EcoFLow

Sustainable and Smart Stormwater Solutions for Future Generations of South Florida

Florida International University
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Abstract

The Florida International University Modesto Maidique Campus (FIU-MMC) is an urban environment that is constantly developing, making it an ideal location for the implementation of sustainable stormwater solutions. Located in the South Florida region, FIU-MMC constantly faces issues regarding stormwater management due to climate change, the low ground elevation, frequent storms, and natural habitat loss. South Florida is subject to extreme environmental stressors, such as flooding, associated with the effects of climate change and rapid urban development in the early 1900's, thus its dense population and infrastructure are highly vulnerable. To address extreme flooding conditions and associated water quality issues, EcoFLow couples existing conventional stormwater systems and green infrastructure alternatives to preserve ecosystems and provide a wide array of benefits to people and wildlife. Not only is EcoFLow proposing the implementation of sustainable and smart stormwater technology, but also restoring historical Florida ecosystems with the creation of artificial wetlands across campus. Using the existing features of the campus, EcoFLow creates an interconnected system that mitigates flooding and stormwater pollution, improves air quality, and conserves water while adding recreational, educational, and aesthetic value to the campus. EcoFLow's proposal focuses on innovative and cost-effective solutions that will benefit FIU-MMC while serving as a model, along with the Campus Master Plan, for green infrastructure practices for FIU's growing and vulnerable community.

I. Introduction

The Florida International University Modesto Maidique Campus (FIU-MMC) is located in the city of Miami, FL, a densely populated area with an extremely unique environment that faces crucial challenges due to development, nutrient pollution, invasive species, and sea-level rise (The Everglades Foundation). The Everglades National Park, which consists of free-flowing wetlands, once covered land extending from Orlando to the southern end of the Florida peninsula but was reduced 50% in size due to urban development and agricultural expansion (Ingebritsen, et al., 95). In 2000, the Comprehensive Everglades Restoration Plan (CERP) was authorized by Congress to provide protection to the South Florida ecosystem and invest more than $10.5 billion into the largest hydrologic restoration project in the history of the U.S. (National Parks Service). FIU-MMC lies roughly seven miles east of the Everglades, therefore incorporating ideas from the CERP into FIU's plans for improving its stormwater management system and restoring natural habitats is extremely important for FIU's and South Florida's future.

FIU-MMC's goals for future stormwater management improvements include providing a system that incorporates sustainable practices, protection of property, and maintenance of groundwater water quality, which are further described in the Campus Master Plan 2010-2020. After careful research, planning, and design, EcoFLow has developed a comprehensive proposal consisting of innovative green infrastructure alternatives that address FIU-MMC's goals for improving water quality, promoting water conservation and reuse, maximizing storage capacity of sub-basins, as well as tackling the regional goal of restoring and protecting South Florida's natural habitats and hydrological systems.

II. The Problem and Challenge

At an average elevation of six feet, South Florida is highly susceptible to flooding due to rising sea levels and frequent storms. According to FEMA Flood Insurance Rate Maps 12086C0269L and 12086C0288L, the majority of the FIU-MMC campus is subject to flooding by the 1% annual chance flood. The existing drainage system of the FIU-MMC campus is insufficient for future large storms. Currently, the water bodies on campus are not interconnected, resulting in an unbalanced system and drainage problems. Some existing drainage structures do not have excess capacity for future development.

Site Description

FIU-MMC, located in unincorporated Miami-Dade County, covers approximately 353 acres. The land use is estimated to be 73% impervious and 27% pervious land. The current stormwater management system consists of exfiltration trenches, positive drainage systems, overland flow, onsite lakes, and infiltration. After speaking with Stuart Grant, the Facilities Planning Coordinator at FIU-MMC, he confirmed that mostly all stormwater runoff is handled through catch basins and exfiltration trenches. According to the National Resources Conservation Service (NRCS), there are three types of soils present at FIU-MMC; udorthents, hallandale fine sand, and urban land (Natural Resources Conservation Service). According to percolation tests conducted in the past, the soil drainage of FIU-MMC is satisfactory except in locations where layers of muck have been buried due to early development of the campus (Grant). EcoFLow obtained scaled aerial photographs from the Florida Department of Transportation (FDOT) and used Microstation to calculate the areas and volumes of six existing lakes on FIU-MMC. The six lakes make up a total area of 3.60 acres and total volume of 18 acre-ft, assuming an average depth of five feet.

Site Problem and Challenge

Existing features of the FIU-MMC campus and stormwater management systems do not incorporate green infrastructure practices. Of the existing stormwater management systems, the majority of the parking lots and portions of the roadways use exfiltration trench systems to convey stormwater. Stormwater runoff from building roofs, plazas, and the arena is conveyed through gravity-driven drainage systems that discharge to lakes on campus. The 15 lakes on MMC are not interconnected, resulting in the no-full utilization of storage in some lakes while producing flooding around some other lakes.

FIU's Campus Master Plan

The 2010-2020 Campus Master Plan includes plans and standards for improving existing stormwater management systems, implementing environmentally-friendly systems to conserve water and energy on existing structures, and creating green landscapes on all FIU campuses to provide botanical and environmental educational values to the campus. Of the goals outlined in the Master Plan, those pertaining to EcoFLow's proposed solutions are:

- Retrofit existing campus buildings with water-saving devices
- Interconnect water bodies to maximize capacity
- Improve the integration of existing and new storm water retention areas as landscape enhancement elements
- Reduce the use of potable water for landscape irrigation by expanding the use of harvested greywater
- Protect natural stormwater management and hydrological areas from contamination
- Pervious walkways of 15 ft. width with canopy shading
- Water quality enhancements
- Meet water quality standards for discharging into canals
- Relocate and incorporate existing valuable plant material in the areas of future construction and development
- Create landscaped areas, gardens, and natural habitats to promote conservation

Throughout the planning and design phases of the project, EcoFLow used the Master Plan as a reference to ensure all proposed alternatives met the goals stated above.

III. EcoFLow's Proposed Alternatives

In order to address all the stormwater difficulties that FIU-MMC faces and prepare for future storms, EcoFLow has proposed seven alternatives that adhere to green infrastructure practices. Detailed descriptions of each alternative, including design considerations and calculations performed, are described throughout this section.

Artificial Wetlands

Wetlands serve many purposes that can benefit FIU-MMC, including water quality improvements, storage, habitat restoration, biological productivity, recreational use, and aesthetic value. EcoFLow has proposed the creation of 11 artificial wetlands across FIU-MMC, with average depths of 2.5 feet, sloped sides (2H:1V), a total area of roughly 33 acres, and a total capacity of about 3.4 million ft^3. Because some of the proposed wetlands are located in areas of high pedestrian traffic, unique elevated walkways will be constructed above the wetlands for pedestrians to travel safely across campus. The walkways will be 15 feet wide and will have 4-foot high railings for safety. Class II structural concrete will be used for the substructure of the walkways (FDOT Structures Design Guidelines, 1-15) while pervious concrete will be used for the deck of the walkways.

Stormwater will enter the wetlands directly from runoff, a pipe connection from an existing drainage structure, or through the proposed remotely-operated and automated siphon system, which is described in more detail on page 5. Prior to larger storm events, the siphon system will be used to drain certain wetlands or lakes, providing extra water storage for the storm event. Because most of the wetlands and lakes will be interconnected, the drainage will be in cascade from high elevation to low elevation. The terminal discharge of FIU-MMC will be to the existing C-4 canal, located to the north of the campus. To comply with SFWMD and Miami-Dade County's Division of Environmental Resources Management (DERM) water quality criteria, EcoFLow recommends that prior to any discharge of water directly from a wetland or lake to the canal, the water must first be filtered to meet water quality requirements. The main functions of the proposed wetlands on FIU-MMC are to remove pollutants from stormwater runoff and maintain an interconnected and self-contained system that does not rely on discharging to the canal.

Based on analysis of the various soil types present on FIU-MMC and characteristics of natural Florida habitats, EcoFLow chose specific native flora for each of the artificial wetlands to properly replicate three historical South Florida habitats. By incorporating these habitats, EcoFLow is promoting restoration of South Florida's natural wetland habitats that existed in the area prior to development. The different ecological characteristics of each wetland will also serve educational purposes for FIU students and visitors. Proposed habitats and corresponding native flora are:

> *Marl Prairie* - Located in areas consisting of udorthent soil. A flatland with marl over limestone substrate that is seasonally inundated. (Hypericum brachyphyllum, Muhlenbergia capillaris, Flaveria linearis, Cyperus odoratus, and Cladium jamaicense)
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> *Bayhead* - Located in areas consisting of urban land soil with organic matter. A wetland with peat substrate that is usually saturated and occasionally inundated. (Myrica cerifera, Psilotum nudum, Canna flaccida, Salix caroliniana, Ilex cassine, and Sagittaria lancifolia)
>
> *Strand Swamp* - Located in areas consisting of hallandale fine sands. A broad, shallow channel with peat over mineral substrate that is seasonally inundated and has flowing water. (Myrsine cubana, Pontederia cordata, Taxodium distichum, Acer rubrum, sabal palmetto, Annona glabra, and Persea palustris)

After contacting local nurseries to obtain prices for each plant, EcoFLow determined that Silent Native Nursery in Homestead, FL was the most viable option based on affordability and proximity to FIU-MMC.

Remotely-Operated and Automated Siphon Systems

Remotely-operated and automated siphon systems serve two purposes; (1) During flood conditions, they allow the full utilization of the combined storage capacity of the wetlands and lakes by diverting excess water from a storage system that is about to flood to another with remaining storage capacity; (2) Prior to large storm events that are forecasted to produce flooding, the remotely-operated siphon system can release water to the existing C-4 canal, maximizing the storage capacity available for flood control on FIU-MMC.

The remote operation of the siphons involves a decision support system (DSS) to compute the schedule of optimal flow releases in the siphons, water level sensors in the wetlands and siphon hardware and the programming logic controller (PLC) to read the status of the sensors, establish the communication (via 4G Cellular connection) between the DSS and the siphon hardware and perform active control of the siphon hardware.

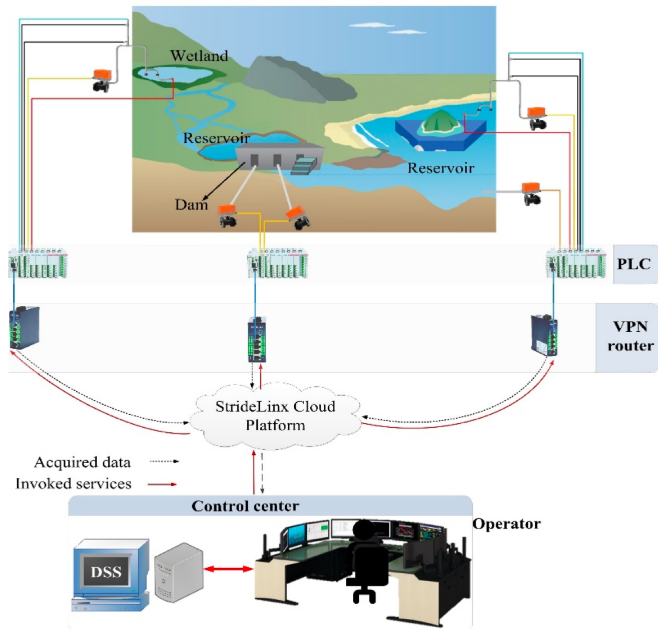

Figure 1: Schematic of the remote operation, communication and control of a network of storage systems for flood control

The schematic of the siphon system hardware, programming logic controller, and power is shown in Figure 1. The siphon system consists of a PVC pipe, liquid level switches, check valves, an air release valve, an actuated valve, and a bilge pump, which is only used for priming the pipe (e.g., filling the pipe with water before the siphon operation). The level switches in the pipe are used for deciding when to prime or re-prime the pipe (e.g., refilling the pipe). The setup is designed to maintain the pipe always primed (e .g., water level is maintained between the two switches in the vertical pipe), so the siphon system can be ready to receive an order for flood control. The two-level switches placed in the wetland inform the system if the wetland is about to overflow or is too dry. All devices that require power (e.g., actuated valve and bilge pump) are solar powered. For power needs during the night and on cloudy days, the siphon system includes a battery backup, which would supply the needed power for a period of up to 4.5 weeks without recharge. Because Florida has very few cloudy days, the power needs would be guaranteed at least during the life time of the battery.

The remotely-operated siphon system can be divided into three layers: data process and display layer, data communication layer, and data acquisition layer. The first layer consists of the sensor control software, which is used to turn on/off the pump and air vent and to control the opening/closing of the outlet valve. The second layer consists of the shielded input/output (I/O) connector and is used for communication between software and sensors. The third layer collects the data on the status of the sensors, which allows it to perform a diagnostic of the system and inform the decision maker if maintenance of any of the sensors is required.

In the actual implementation of the project, EcoFLow will have in total 30 siphon systems that will be operated simultaneously using a decision support system (Figure 2) developed at FIU in a MATLAB platform. The DSS utilizes forecasted data of precipitation (obtained from the National Oceanic and Atmospheric Administration), hydrological modeling (HEC-HMS), hydraulic modeling (HEC-RAS), and genetic algorithm optimization. The automated exchange of data between these models is made via HEC-DSS files. Parallel computing is used for running all models so the optimal solutions can be obtained much faster than those obtained when using serial computing. In general, the time interval of parallel computations are between 1/20 and 1/100 of the time compared to serial computing. The DSS can be used as a guide for the optimal water releases from a network of wetlands, detention ponds, and other storage systems for mitigating floods. This approach can enable adaptive release of water from wetlands hours or days ahead of rainfall events, thereby maximizing storage capacity and minimizing flooding. For this approach to be implemented, conventional storage systems, such as detention ponds, would be retrofitted (e.g., adding large gates) and the gates and siphons of these systems would be remotely controlled in an integrated manner using the DSS. Figure 3 shows the software interface used to remotely control siphons in a network of wetlands, detention ponds, and/or other storage systems. This software interface was written in C# and can be easily modified to adapt to evolving needs and challenges.

Bioswales and Rain Gardens

The majority of stormwater runoff is currently treated through exfiltration trenches, but when the water table is high, this form of water quality treatment is ineffective because the perforated pipes are submerged. In order to capture stormwater directly and allow infiltration into the ground, EcoFLow has proposed the implementation of bioswales along roadway shoulders and rain gardens within parking lot medians.

The bioswales and rain gardens cover a total area of approximately 5.4 acres and are 1.5 feet deep on average. They include native flora, such as Zamia integrifolia, Rondeletia leucophylla, Asclepias, and Spartina bakeri, because of the various benefits these plants offer, including increased biodiversity, air-purification, improved water quality, and pollinator attraction. EcoFLow designed the bioswales and rain gardens so that 70% of the total area will consist of flora, then estimated the surface area surrounding each plant based on their relative sizes, and lastly calculated the quantities for each plant. For 10 different native plants, a total of 214,255 plants will be required for all the bioswales and rain gardens.

Rainwater Harvesting

The capture and reuse of rainwater for irrigation purposes is a sustainable alternative to using potable water because it is easily captured and contained on-site, whereas potable water must be pumped from water treatment facilities and purchased by FIU. Therefore, EcoFLow has proposed to retrofit 12 buildings with rainwater harvesting systems in order to reduce stormwater runoff, conserve water, and reduce costs associated with potable water conveyance and use. Using the Rational Method for calculating surface runoff with an average annual rainfall intensity of 0.007 in/hr for Miami (U.S. Climate Data), a total area of 19.7 acres for the roofs used as catchment basins, and a runoff coefficient of 0.95 for concrete roofs (FDOT Drainage Design Guide), the rainwater harvesting systems are able to collect a total of 31.2 million gallons of rainwater annually. This captured rainwater can be used to irrigate surrounding landscapes and vertical gardens, thus reducing potable water use by 31.2 million gal/yr. The excess water can be conveyed to existing lakes and artificial wetlands as well.

The required storage tank volumes and quantities for each building were determined using the Rational Method based on a 1-year, 24-hour design storm. An intensity of 0.22 in/hr was obtained from an FDOT IDF Curve for Zone 10 for this design storm. A total of 36 tanks, ranging in size from 2500 to 6000 gallons, are required for the 12 buildings. The storage tanks can be purchased from the company National Tank Outlet, located within 165 miles of FIU-MMC. The tanks will be installed adjacent to the buildings on the ground floor and will be wrapped with green-designed vinyl for aesthetic purposes. Particles and contaminants will be filtered prior to storage by installing Twist II Clean Screen Filters. These filters prevent damage and clogging in the irrigation system by removing unwanted debris.

Vertical Gardens

The growth of vertical gardens along FIU-MMC buildings would reduce cooling costs for air-conditioned buildings, reduce CO_2 emissions into the atmosphere, reduce heat islands and their effect on wildlife and humans, decrease direct stormwater runoff, and bring tremendous aesthetic value to FIU. The native Wild Allamanda (*Pentalinon luteum)* vine was chosen as the vegetation for the vertical gardens due to its long lifespan and its capability to grow in USDA hardiness zone 10B. These vines grow up to 10 feet tall and require full to partial sunlight. They can be purchased at Sandhill Growers in Arcadia, FL. EcoFLow researched products that would provide a rigid platform for the vines to grow on and determined that the “Basic Wall System” designed by a company called “GSky” was the best option. GSky specializes in living green wall systems and is located in Delray Beach, FL. The Basic Wall System consists of cage-like panels measuring 5-10 feet tall prepared with an irrigation framework. To ensure that the vegetation does not attach to the building itself, the steel frames will be placed 12 inches away from the façade of the building.

EcoFLow proposes to implement vertical gardens on walls facing west and south for six parking garages and six air-conditioned buildings on FIU-MMC. The selected building wall heights and widths range from 40-83 feet and 130-150 feet, respectively. The total area covered by vertical vegetation is estimated to be 124,640 ft2, consisting of 361 panels, 87 planters, and a total of 348 vines. Using a correlation between average tree surface areas and the total area of wall vegetation, as well as the assumption that trees can absorb CO_2 at a rate of 48 lb/year (McAliney), the CO_2 sequestered by the vertical gardens was estimated to be 34,187 lb/yr.

A drip irrigation system was chosen to water the vertical gardens using the collected rainwater from the building roofs because it is a versatile and cost-effective method. Compared to sprinkler irrigation, it reduces water losses due to evaporation and runoff by delivering water directly to the roots of the vines. The system will consist of 1 gal/hr pressure-compensating emitters, soil humidity sensors, vertical mainlines from the storage tanks to the highest planters, lateral lines scaling the building horizontally at vertical intervals of 10 feet, drip lines at every vine, slip ball valves, end caps, and pumps. Humidity sensors will be installed in each planter to detect dry-soil conditions, allowing the irrigation system to automatically deliver water from the storage tanks when necessary. Along with this, the emitters will also deliver 1 gallon of water per week at a water pressure of 25 psi, except during Florida's rainy season (May-October). The mainline will be connected to a pump that is connected to each water storage tank. Water from the tank will be transported vertically along the mainline, laterally across the width of the wall, and then delivered to each vine through the drip line. EcoFLow determined that the vines will only require 9,733 gallons of water annually, based on the total number of vines (348), a 28-week watering period (52 weeks minus 24 weeks for rainy season), and an average watering rate of 1 gal/vine/week. This water demand is just 0.03% of the total water supply of 31.2 million gallons/year calculated previously. Therefore, the excess water collected from rainwater harvesting can also be used for irrigation in other parts of FIU-MMC.

Permeable Walkways and a Continuous Urban Tree Canopy

By creating a campus-wide permeable walkway and incorporating 10 permeable parking lots, EcoFLow's design reduces the impervious area of FIU-MMC by approximately 14% by converting roughly 48 acres of impervious land to pervious. The proposed walkway is a 7.5 mile path throughout the campus, surrounded by an urban tree canopy to provide shading. The pathway will allow infiltration of stormwater while providing a safe area for pedestrians and bicyclists to travel across the campus. The pathway will be 15 feet wide, a requirement stated in the Master Plan, which will allow half of the walkway to be dedicated space for pedestrians to walk, while the other half will be for bicyclists to travel. The permeable parking lots will cover 35 acres of the campus.

The urban tree canopy along the proposed walkway will consist of relocated trees due to the construction of wetlands, Gumbo Limbo (Bersera simaruba) trees, and Mahogany (Swietenia mahagoni) trees, which are both native to South Florida. Mahogany is listed as a threatened species by the state of Florida, therefore planting these trees around FIU-MMC will promote conservative actions. The purpose of the urban tree canopy is to reduce the urban heat island effect caused by human activity, sequester CO_2, provide wildlife habitats, increase the level of comfort for pedestrians, and intercept rainfall that would otherwise travel to impervious surfaces and gather pollutants along the way (Center for Watershed Protection). Using i-Tree Canopy, an online application in which 500 random sample points within FIU-MMC were selected and defined as either "tree" or "non-tree", EcoFLow determined that tree canopies cover approximately 21% of the entire campus, or roughly 75 acres (of 353 acres).

After analysis of the number of existing trees located within areas of proposed wetlands, it was concluded that approximately 136 trees would be relocated along the proposed walkway. Based on a walkway length of 7.5 miles, an average tree spacing of 20 feet, and trees located on both sides of the walkway for 60% of the total length, it was determined that a total of 2,376 trees would be needed (1,120 Gumbo Limbo, 1,120 Mahogany, and 136 relocated trees). Average canopy spreads were assumed to be 50 feet and 32.5 feet for Mahogany and Gumbo Limbo trees, respectively (Gilman and Watson). The total additional canopy area was then estimated to be 72 acres based on the respective canopy spreads, the circular shape of the canopies, and the quantity of each proposed tree. Therefore, EcoFLow's design increased the area of tree canopies covering FIU-MMC from 75 to 147 acres (96% increase). Not only that, but based on the assumption that a single mature tree can absorb CO_2 at a rate of 48 lb/year (McAliney), the CO_2 sequestered by new trees was determined to be 107,520 lb/yr. By increasing the tree canopy to now cover 42% of the campus, EcoFlow is also helping to reduce the urban heat island effect and provide comfort and aesthetic value for the FIU community.

IV. Flood Control

Using the EPA's Storm Water Management Model (SWMM), EcoFLow modeled the pre-development and post-development stormwater management systems of FIU-MMC (Figure 2). For both pre- and post-development, precipitation data was obtained from U.S. Climate Data; sub-catchment areas were denoted with respective percentages of pervious and impervious land; coordinates, invert elevations, and maximum depths of junctions were defined; and lastly, sizes, depths, lengths, slopes, and roughness coefficients for pipes were specified in the model. The SWMM model was then simulated using the Dynamic Wave Routing Model for processing models rainfall/runoff and flow routing.

Figure 2: SWMM Model

To create flood inundation maps, the results for each scenario were exported into ArcGIS. The operations performed in ArcGIS to obtain the flood inundation maps included importing surface data with respective coordinates, importing the Digital Elevation Model (DEM) obtained from SFWMD for Miami-Dade County, using the Raster Interpolation tools in ArcGIS to create a continuous surface of FIU-MMC from the sampled points, and lastly performing a cut-and-fill operation to generate the flood inundation map.

The final flood inundation maps were then generated for the pre- and post-development conditions. The results indicated that the existing stormwater management system is insufficient for mitigating flooding during a 25-year return period, as shown in Figure 3. When artificial wetlands, rain harvesting systems, permeable pavement, and interconnection between water bodies were incorporated throughout FIU-MMC, the results showed that flooding is mitigated for a 25-year return period and peak flow is reduced by 8.4% (Table 1).

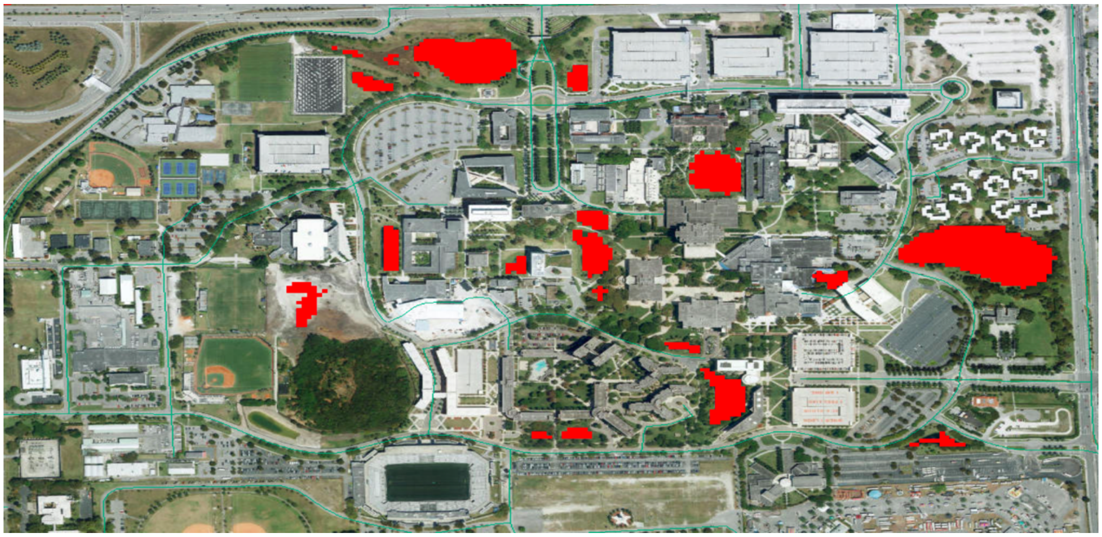

Figure 3: Pre-development inundated areas on FIU-MMC for existing stormwater management systems during a 25-year return period

Table 1: Peak-Flow Reduction

Condition	Land Use	Area (acres)	Runoff Coefficient, C	Composite C	Rainfall Intensity (in/hr)	Discharge, Q (cfs)	Total Peak Flow ($ft^3/s/acre$)	% Reduction of Peak Flow
Pre-Development Conditions	Impervious	258	0.95	0.81	0.22	62.97	0.18	8.4%
	Pervious	83	0.50		0.22			
	Water	12	0.00		0.22			
Post-Development Conditions	Impervious	185	0.95	0.74	0.22	57.69	0.16	
	Bioswales	5	0.50		0.22			
	Permeable Pavement	48	0.75		0.22			
	Rain Harvesting	20	0.95		0.22			
	Remaining Pervious Area	59	0.50		0.22			
	Water	36	0.00		0.22			

V. Water Quality Enhancement

For natural stormwater treatment, the water quality improvement across the 11 proposed wetlands was estimated using empirical formulas developed by authors Kadlec and Wallace in the second edition of *Treatment Wetlands*. The calculated percent removal of common contaminants across the proposed free water surface wetlands are shown in Table 2.

Table 2: Natural Wetland Pollutant Removal Capacity

Pollutant	Typical Influent Value in Stormwater, C_i	Computed Output Value in FWS Wetlands, C_o		Estimated % Removal Across 11 Proposed Wetlands	
BOD (mg/L)	17.20[a]	7.60		56%[c]	
TSS (mg/L)	94.30[a]	22.25		79%[d]	
Total Nitrogen (TN) (mg/L)	2.83[a]	0.80	0.00	72%[e]	100%[e]
Total Phosphorus (TP) (mg/L)	0.43[a]	0.05	0.00	88%[f]	100%[f]
Fecal Coliform (#/100mL)	73000[b]	1053.19	0.00	99%[g]	100%[g]

[a] (Harper, 15) [b] (U.S. EPA, 5)

[c] Calculated using First-Order Modeling for free water surface (FWS) wetlands, Co = 1.13*Ci^0.67 (Kadlec and Wallace, 242)

[d] Calculated using regression of annual information, Co = 1.5 + 0.22*Ci (Kadlec and Wallace, 222)

[e] Calculated using Plug-Flow Reactor Model based on the following values: average first-order areal rate constant (k=22 m/yr) (Kadlec and Knight, 430), <10% k=1.2 (Kadlec and Wallace, 308), calculated hydraulic loading rate (q=0.95 m/yr) based on a maximum flowrate of 345 m3/d for the siphon system and total area of 132,939 m2 for proposed wetlands, assumed background concentration of zero (C*=0), and assumed apparent number of TIS of zero (P=1) (Kadlec and Wallace, 166)

[f] k=12.1 m/yr (Kadlec and Knight, 466), lower k=1.99 (Kadlec, 5), q=0.95 m/yr, C*=0,, and P=1 (Kadlec and Wallace, 166)

[g] k=0.011 m/d (Kadlec and Knight, 538), q=0.95 m/yr, C*=0, P=1 (Kadlec and Wallace, 166)

VI. Engagement of Campus and Surrounding Community

An important goal of the EcoFLow project is to involve the FIU community and surrounding community of Sweetwater in the planning, design, implementation, and operation of the project. A campus "EcoFLow Project Organization" will be established to coordinate with the FIU Facilities Department and engage the community with the project. The organization will be responsible for hosting volunteering events with the community, contacting stakeholders for support, and spreading awareness about the importance of green infrastructure. Volunteering events will be held three times a month, in which FIU students, faculty, alumni, and community members will join to conduct routine maintenance of the various alternatives implemented, such as removal of invasive species from bioswales and rain gardens. The organization will also be responsible for gathering volunteers to construct the bioswales and gardens in order to reduce costs.

As an educational contribution to the Sweetwater community, the organization will establish a semi-annual STEM Day, in which local K-12 schools will attend FIU-MMC to learn about green infrastructure practices. The event will begin with a tour of the stormwater alternatives implemented, followed by a hands-on activity in which students will be able to design their own solutions for various stormwater issues faced in South Florida. An event like this will attract stakeholders and provide an opportunity for the EcoFLow Project Organization to establish partnerships and gain financial support for the project. For example, space for informational booths can be offered to stakeholders, such as engineering design firms, construction companies, non-profit organizations, and government agencies, in which they can make a financial donation to the project to secure a spot.

VII. Project Phasing

The EcoFLow Project will be implemented in four phases over a total period of about 7 years, beginning in January 2020 and ending in December 2026. Construction of wetlands will occur during the Summer-terms since less people attend FIU during those months. EcoFLow estimates that wetlands 1, 5, and 7 will require 320 hours of work; 4 and 10 require 120 hours; 2 and 9 require 100 hours; 3, 8, and 11 require 60 hours; and 6 requires 40 hours. Interconnection of water bodies and assembly of the siphon systems will begin as the wetlands are constructed. Assuming the EcoFLow Project Organization volunteers can complete 1% of the total bioswales and rain gardens each time they meet (3 times/month), the construction will take about 34 months in total. Rainwater harvesting systems and vertical gardens will be implemented simultaneously, completing an average of two buildings within 4 weeks. Due to high activity at FIU-MMC during normal business hours, construction of the permeable walkways must be conducted between 10 PM - 3 AM. Assuming 0.15 miles of the walkway can be completed each night, the walkway will take 50 work days to complete. Assuming construction of the walkway occurs 3 times a week, the total period of construction will take a little over 4 months. The construction of the 10 permeable parking lots is divided over a period of 5 years. Only one lot will be constructed at a time in order to minimize the conflicts involved with reducing parking during construction. As a temporary traffic control plan during construction, vehicles will be redirected to the neighboring Tamiami Park and a shuttle service will be provided. Planting of the proposed trees will begin after completion of the walkway. EcoFLow estimates that 10 trees can be planted in a work day. Assuming trees are planted 4 days/week, 15 months is required to plant all 2,376 trees.

The timeline for implementation (Table 3) was created in such a way that dates and construction periods are flexible to allow adaptation to changing circumstances over time.

Table 3: Construction Timeline for EcoFLow Project

Phase 1	January - May	May - August	August - December
2020	EcoFLow Project Organization is established. Grants, loans, and other sources of financing are researched. Future events are planned, including volunteering, educational, and fundraising events. A strong relationship with the FIU Facilities Department is established. Potential stakeholders are contacted.		

Phase 2	January - May	May - August	August - December
2021	*Begin Construction* ● Begin construction of permeable walkway	● Construction of wetlands 1 & 4	● End construction of permeable walkway ● Construction of vertical gardens & rain harvesting for PVH1, PVH2, & PVH3
2022	● Construction of Parking Lot 5 ● Begin construction of bioswales and rain gardens ● Construction of vertical gardens & rain harvesting for PG1 & PG2 ● Begin tree planting	● Construction of Parking Lot 9 ● Construction of wetlands 5 & 10	● Construction of vertical gardens & rain harvesting for PG3 & PG4
Phase 3	**January - May**	**May - August**	**August - December**
2023	● Construction of Parking Lot 3 ● Construction of vertical gardens & rain harvesting for GC	● Construction of Parking Lot 4 ● Construction of wetlands 2 & 7 ● End tree planting	● Construction of vertical gardens & rain harvesting for PG5 & PG6
2024	● Construction of Parking Lot 2 ● Construction of vertical gardens & rain harvesting for PC & ARE	● Construction of Parking Lot 7 ● Construction of wetlands 9, 8, 11, & 6	● End construction of bioswales and rain gardens
Phase 4	**January - May**	**May - August**	**August - December**
2025	● Construction of Parking Lot 1	● Construction of Parking Lot 6	
2026	● Construction of Parking Lot 8	● Construction of Parking Lot 10	*End Construction*

VIII. Budget and Funding Sources

In coordination with the FIU Facilities Department, the EcoFLow Project Organization must establish partnerships with stakeholders in order to gain financial support for the project. Based on the cost of materials and labor, the total estimated cost for the project is $8.0 million (Table 4). This project is eligible to apply for the Home Depot “Retool your School” campus improvement grant, which awards schools to make sustainable improvements to their campus. Another promising option is the Knight Foundation, which granted $1 million to Harvard

University to create solutions for some of the sustainability and resiliency challenges faced Miami.

Table 4: Cost-Estimate for the EcoFLow Project

Alternative	Unit Price		Quantity		Total Cost
Artificial Wetlands					
Bayhead Wetland Plants	$0.50-$95.00	/Plant	1,735	Plants	$22,244
Marl Prairie Wetland Plants	$0.50-$20.00	/Plant	970	Plants	$2,968
Strand Swamp Wetland Plants	$0.50-$95.00	/Plant	2,307	Plants	$35,038
Construction Costs:					
Excavation/Compaction	$0.07	/ft3	4,330,421	ft3	$282,035
Labor (Construction crew of 10 people)	$35.00	/hr	640	hr	$224,000
Total Wetland Costs:					**$566,284**
Remotely-operated and automated siphon systems					
Liquid Level Switch	$17.00		120		$2,040
Bilge Pump	$30.97		40		$1,239
6" Clear PVC Utility Swing Check Valve, Socket, EPDM	$124.71		80		$9,977
Air vent with solenoid	$11.00		40		$440
6" Solid PVC Schedule 40 Pipe	$3.96	/ft	600	ft	$2,376
6" Clear PVC Schedule 40 Pipe	$64.90	/ft	80	ft	$5,192
6" Schedule 40 PVC 90 Elbow Socket	$20.42		120		$2,450
6" Schedule 40 PVC Tee Socket	$31.41		80		$2,513
6" PVC Drain Cap	$4.89		40		$196
6" Schedule 40 PVC Coupling Socket	$9.32		40		$373
6" Schedule 40 PVC Van Stone Flange Socket	$19.81		40		$792
6" EPDM Flange Gasket	$8.01		40		$320
Total Siphon-System Costs:					**$27,908**
Bioswales and Rain Gardens					
Plants	$0.50-$50.00	/plant	214,255	Plants	$313,487

Total Bioswale and Rain Garden Costs:					**$313,487**
Rainwater Harvesting					
Tanks	$607-$3581	/tank	36	Tanks	$97,950
Labor (4 workers)	$35.00	/hr	40	hr	$5,600
Total Rainwater Harvesting Costs:					**$103,550**
Vertical Gardens					
Tubing	$14.98	/250 ft of tubing	3,240	ft	$194
Slip Ball Valve with Tee Handle	$0.06	/valve	590	Valves	$35
Emitters	$9.79	/30 emitters	348	Emitters	$114
End Caps	$0.67	/end cap	475	End caps	$318
Wild Allamanda Vines	$5.00	/vine	348	Vines	$1,740
"Basic Wall System" Panels	$130.00	/panel	361	Panels	$46,930
Singflo 24V Solar Water Pump	$85.00	/pump	24	Pumps	$2,040
Soil Moisture Sensors	5.95	/sensor	348	Sensors	2070.6
Labor (5 workers)	$35.00	/hr	480	hr	$84,000
Total Vertical Garden Costs:					**$137,442**
Permeable Pavement					
Permeable Pavers	$1,849.00	/ 600 ft2	2,090,465	ft2	$6,442,115
Labor (5 workers)	$35.00	/hr	400	hr	$70,000
Total Permeable Pavement Costs:					**$6,512,115**
Urban Tree Canopy					
Gumbo Limbo Tree	$125.00	/tree	1,120	Trees	$140,000
Mahogany Tree	$125.00	/tree	1,120	Trees	$140,000
Labor (2 workers)	$35.00	/hr	1,600	hr	$112,000
Total Tree-Planting Costs:					**$392,000**
Estimated Total Cost for EcoFLow Project					**$8,052,786**

X. Conclusion

By examining the existing conditions of FIU-MMC and carefully reviewing the goals outlined in the Master Plan, EcoFLow proposed seven green infrastructure alternatives for FIU's stormwater issues. When implemented together, the alternatives achieved the desired results. The incorporation of wetlands, bioswales, rain gardens, permeable pavement, and rainwater harvesting systems reduces the impervious area of FIU-MMC by 21% and therefore decreases the peak flow of the system by 8.4%; Rainwater harvesting reduces potable water use for irrigation by 31.2 million gal/yr; Vertical gardens and urban tree canopies collectively sequester 141,707 lb CO_2/yr; Artificial wetlands have the capacity to remove 56% BOD, 79% TSS, 72-100% TN, 88-100% TP, and >99% fecal coliform from collected stormwater; The area of tree canopies covering FIU-MMC was increased by 96%; The entire system was capable of mitigating flooding within FIU-MMC during a 25-year return period.

EcoFLow's innovative designs address major sustainability goals outlined in the Master Plan, including water quality enhancements, flood mitigation, habitat restoration, reduced runoff, water storage maximization, and water reuse. Every aspect of the proposed designs was carefully thought-out, taking into consideration sustainable practices that would help restore the natural habitats of South Florida, enhance water quality, and mitigate flooding while providing educational, recreational, and aesthetic value to FIU. In such a sensitive environment that is highly subject to the negative effects of climate change, it is essential for FIU to consider EcoFLow's proposal as a model for implementing green infrastructure practices in the near future.

XI. References

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