(Re)SEARCHING FOR A SPOT

A Parking Lot Laboratory for Desert Stormwater Management, Research, and Education

Demonstration Category D7 The University of Arizona

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ABSTRACT

The University of Arizona (U of A) located within the Sonoran Desert, is known for high temperatures and lack of rainfall. Seasonal rain events are often brief and violent, and the 269 campus parking lots are prime examples of a lack of planning for stormwater retention and water quality services. The parking lot south of the College of Architecture, Planning, and Landscape Architecture (CAPLA) serves six colleges without addressing stormwater management or pedestrian safety. This single-function parking lot has the potential to improve public safety by improving pedestrian networks and remediating environmental health using increased water quality, infiltration capacity, and a holistic approach to stormwater management. The U of A is committed to research and this project will provide infrastructure to assess stormwater basin performance through the presence of microbial communities and investigate the capacity of arid-adapted plants as phytoremediators. *(Re)Searching for a Spot* will function as a demonstration project, highlighting the collaborative research and design effort among the School of Landscape Architecture and Planning, School of Natural Resources and the Environment, and Department of Hydrology and Atmospheric Sciences. This project will highlight green infrastructure (GI) benefits and performance. The quantitative performance data of GI- critically lacking in the arid environment currently, will provide evidence and confidence for future parking lot retrofits on campus and across the surrounding communities.

INTRODUCTION + SITE SELECTION

The University of Arizona (U of A) as a Research I Institution, is located in Tucson, Arizona, within the Sonoran Desert. The U of A has 130 year legacy of seeking innovative solutions and it is perhaps the first institution in the nation to include the "built environment" as part of the University's Strategic Plan (effective 2019). The built environment is an asset to all university campuses, and by highlighting the health and environmental benefits provided by built surroundings, the U of A is positioned to become a leader in campus development.

Specifically, U of A is committed to sustainable practices and expects to implement green stormwater infrastructure to manage runoff in the changing climate. Through integrating active and passive systems, new construction benefits from rainwater harvesting basins and underground detention cisterns to reduce peak flows while addressing the presence of the campus' 100-year flood plain. Interdisciplinary studies on the built environment area at the core of green infrastructure adoption. The College of Architecture, Planning, and Landscape Architecture (CAPLA) is positioned as a campus facilitator, providing its students with the skill set to working with a wide variety of departments and entities on campus to integrate innovative green infrastructure (GI) into future campus development. Campus parking lot development has been focusing on creating the highest number of parking stalls, sacrificing its overall performance in the environment and social aspects of sustainability; particularly educational benefits are least emphasized.

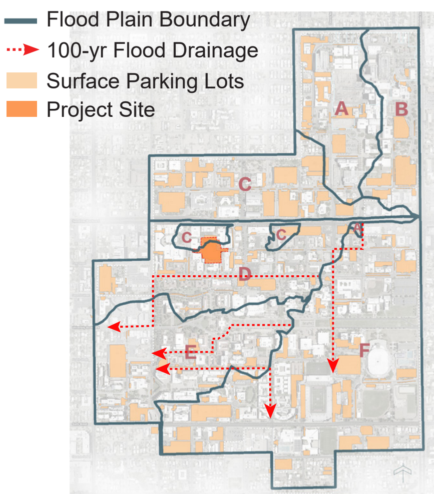


Figure 1 - Context map & watershed

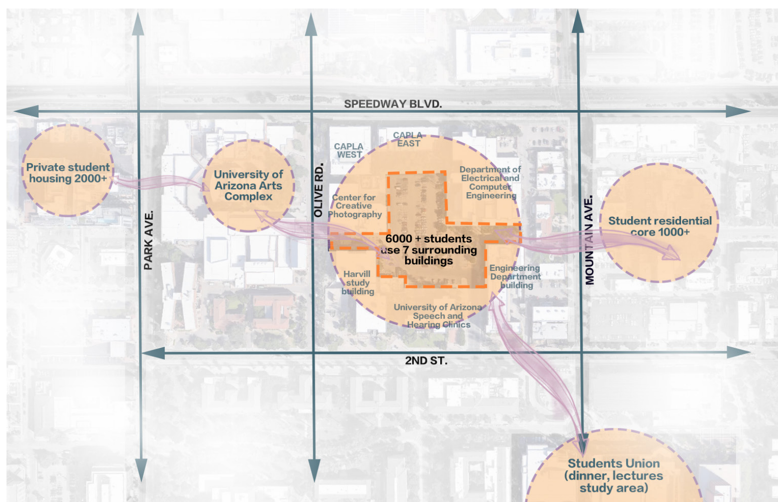


Figure 2 - Campus context

INVENTORY + ANALYSIS

Parking lot development has resulted in a total of 269 parking areas (Figure 1) and parking lot vegetative cover shows that more than 95% of the surface lots contained *negligible* canopy cover. The parking lot south of CAPLA was selected as a demonstration project because it (1) critically lacks vegetative cover, (2) is a highly used, yet unsafe traffic hub for six major colleges surrounding it, (3) is in close proximity to nearby campus amenities, and (4) is situated in an upstream location, and contributor, feeding into the 100-year flood plain (Figure 2).

This project will showcase the performance benefits of adopting GI strategies, and how the U of A can retrofit other parking lots to better serve campus. Expected benefits from a parking lot retrofit include: (1) entirely eliminate runoff from the site during 2-year storms, (2) reduce the parking lot's contribution to the adjacent 100-year floodplain by 22,929 gallons of runoff, (3) improve water quality through reductions in sediment and pollutant loads, and (4) increase the Time of Concentration (Tc) of the sub watershed by approximately 600%.

To establish a baseline for GI performance assessment and subsequent research work, the team collected water quality samples at two drainage points on site and tested for contaminants commonly associated with vehicles. Results are presented in Table 1 below.

	Constituent Concentration (ug/l)			
Water Sample (UA project)	Pb	Zn	Cd	Cu
1	0.16	16.88	0.04	6.95
2	0.09	29.16	0.04	4.06
National Standards (Kadlec and Knight, 1996)	180	200	1.5	50

Table 1 - Water quality samples compared with national standards.

When compared to the national standards on stormwater pollutant levels (Table 1), the water quality constituent levels sampled on site are lower than typical urban runoff (Kadlec and Knight, 1996). Nonetheless, these samples show the existing quality of stormwater runoff without treatment from vegetation or bioswales, which provide a baseline for water quality improvements.

GIS information was combined with on-site observations to understand the current drainage pattern on site (Figure 3). The site's high point is centrally located and divides the parking lot into a northern and southern sub-watershed. The grading plan benefits the site because water can be managed in smaller quantities which provides options for effectively infiltrating stormwater through the use of smaller, low impact interventions.

The parking lot is shared by CAPLA and five other colleges, but it provides little university context, or accommodation for pedestrian movement, or stormwater management. Personal

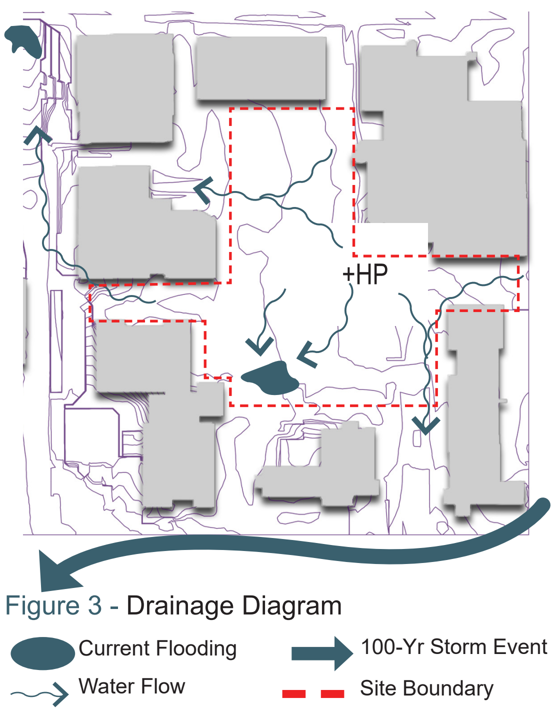


Figure 3 - Drainage Diagram

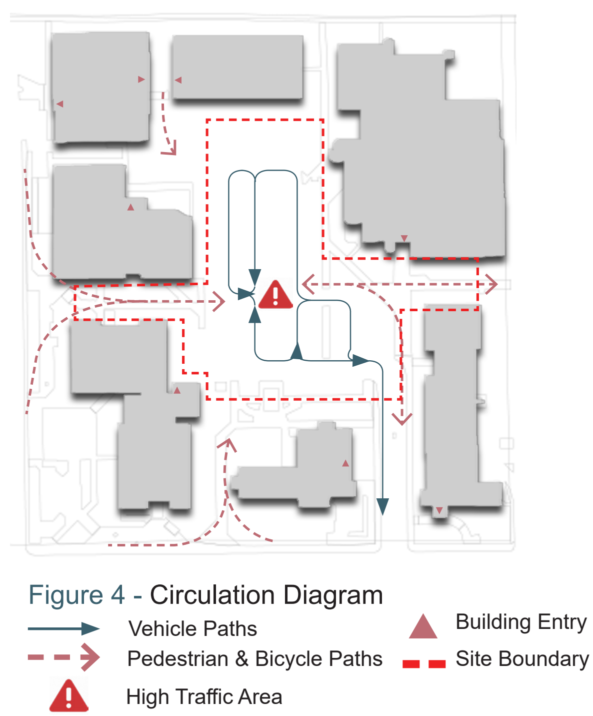


Figure 4 - Circulation Diagram

observations of the site recorded the interactions that occurred between pedestrians and vehicles, and what routes were necessary for maintaining the necessary functions of access and parking. (Figure 4) The following diagram shows the dangerous context occurring through the center of the parking lot along the unofficial pedestrian corridor.

The U of A is a Research I Institution and a new Strategic Plan highlights the role of research in the built environment to support campus growth. The CAPLA Dean and Strategic Plan board member stated, "It is clear that a pan-university effort around the built environment is a differentiator...It is an initiative that will bring a multiplicity of researchers together to take on the grand challenges of the built environment." This parking lot design will provide an opportunity to assemble a multidisciplinary team to collaborate on research that benefits the community as a land grant institution committed to community outreach.

The drainage and circulation analysis revealed opportunities and challenges that currently exist on site. Project goals were developed to address water quality and management, and pedestrian safety. These goals seek to improve the impact the U of A has on the environment and surrounding community as well as the health and well-being of the student body. As a third goal, the team defined research as an opportunity to reach out to the community and capitalize on the university's resources to provide quantifiable GI data and its impact on stormwater management in arid environments.

Goals	Objectives	Relevance
Treat 100% of a 25-year storm event	• break up impervious surfaces • provide areas for infiltration • slow water using weirs and linked basins • increase phytoremediating vegetation	Reduce pollutant loads delivered to surrounding watersheds and enhance the quality of 100-year flood plain
Enhance multi-modal safety and circulation	• alert vehicles to pedestrian crossing • provide protected circulation routes • promote universal access • enhance campus way-finding	Increase safety and efficiency of transportation campus environment
Provide infrastructure for collaborative research and education on campus	• re-create real world infrastructure for research • provide areas for self and guided learning • form relationships between colleges	Collect crucial GI data to improve public health and environmental quality related to arid environments

Table 2 - Goals and objectives

RESEARCH

To enhance the design concept within the campus environment, the team relied on research to create defensible design choices. This provided the design with innovative options for retrofitting a parking lot and allowed the design to appeal to a wider user group. Research was conducted in psychology, water quality/management, ecohydology, education, and the urban heat island effect.

Psychology

Improving parking lots on campus will benefit the psychological health of student population, the population majority on campus. Students are focused on their academic performance and often experience stress related to their studies. The installation of vegetation on campus provides the following:

• Student health and access to green space showed positive relationships between nature exposure and student performance. Specifically, views with greater quantities of trees and shrubs from windows are positively associated with standardized test scores, graduation rates, percentages of students planning to attend a four-year college, and fewer occurrences of criminal behavior (Matsuoka, 2010).
• Students with higher perceived campus greenness report greater quality of life, a pathway significantly and partially mediated by perceived campus restorativeness (Hip et al., 2016).
• Sustainable campus landscape design is valuable for college students and highlights the healing power of natural space on campus (Lau and Yang, 2009).

Water Quality/Management

Efficiently managing stormwater on campus will improve the campus's environmental impact and enhance safety by reducing the amount of water released onto streets and sidewalks. The addressing these factors in the context of the arid desert environment will provide the following.

• Basin volumes and impervious surfaces were compared to model the amount of runoff that could be captured on-site. 100% of 2-year storm events can be retained through the use of infiltration basins, weirs, and bioswales.
• Tc (Time of Concentration) will increase by 600% by breaking up impervious surfaces and including vegetative swales and basins to direct water through longer pervious channels that facilitate infiltration.
• Water quality can be improved by slowing stormwater runoff, allowing heavy metals and suspended solids to drop out of the flow. (Davis, 2003) Phytoremeditaion plants can also uptake and bind pollutants neutralizing their presence in the soil (Marquez et al. 2009).

Ecohydrology

Stormwater basins are common in the Tucson Area, and support ecological functions and stormwater management. Research can be conducted to determine how basins in this environment could increase performance to benefit ecology, stormwater quality, and infiltration.

• Few studies have explored the impact water harvesting techniques have on greenhouse gas emissions and soil chemistry (Pataki et al. 2011).
• Studies have shown an increase in soil microbial diversity and richness in bioretention swales when compared to non-swale areas in the same region (Kazemi, Beecham, and Gibbs 2011)
• Vegetated bioswale first flush samples show 92% fewer suspended solids, 87% less Total Nitrogen, 92% less Total Phosphorus, 96% less Zinc and Lead, and 82% less Copper than the samples from the traditional stormwater system (Yang et. al. 2015).

Education

The U of A seeks to produce innovative research opportunities and synthesize new ideas by promoting collaborative research from experts in unrelated fields. By approaching problems from different viewpoints, professors can arrive at results in unexpected ways.

• Research of the built environment and collaborative research has been identified in the UA Strategic Plan (released 2019), and the site interacts with 6 college institutions.
• Sustained research of stormwater strategies over time can improve and refocus stormwater management plans through collaboration of different groups (Brown et al. 2013).
• Surface temperature, hydrology, carbon storage and sequestration, and biodiversity must be quantified to understand the level of improvement landscapes can provide (Whitford, 2001).

Urban Heat Island Effect

Figure 5 & 6 illustrate Tucson's vulnerability to extreme temperatures and the negative effects impervious surfaces like mall parking lots and airplane runways have on the surroundings. This issue must be addressed to protect the surrounding community. Parks and campuses have substantially lower temperatures, but even parking lots on campus retain heat more readily than green spaces.

- Climate related exposure can be a direct cause of illness or death (Luber, 2008).
- The effects of extreme heat disproportionately affect populations of lower socioeconomic classes (Jenerette, 2011).
- Summer exposed asphalt temperatures reach an average of 148°F in Arizona Parking lots (Celestian and Martin, 2004).

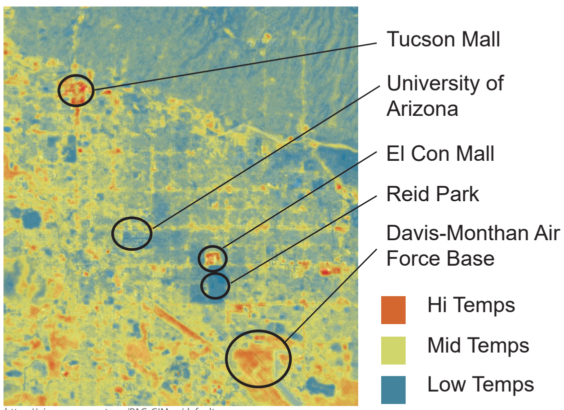


Figure 5 - Tucson Heat Map

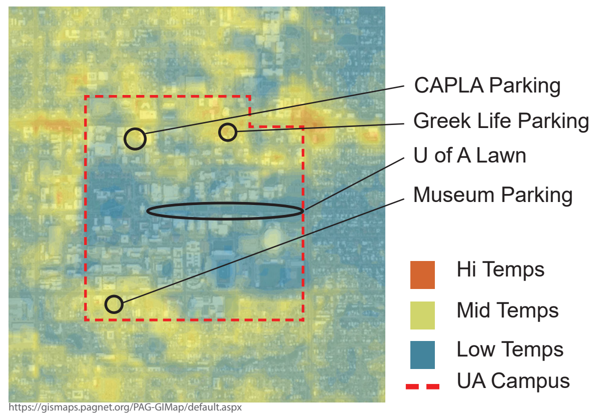


Figure 6 - U of A Heat Map

Selected Interviews

Interviews were conducted across campus, seeking input from experts in numerous backgrounds to gain input from additional experts with experience on the U of A campus.

Eric Bell, the Program Coordinator of Physical Access at the Disability Resource Center (DRC) provided feedback on the design proposal, and existing limitations that could be addressed on site. The mission of the DRC seeks to create a "seamlessly accessible" campus regardless of physical limitation (DRC About Us, 2018) Mr. Bell identified several ramps as non-compliant ADA accessible and suggested improvements for accessibility of pedestrian corridors. His knowledge of campus was invaluable because he knew where universally accessible building entrances were located and what routes would be most convenient for building access.

Dr. Tanya Quist, U of A Arboretum Director, was interviewed regarding the Arboretum's vision for campus. Director Quist highlighted the campus arboretum's desire to promote sustainability research through the inclusion of native and arid adapted species appropriate to desert climates, and expanding the diversity of the collection. Both goals coincide with the Campus Arboretum 2021 Strategic Plan and promote sustainable low impact development to campus.

President Shawn Kelly ASLA President was interviewed regarding his experience in planting design to improve water quality using phytoremediation. He stressed the use of plants that can perform rhizodegradation, and photodegradation, rather than accumulation, performing services that breakdown or bind pollutants rather than collecting pollutants into plant tissues that contain concentrated pollutants at toxic levels.

PROJECT DESCRIPTION

(Re)Searching for a Spot (Figure 7) provides an innovative solution for an under performing public space by addressing the needs of a diverse community. Safety, research, and stormwater management are all paramount for a healthy and successful campus retrofit design. *(Re)Searching for a Spot* will incorporate these aspects to benefit the surrounding community, and will provide green infrastructure research for the future, addressing environmental problems within the community's built environment in the context of arid climates.

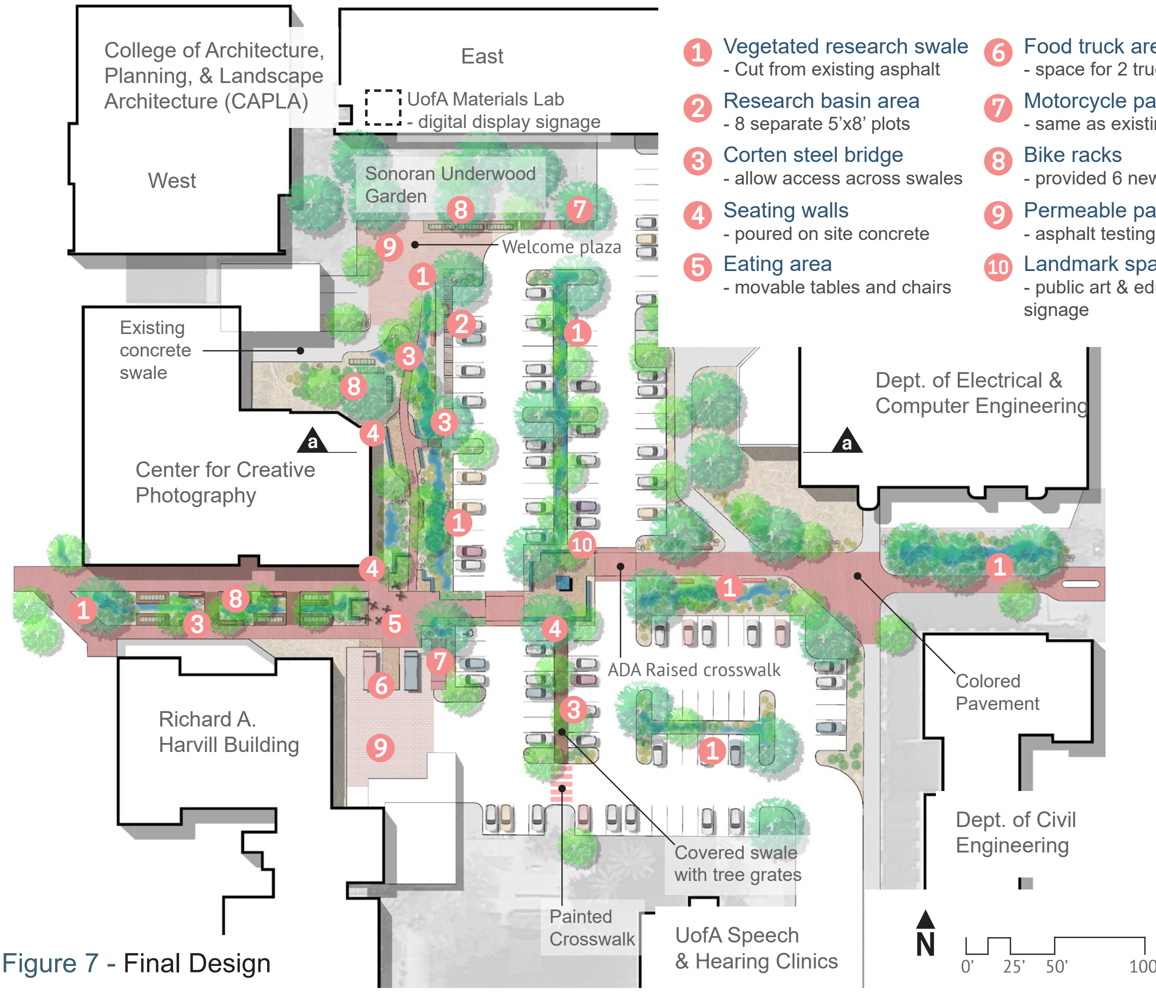


Figure 7 - Final Design

Stormwater Management

The current U of A Campus Stormwater Management Plan utilizes street surfaces to transport water off campus, interfering with vehicle and pedestrian transportation and prohibiting infiltration on site. Asphalt prevents toxins from being treated by soils and plants near the site at safer, lower concentrations, and quickly transports vehicular pollutants into ecologically sensitive watersheds.

To improve water quality leaving the 2.48 AC site, the infiltration capacity was studied with team members from the Department of Hydrology & Atmospheric Sciences. Due to the urban context of the site the infiltration rate will determine if the site exhibits excessive compaction or contains caliche, (calcium carbonate deposits common in arid regions). The infiltration rates can be found in Table 3 and locations (Figure 8).

	Average U of A Infiltration Rate mm/min			
Site	1	2	3	4
Rate	0.22	0.11	0.12	0.32

Table 3 - Infiltration Rates

The site's average infiltration rate is 2 mm per minute, which shows infiltration readily occurs on the site. These numbers prove basins and swales in the design will be able to absorb the 12" of water held by check dams and weirs within the 12-hour limit defined by the City of Tucson's stormwater management code. Soil ripping during construction will continue to improve the infiltration rates and further reduce stormwater runoff.

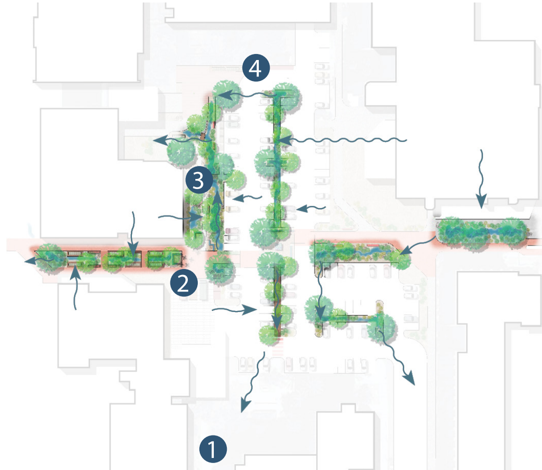


Figure 8 - Drainage Plan & Infiltration Test Sites

(Re)searching for a Spot uses stormwater infiltration to improve groundwater recharge, reduce surface flooding, and improve stormwater quality. A network of stormwater basins, connected by weirs (Figure 9) and check dams allows for the capture of 22,929 gallons of stormwater (3,065ft^3) and associated pollutants on site. Installing check dams and weirs is important to the design because they hold water within swales and basins, which provides additional time for water to infiltrate into the soil and recharge groundwater sources. Pooling water also allows vehicle-deposited contaminants to seep into the soil where they can be immobilized at low concentrations.

To reduce the site's impact to the 100-yr flood plain, the Time of Concentration (T_C) was analyzed and modified to increase the sheet flow and shallow concentrated flow distances. Previously, stormwater took only 22 minutes to travel across an expansive asphalt surface before draining off site. To increase the T_C, the team designed a solution that increased watershed distances while breaking up impervious surface types (Figure 10). Changing surfaces from asphalt to vegetated basins and rock-lined permeable swales increased the T_C to 2 hours and 18 minutes. These design interventions also increased the percentage of perviousness in the watersheds, and allowed suspended solids and pollutants to drop out of stormwater before joining ecologically sensitive watersheds.

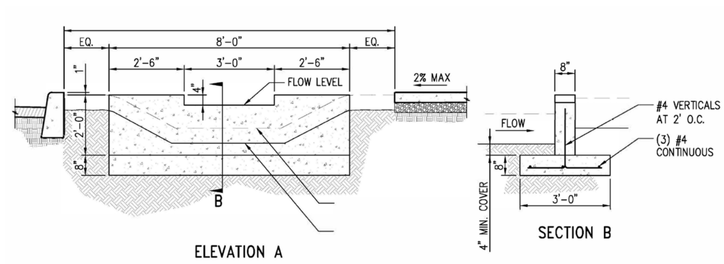


Figure 9 - Weir Construction Detail

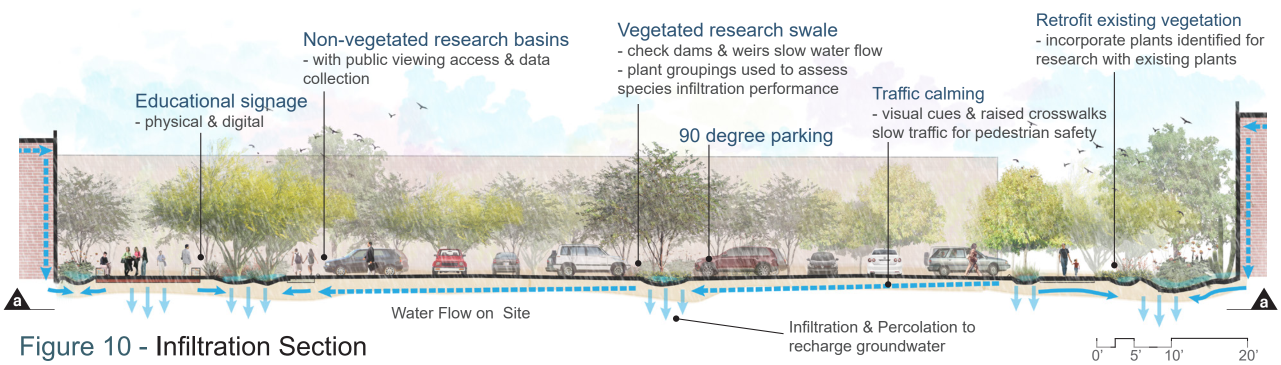


Figure 10 - Infiltration Section

Adopting green stormwater infrastructure will also improve the quality of life on campus, reducing flooding within the parking lot and its contributing watersheds, and improving safety and efficiency of pedestrian and vehicular transportation. These overlaying benefits maximize the impact of the design. The following assessment on hydrologic performance was conducted with input from Dr. Thomas Meixner, professor and associate department head of the Department of Hydrology and Atmospheric Sciences.

(Re)Searching for a Spot seeks to improve stormwater management within the context of a functioning parking lot to highlight the opportunities available for green infrastructure retrofits. Expertise from faculty members and student collaborators came together to provide a cohesive design to enhance stormwater capacity through bioswales and basins, break up the extensive impervious surfaces, and provide opportunities to infiltrate pollutants at the source. Storm surge effects have been reduced by increasing the T_C and lengthening the distance stormwater travels before exiting the site. These improvements are invaluable in arid-environment contexts where water is limited, and as urban populations expand, these solutions will become even more critical.

Pedestrian Use

This site was selected due to its central location on campus, and the safety hazards present between pedestrians and vehicles. Its central location links student housing, with the arts district and Student Union, maximizing the parking lot's visibility. Increased safety measures and defined pathways will encourage pedestrian use and enhance community interactions. *(Re)Searching for a Spot* highlights pedestrian presence and encourages student use (Figure 11), by improving on the corridor pedestrians have identified through the parking lot.

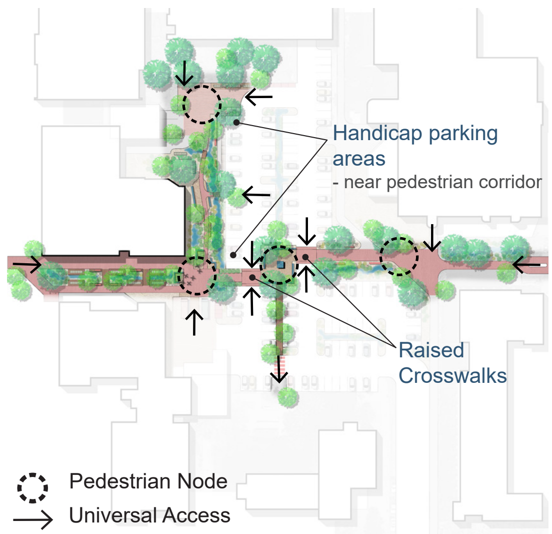


Figure 11 - Pedestrian Circulation

Campus circulation is important for the health and safety of all campus users, and the U of A is particularly concerned about the pedestrian campus experience. The design team reached out to the UA's Disabilty Resource Center (DRC), which seeks to ensure all users on campus regardless of physical limitation, have the same University experience. Eric Bell, Program Coordinator of Physical Access provided input on incorporating universal access into the design. Mr. Bell provided critical feedback on the function and location of access ramps. His expertise highlighted inaccessible ramps in the area, and the most convenient ramp locations.

Pedestrian pathways are designed to aid stormwater infiltration, while improving user experience. Most paths are defined by color, using a combination of permeable pavers and stained concrete to aid wayfinding while eliminating pooling on walkways (Figure 12). The pathway to the east uses a daylighted swale to direct users through the site and provide opportunities to sit, meet classmates and provide bike parking while interacting with green infrastructure. The north pathway uses several types of permeable pavers, installed in a successive pattern to investigate the performance and longevity of infiltrating paving products. Finally, the pathway to the south uses a bar-grate catwalk, leading pedestrian over a swale to a defined crosswalk. Performance audits are scheduled in the maintenance schedule to track the success or failure of these materials, and

Figure 12 - Sidewalk drainage detail

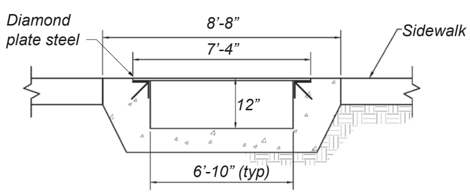
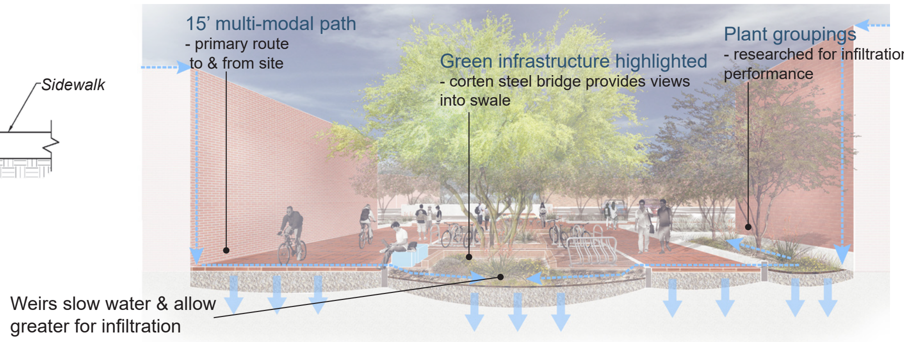


Figure 13 - Infiltration section



aid in selecting materials appropriate for arid environments. All pathways link to surrounding sidewalks within the pedestrian plan and provides signage and tactile cues to enhance wayfinding through the 380-acre campus. Project feasibility including cost estimates were reviewed by Dr. Alejandro Angel, Vice President and Principal at Psomas engineering company.

Social components are integrated into the design to aid the community and teach users about the benefits of green infrastructure. Entrances to CAPLA and Engineering are highlighted as thresholds. These areas provide chances to interact with users and include educational signage to explain specific GI strategies used. The center area is defined as a landmark, providing a wayfinding opportunity and meeting location users can easily identify and communicate to new visitors. To the west, the function of the bioswale is revealed, allowing students to interact with unlined bioswales and weir systems (Figure 13). The node to the west includes movable seating and food truck parking to activate the parking lot and engage students to interact with one another. Educational signage is provided throughout the site and explains on-going research to the public.

Research Infrastructure

The U of A is a Research I institution, and incorporating collaborative research into the built environment aligns directly with the university's Strategic Plan. Research infrastructure will be included within the site design (Figure 14), providing opportunities not limited architecture, sustainable development, plant sciences, microbial sciences, hydrology, ecology and outreach. These topics will provide valuable research about GI in arid environments, where information specific to this climate is not readily available.

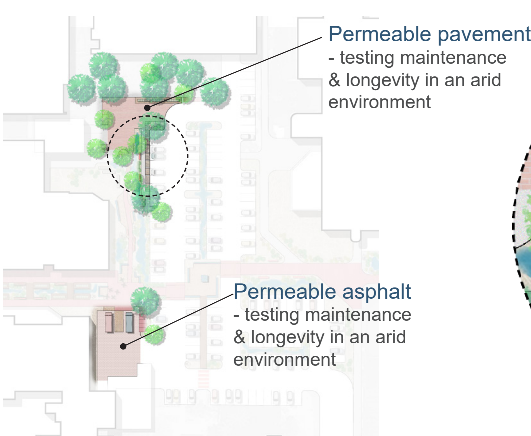


Figure14 - Research Infrastructure

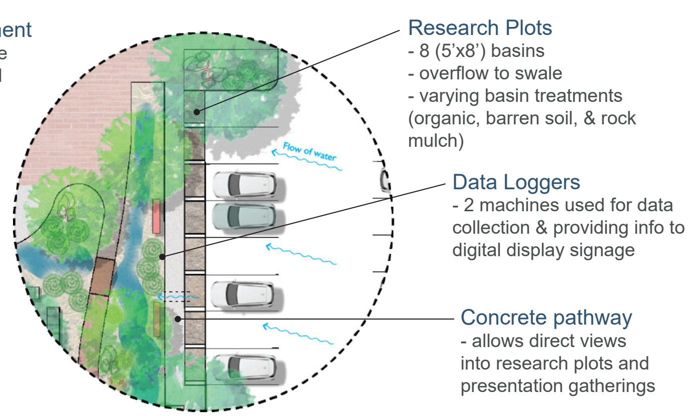


Figure15 - Research Infrastructure

Figure 16 - Sidewalk drainage detail

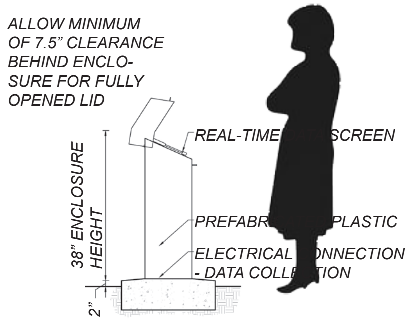
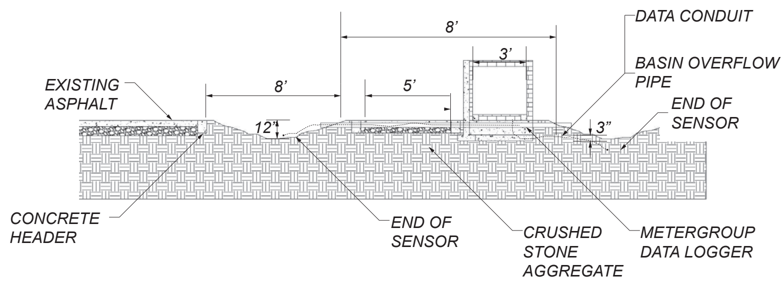


Figure 17 - Sidewalk drainage detail



One partnership (Figure 15) created for the design with Dr. Laura Meredith from the School of Natural Resources and the Environment will study microbial presence in basins, and treatment impact on basin infiltration. The design will provide 8 study basins to repeat study treatments exposed to parking lot runoff. This experiment will provide educational opportunities through signage (Figure 16) and tours of the site. Metergroup data loggers will be installed on site (Figure 17) and connected to electronic signage that will provide real-time data updates to engage the public and encourage research support.

The design provides infrastructure for studying the effectiveness of phytoremediation in arid environments (Figure 18).. Current research provides little information related to arid climates, but this topic is crucial due to the concentration pollutants reach after months without rain. Vehicles deposit Cd, Cu, Pb, and Zn, which collect on parking lot surfaces and concentrate in riparian areas after rain events. If left untreated, these pollutants can reach toxic levels, and infrastructure devoted to this study can be used in arid environments experiencing dangerous pollution levels. Experts in the field of planting design were consulted, Shawn Kelly, President of ASLA, and Margaret Livingston, Professor at CAPLA for input on plants selected for the design. Based on existing research and gaps in research, they agreed that this experiment would provide valuable research throughout the site. Each water harvesting basin will become a study area, with defined planting groupings that will be periodically harvested and tested for pollution concentrations.

Other provided infrastructure will relate to material longevity and performance. Permeable paving options have become increasingly popular over the years, but their performance in this environment has yet to be quantified. Small permeable paving projects have been installed on campus, but without proper research, the U of A cannot invest in these new materials. A series of permeable pavers will be installed along with permeable asphalt to

Figure18 - Research infrastructure and pedestrian interaction

determine the maintenance regime required for optimal performance and the longevity of the product in the hot dry environment of the desert. This information is incredibly important to the landscaping industry as a whole and this information will determine if permeable materials have been successfully developed for arid environments.

Existing research for phytoremediation currently focuses on aquatic plant species capable of filtering toxins. In arid environments, this information is not applicable due to the limited presence of surface water. This design looked at research completed in nearby western environments (Yang, 2015). This data allowed the team to extrapolate on plant families, and use relatives of plant species which have been identified as phytoremediators (Table 4). Basins throughout the site will become study areas, using repeatable plant combinations to create phytoremediating test plots to isolate and identify which arid adapted plants are best suited for environmental remediation. CAPLA faculty, and Shawn Kelly, President of ASLA were consulted in the concept and selection of plant materials.

Table 4 - Phytoremediating plant palette

Trees		Shrubs				Grasses/Accents	
Celtis reciculata	Netleaf Hackberry	*Asclepias subulata*	Desert Milkweed	*Ericameria nauseosus*	Rabbitbush	*Aristida purpurea*	Purple Three-Awn
Chilopsis linearis	Desert Willow	*Atriplex canescens*	Fourwing Saltbush	*Eriognum fasciculatum*	Flattop Buckwheat	*Hesperaloe parvifolia*	Red Yucca
Dalea spinesa	Smoketree	*Gutierrezia seortina*	Late Snakeweed	*Euphorbia antisyphiliticia*	Candellia	*Muhlenbergia porteri*	Bush Muhly
Prosopis velutina	Velvet Mesquite	*Datura wrightii*	Sacred Datura	*Hymenoclea salsola*	Burrowweed	*Muhlenbergia rigens*	Deer Grass
Quercus virginiana	Live Oak	*Ephedra nevadensis*	Mormon Tea	*Kraschenin-nikovia lantana*	Winterfat	*Nolina Macrocarpa*	Beargrass
		Ericamerica larcifolia	Turpentine Bush	*Larrea tridentada*	Creosote	*Yucca Pallida*	Pale-leaf Yucca
		Ericameria paniculata	Mohave Rab-bitbush	*Pluchea sericea*	Arrowweed	*Yucca rostrata*	Beaked Yucca

Finances

The team created a budget to identify the funding required for a project of this size. The team reached out to Dr. Alejandro Angel, Vice President and Principal at Psomas Engineering Firm for examples of parking lot renovation budgets. His advice addressed the feasibility of expensive components and assisted the team in reconsidering a 75,000 ft^3 underground cistern to retain 100% of a 25-year storm event due to cost constraints. His advice was crucial for an effective proposal and timely implementation if the design is constructed on the U of A campus.

A funding strategy was developed for local sources, focusing on the University and six surrounding colleges and museums bordering the site. In particular, support could come from the Dean of CAPLA, who serves on the U of A's Strategic Plan Board, and defined the built environment as an asset to be enhanced across campus. Financial support from CAPLA could influence surrounding leaders to initiate funding for the project.

The UA provides grants through the Green Fund, supporting sustainability projects on campus. Green Fund Annual Grants have no budget limit, and project that are allocated the

$10,000 award can be accomplished over 1-3 years. The Office for Research, Discovery, and Innovation provides funding and support for new projects. Grants for new projects and faculty like Dr. Meredith, are supported Category I Grants. Faculty Seed Grants of $10,000 can "jump start" projects and aid in further funding development. National and State awards can be found in Table 5.

Table 5 - Funding opportunities

Entity	Grant Title	Grant Description	Amount Awarded
USDA	Conservation Innovation Grant	Projects that drive public and private center innovation while conserving resources	Max $1 Million
	Why is it Applicable?	The value of parking lots increase as the services they provide are enhanced. This project improves water quality and temperatures associated with parking lots	
USDT	Transportation Alternative Program	Projects that address enhanced mobility options, and environmental mitigation related to stormwater	Max 80% of project cost
	Why is it Applicable?	This project focuses on pedestrian, bicycle, and other multi-modal users integrating into the site's pedestrian networks	
NSF	Rapid Response Research	Projects related to gathering research based on anthropogenic disasters	Max $200,000
	Why is it Applicable?	Mitigating the urban heat island effect will reduce high temperatures which can lead to medical complications and cause heat related deaths	
Landscape Architecture Foundation	Case Study Investigation Grant	Projects that examine the services the landscape provides through fieldwork and data collection.	$10,000
	Why is it Applicable?	This project will provide research on landscape performance related to stormwater infiltration and pollution sequestration	
AZ Dept of Forestry and Fire Management	Community Challenge Grant	Programs that support sustainable urban and community forestry programs at the local level	$5,000- $20,000
	Why is it Applicable?	This project will supplement urban forestry on campus using native low water use species	
National Garden Club	State Garden Club Scholarship	For student training and environmental education	$4,000
	Why is it Applicable?	Project research conducted by graduate students will improve knowledge of the landscape's impact on arid environments	
EPA	Pollution Prevention Grant	For entities providing pollution prevention outreach education to local businesses.	$40,000-$500,000 for up to 2 years
	Why is it Applicable?	Parking lot retrofits demonstrate how businesses can improve water quality & reduce cooling costs associated with parking lot temperatures.	
	Environmental Education Grant	Education projects that promote environmental awareness and provide skills to protect the environment.	$50,000- $100,00 for up to 2 years
	Why is it Applicable?	Signage & tours of research on the parking lot will educate the community about the impact of vehicles & parking lots on our environment	
	Environmental Justice Grants	Projects that address local environmental and public health issues in the community.	$30,000
	Why is it Applicable?	Improving water quality and reducing heat island effects in desert communities is important for reducing heat related illnesses and deaths.	
	Community Development Block Grant	Projects aimed at long term community needs and repair community infrastructure.	$200,000- $1 million
	Why is it Applicable?	The U of A is a public campus, and improving infrastructure like parking lots will benefit the community's temperatures, water quality, and pedestrian safety.	
	Section 319 Grant	Projects related to water pollution prevention programs education and demonstration	60% of the approved cost
	Why is it Applicable?	This site highlights reductions in stormwater runoff and reduces the amount of pollution coming off-site and into surrounding watersheds.	
	Science to Achieve Results Grant	Projects related to water quality and sustainability	$44,000 per year, max 2 years
	Why is it Applicable?	By utilizing bioswales and phytoremediators, the design seeks to maintain parking spaces while improving water quality coming off-site	

Operation and Maintenance

Project maintenance is crucial for the sustained function and benefit of the site's design. To optimize operation and maintenance of (Re)Searching for a Spot, the team contacted Woody Remenicus, Project Manager and Stormwater Management Supervisor for Facilities Management (FM) to develop the following maintenance plan for the project (Table 6).

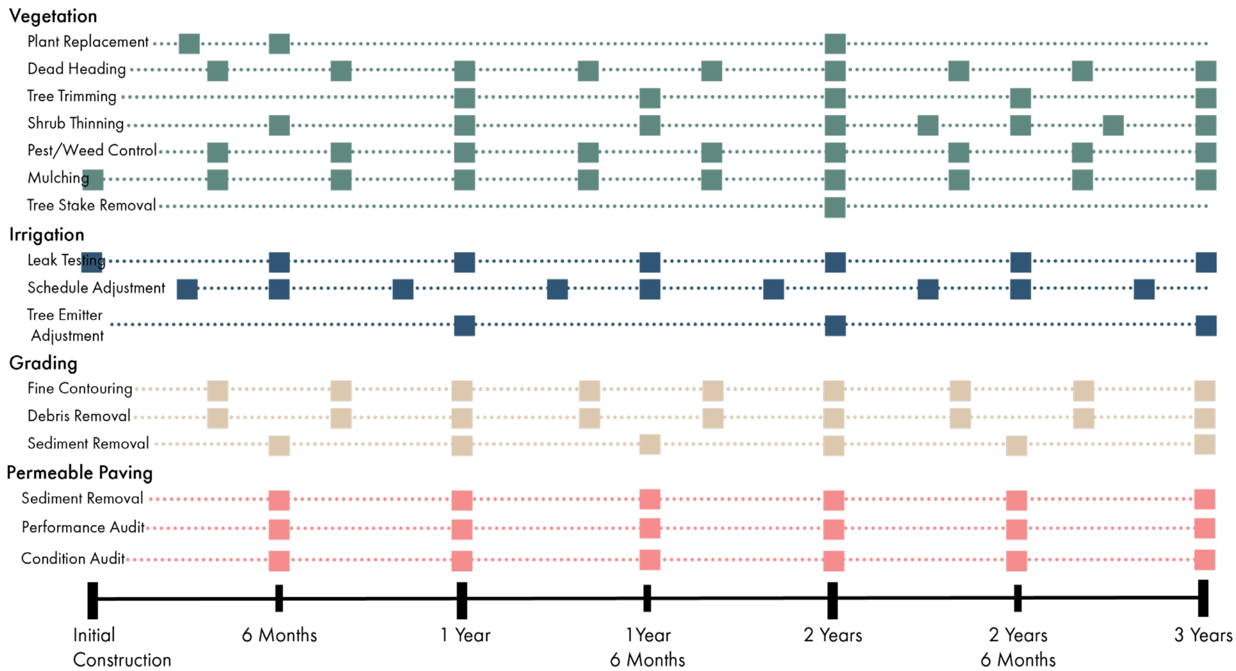


Table 6 - Maintenance schedule

Community Impact

This project demonstrates the benefits an enhanced parking lot can provide, and how the concept can be replicated across the campus and surrounding communities. This project expects to bolster educational offerings on U of A campus and the surrounding communities on green infrastructure, stormwater management, environmental education, and art, for faculty, students (K-graduate), and the general public. Through courses offered by the collaborating departments on this project, the research spot located on the project site would offer students practical skills by learning in authentic environments to design for sustainability.

In addition, tours will assist the publics' visibility of the project site. Tucson groups such as Watershed Management Group, a local non-profit, and Brad Lancaster, a Tucson water harvesting expert frequently use U of A's water harvesting projects as institutional GI examples. The site will impact the urban heat island (UHI) effect which typically affects underserved populations at risk from heat related illness and death. *(Re)Searching for a Spot* can provide an example of a parking lot retrofit through GI strategies could alleviate UHI and improve the health and environment in underserved communities. This study will provide empirical findings that support decision-making on U of A campus, and city/state level "million-dollar" stormwater infrastructure. Agencies need GI performance data (in particular, arid environments) prior to adopting alternative environmental policies for cost-effective stormwater management solutions. In summary, *(Re)Searching for a Spot* expects to leave a lasting impact on the U of A campus and the Tucson community in providing resilience design solutions to enhance the built environment.

BUDGET & CALCULATIONS

Table 7 - Budget

Units	Walkways	Quantity	Price	Total
SF	Permeable Pavers	8,681.00	$4	$34,000
Ton	Base aggregate	215 (1" depth)	$17.50	$3,800.00
Ton	Decomposed Granite	32 (3" depth)	$5	$160
EA	Corten Steel Bridges	53 (4x8 1/2"sheet)	$980	$52,000
EA	Concrete Scupper	2	$600	$1,200
LF	Concrete Header (landscape) 4"x6")	1,979	$20	$39,500
SF	Concrete Sidewalk	1,533	$4	$6,000
EA	Curb Access Ramp	6	$2,500	$15,000
SF	Pavement Staining	12,685	$5	$63,500
LF	Hand Rail	313	$40	$1,500
				$216,660
Units	Landscape	Quantity	Price	Total
SY	1/2" Screened	1,666	$4.29	$7,147
SY	4"-8" Rock Mulch	1,666	$23.01	$38,334
EA	Trees 24" Box	14	$185	$2,590
EA	Trees 15 gal	38	$137	$5,222
EA	Shrubs 5 gal	130	$25	$3,250
EA	Shrubs 1 gal	100	$10	$1,000
Ton	Boulders	9 (30 18" rocks)	$300	$9,000
LF	PVC 1" sch 40	1522 /100=15	$109.71 per 100ft	$1,669
LF	1/4" poly tubing	500	4.16 per 25' roll	$83
LS	Valve Assembly	1	$15,000	$15,000
CY	Landscape Excavation	267	$34.50	$9,200
SY	Landscape Fine grading	803	$2.45	$2,000
HOUR	Landscape Pruning	20	$250.00	$5,000
EA	Tree Grate and Frame	5	$2,800.00	$14,000
LF	Concrete Weir	25	$45.00	$2,250
LF	Rock Check Dam	25	$25.00	$1,250
EA	PVC sleeving	5	$136 (per 5" x 20')	$680
LS	Landscape Establishment	1	$25,000	$25,000
LS	Miscellaneous work (basin outlet)	1	$5,000	$5,000
LS	Mobilization	1	$10,000	$10,000
				$157,675
Units	Seating	Quantity	Price	Total
CY	Cast in place seat walls	20	$90	$1,800
CY	Concrete Base	100	$90	$9,000
EA	Benches	8	$3,000	$24,000
				$34,800
Units	Signage	Quantity	Price	Total
EA	Educational signage	5	1x steel $980 + .5 cy concrete $50	$5,150
EA	Wayfinding signage	10	1x steel $200 + .2 cy concrete $25	$2,250
EA	Bench signage	3	Acrylic Sheets 24x48 $20	$60
CY	Concrete Base	4	$90	$360
SF	Concrete Engraving	600	$20	$12,000
				$19,820
Units	Parking lot	Quantity	Price	Total
SF	Permeable asphalt	4197	$6	$25,180
TON	Aggregate	257 (6" depth)	$156.00	$40,000
TON	New asphalt	213 (4" depth	$171	$35,000
EA	Wheel Stops	138	$70	$9,660
LF	Header Curb	2,224	$15	33,360
LF	Pavement Marking	2,502	$0.25	$625
SY	Fog Coat	2,120	$25	$53,000
				$196,825
Units	Demolition	Quantity	Price	Total
				$40,000
Units	Extra	Quantity	Price	Total
LS	Contingency			$93,000
LS	Temporary Traffic control devices			$20,000
LS	Contractor Quality Control			$20,000
LS	Art Work			$20,000
LS	Labor			$93,000
				$246,000
Units	Walkways	Quantity	Price	Total
EA	Data Logger	2	$800	$1,600
YEARS	Cloud Storage	5	Annual subscription $185	$925
				$2,525
			TOTAL	$915,000

Table 8 - Time of Concentration

	Subwatershed 1 (min)	Subwatershed 2 (min)	Total (min)
Existing	13.19	8.7	22
Proposed	72	66.84	138.84

Table 9 - Total Runoff

Area	Area Sq. Ft.	2-year Runoff (ft^3)	25-year Runoff (ft^3)
Parking lot	108,000	190,080	329,400

Table 10 - Basin Capacity

Basin Location	Avg. Depth (ft)	Cubic Feet (ft^3)	Gallons (gal)
Non-Vegetated Research Area	1	360	2,693
Vegetated Research Swales	1	22,569	168,828
Total		22,929	171,521

Table 11 - Total Runoff Depth

Storm Event	Total Runoff Depth (in)
2- year Existing	1.26
2- year Proposed	1.22
25- year Existing	2.50
25- year Proposed	2.46

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