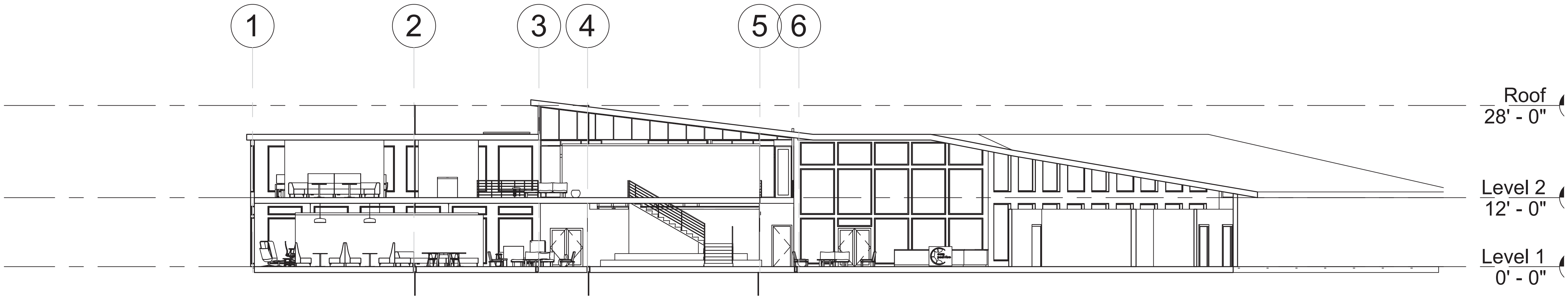
1" = 20'-0"

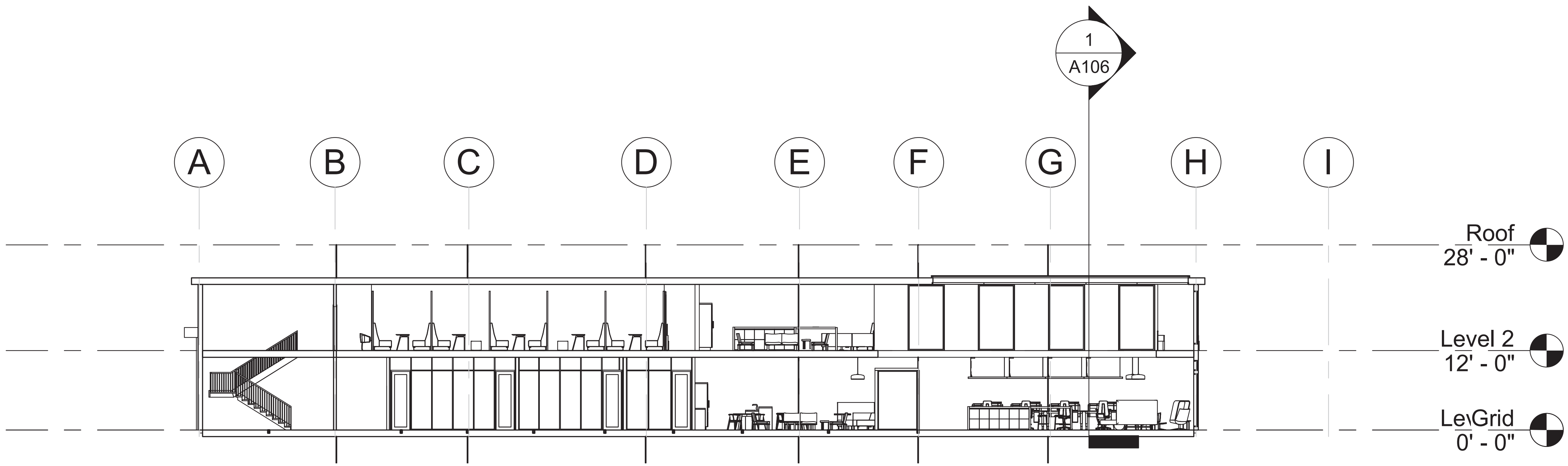


2 South Elevation
1" = 20'-0"

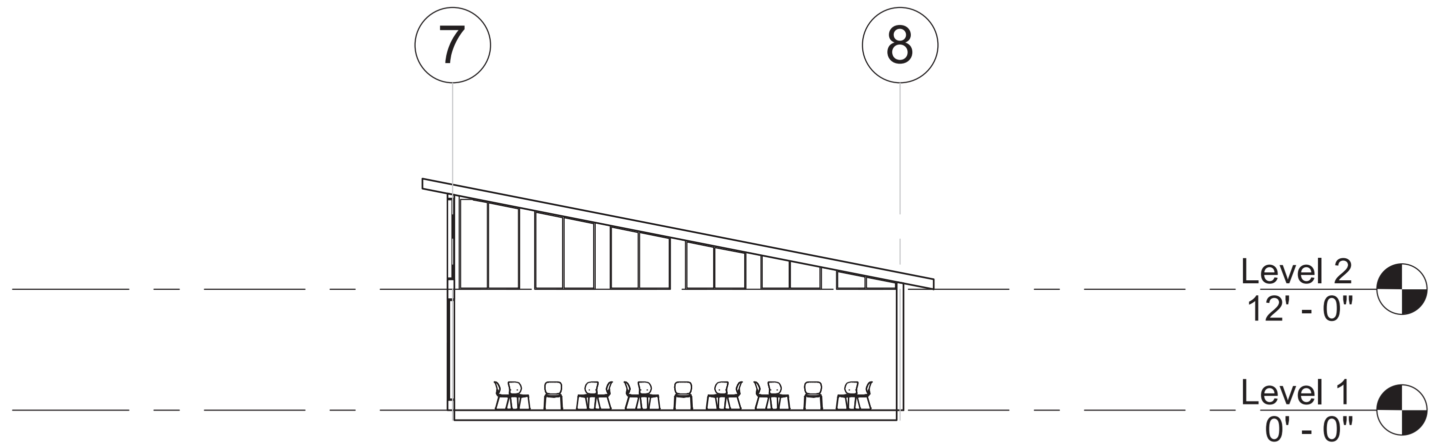
Elevations



3 Section 3
1" = 20'-0"



Sections



2 Section 4
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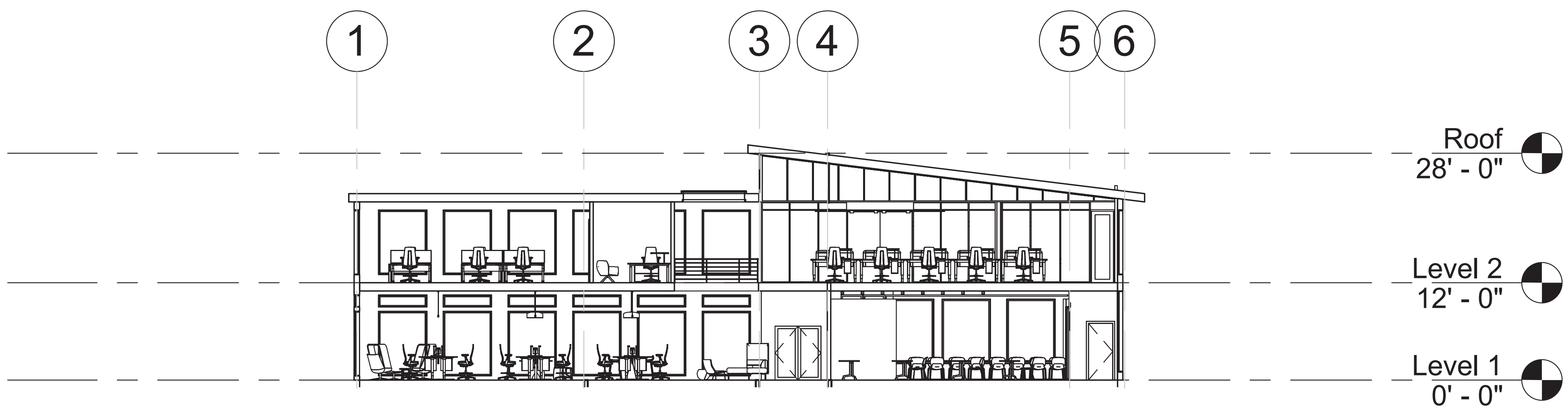


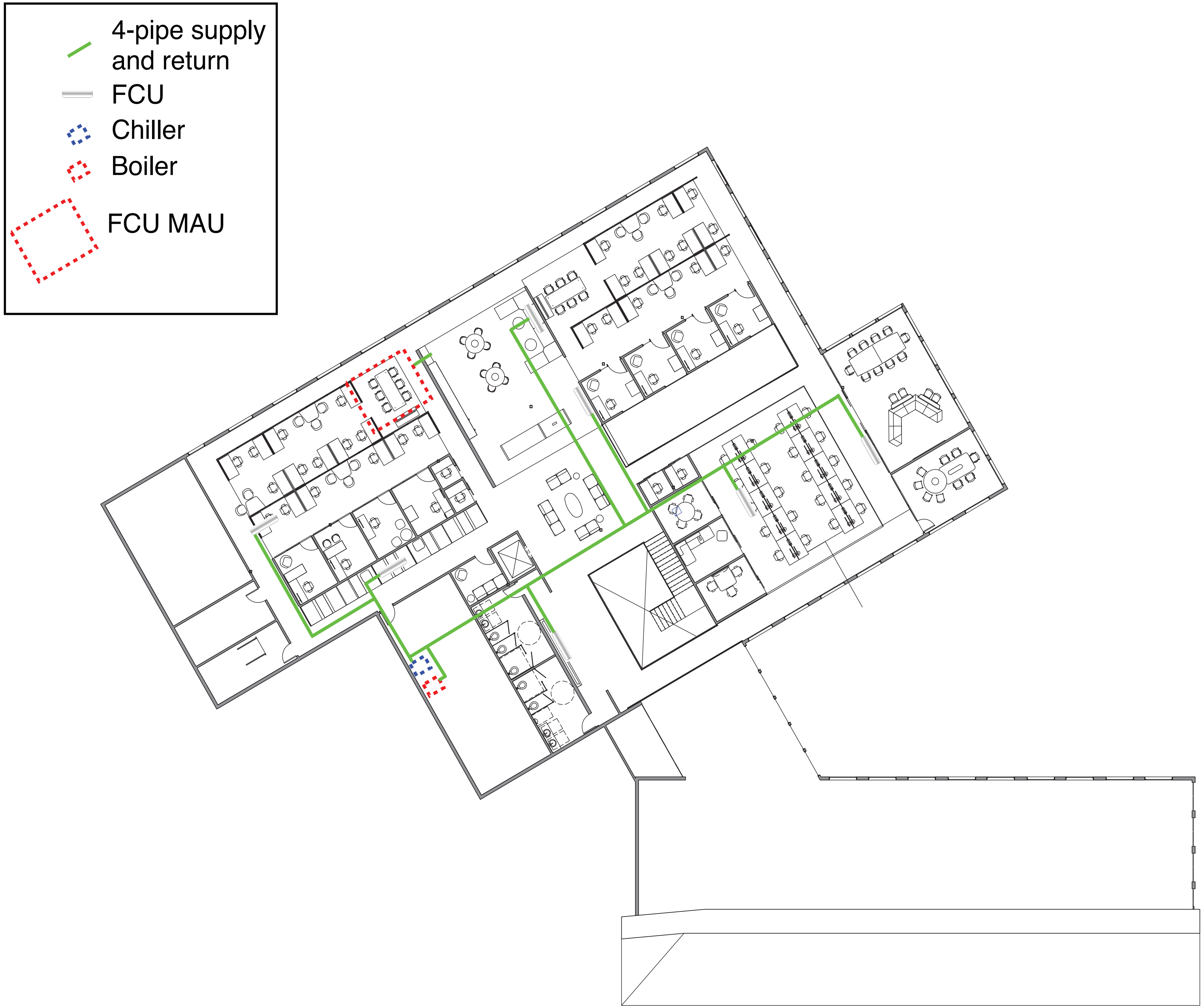
1 Section 5
1" = 20'-0"

Sections

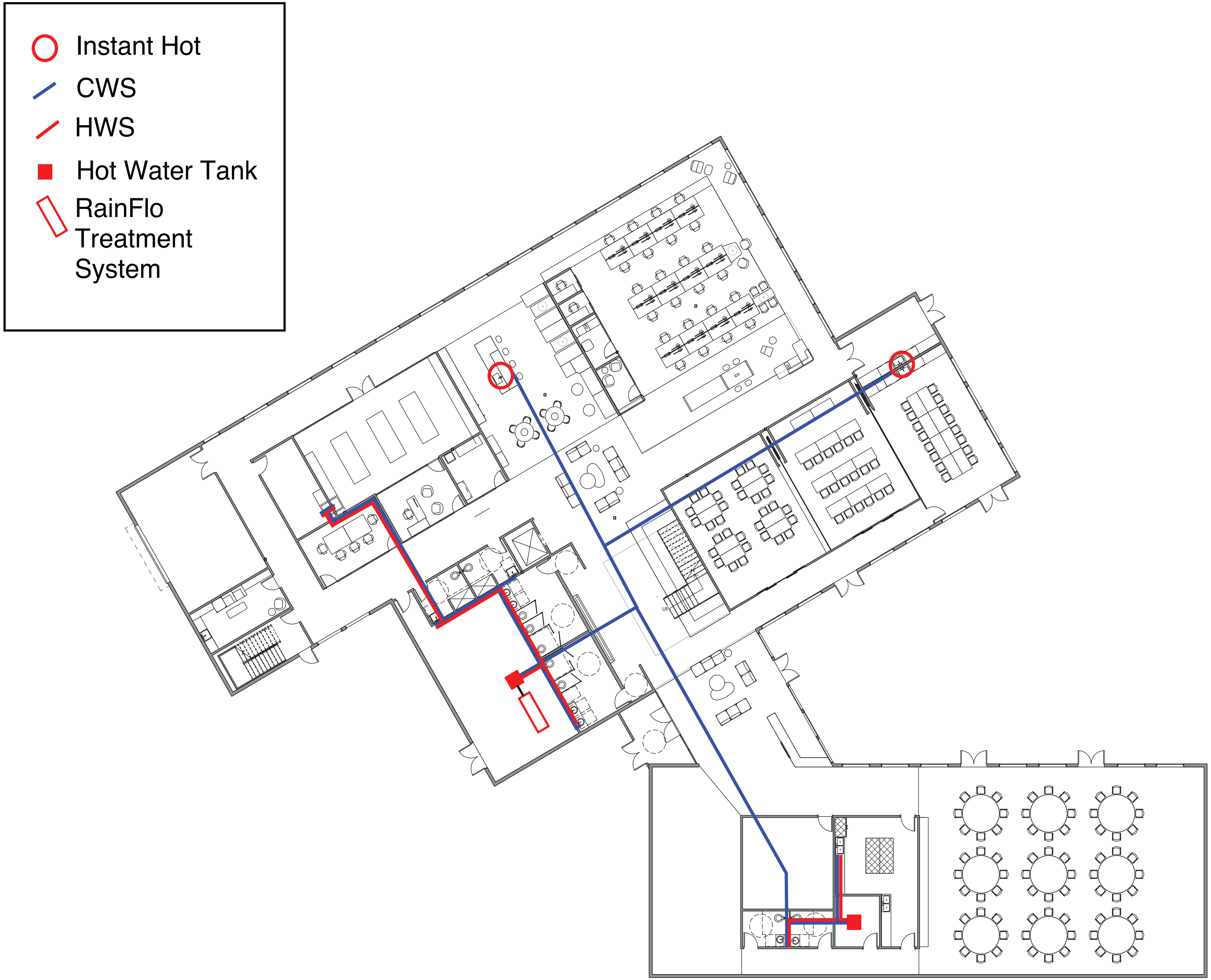
Level 1 - Mechanical Plans

Level 2 - Mechanical Plans

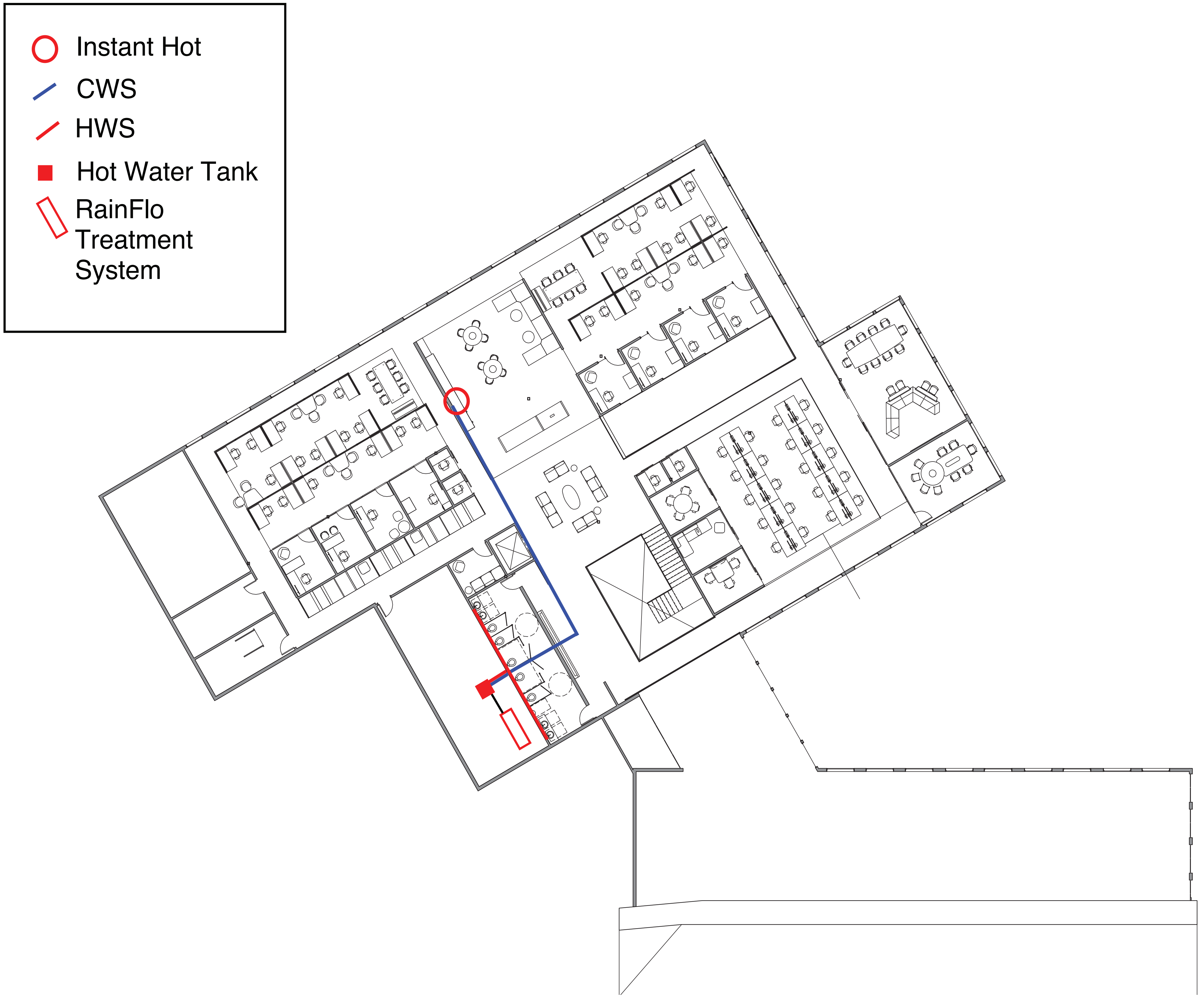
Level 1 - Hydronic Piping



Level 2 - Hydronic Piping



Level 1 - Plumbing



Level 2 - Plumbing

OpenStudio Results

Model Summary

Building Summary

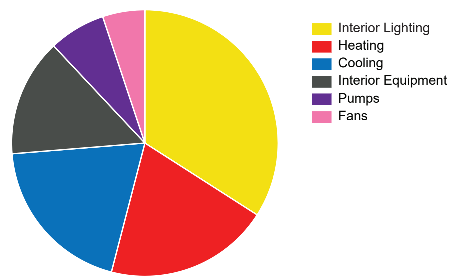
Data	Value
Building Name	first floor restrooms
Total Site Energy	491,709 kBtu
Total Building Area	33,957 ft^2
Total Site EUI	14.48 kBtu/ft^2
OpenStudio Standards Building Type	n/a

Weather Summary

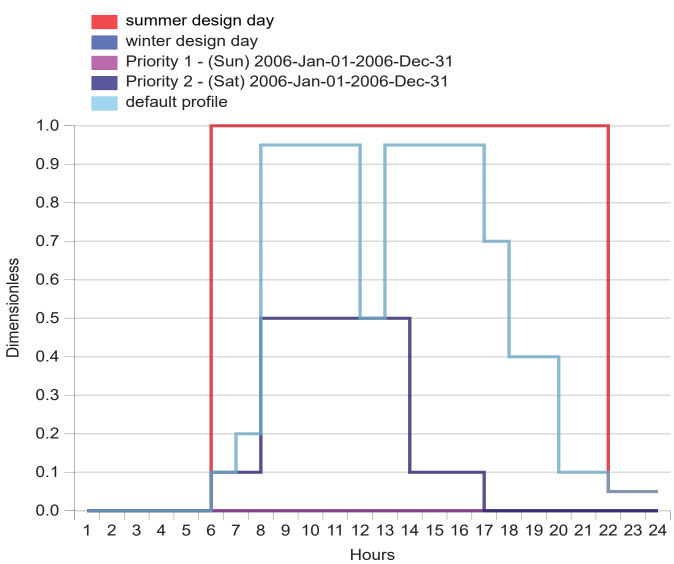
	Value
Weather File	Manassas Muni Awos VA USA TMY3 WMO#=724036
Latitude	38.72
Longitude	-77.5
Elevation	194 ft
Time Zone	-5.0
North Axis Angle	0.00
ASHRAE Climate Zone	

Annual Overview

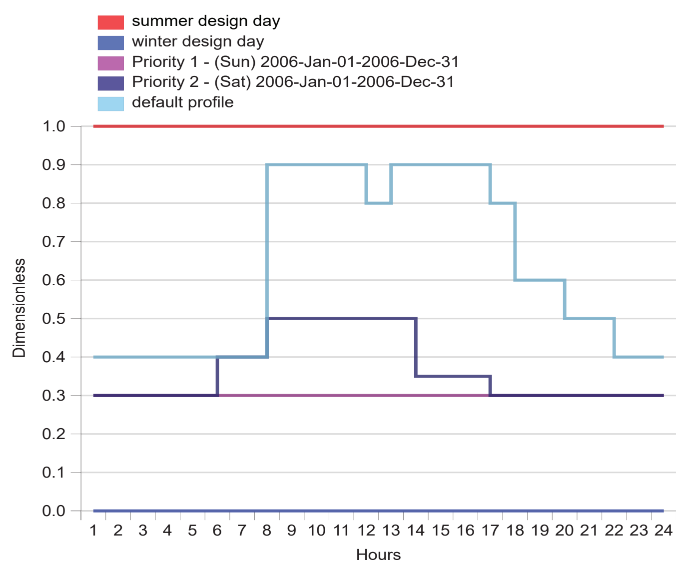
End Use - view table



Medium Office Bldg Occ

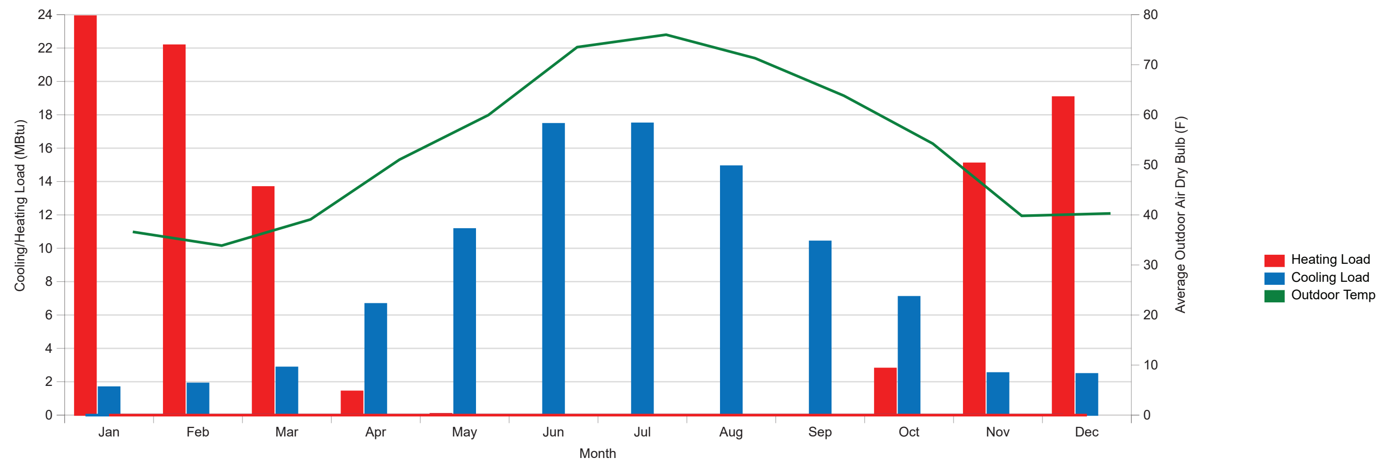


Medium Office Bldg Equip



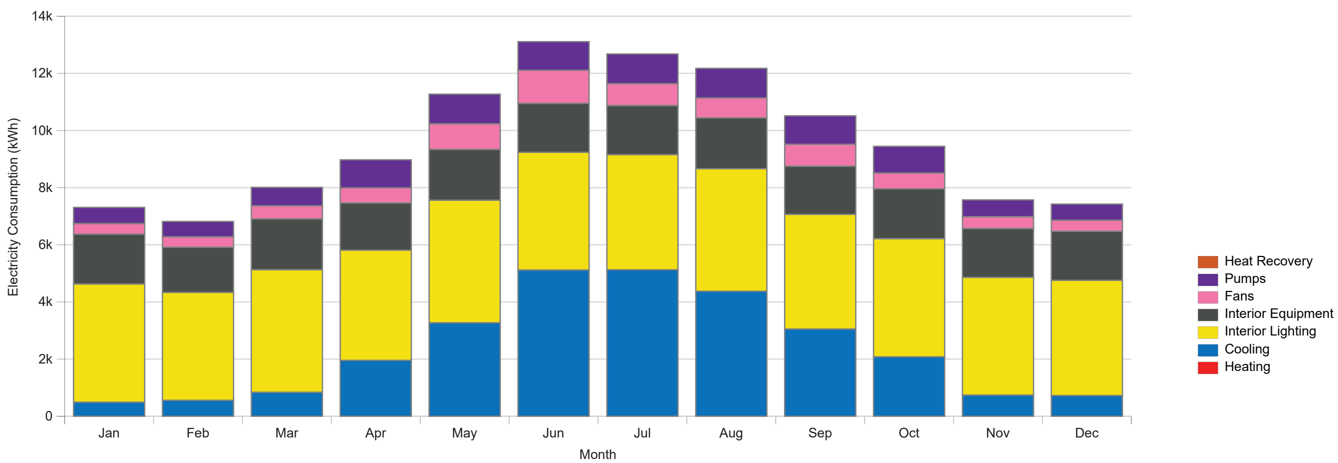
HVAC Load Profiles

Monthly Load Profiles - view table



Monthly Overview

Electricity Consumption (kWh) - view table



Site and Source Summary

Site and Source Energy

	Total Energy (kBtu)	Energy Per Total Building Area (kBtu/ft^2)	Energy Per Conditioned Building Area (kBtu/ft^2)
Total Site Energy	491708.6	14.5	14.5
Net Site Energy	491708.6	14.5	14.5
Total Source Energy	1352554.0	39.8	39.8
Net Source Energy	1352554.0	39.8	39.8