MEMORANDUM

Date: September 5, 2018

To: Linda Mayro, Director
Sustainability and Conservation

Ursula Nelson, Director
Department of Environmental Quality

Suzanne Shields, Director
Regional Flood Control District

From: C.H. Huckelberry
County Administrator

Re: **Green Infrastructure Plan**

I have reviewed your August 17, 2018 memorandum and approve the recommendations, including the two pilot projects listed with the addition that the pilot program is to be expanded to include the Kino Sports Complex and urban stormwater expansion for turf irrigation.

In addition, all Loop vegetation projects are approved and are to be given priority similar to the pilot program projects.

Finally, I would appreciate more detailed development of funding sources associated with these projects and the cost of implementation. Please include staff and resource commitments that may be necessary to enhance the production of native plants at the Native Plant Nursery to support the Green Infrastructure Program.

CHH/anc

Attachment

c: Carmine DeBonis, Jr., Deputy County Administrator for Public Works
Chris Cawein, Director, Natural Resources, Parks and Recreation

PIMA COUNTY

Sustainability ~ Conservation ~ Historic Preservation

Date: August 17, 2018

To: C.H. Huckelberry, County Administrator

Thru: Carmine DeBonis, Jr., Deputy County Administrator for Public Works

From: Linda Mayro, Director, Sustainability, Conservation and Historic Preservation
Ursula Nelson, Director, Pima County Dept. of Environmental Quality
Suzanne Shields, Director, Pima County Flood Control District

Subject: **Report and Recommended Action Plan for Green Infrastructure, Low Impact Development & Trees (GI/LID + Trees): Climate Resolutions 2017-39 & 2017-51**

In response to your July 20, 2017 memo requesting reports on actionable climate mitigation and adaptation measures to meet the County's Paris Agreement 2025 goals, this report details the work completed on *Item E. Green Infrastructure and Low Impact Development with Trees (GI-LID + Trees).*

A working group of internal and external experts was formed and led by PDEQ to identify County properties and rights-of-way (ROWs) for GI and tree installations. The group focused on expanding the County's previous work to restore riparian and watershed areas. In particular, the work group focused on potential returns on investment that could be attributed to GI and tree installations, for example in terms of providing shade and cooling, reduction in urban heat island effects, improvement in air quality, stormwater management, flooding abatement and carbon sequestration.

This type of analysis was undertaken through a pilot study of two sites to evaluate the utility of Autocase™, a cloud-based software modeling tool, in providing triple bottom line cost-benefit analyses that quantify not only the financial impacts but also the social and environmental impacts. For this pilot study, Autocase™ was used to evaluate the triple bottom line for the Meander Bend and the Southern Arizona Children's Advocacy Center green infrastructure projects.

In the process of preparing this report, Moody's Investors Service, a leading provider of bond credit ratings, announced that they plan to consider a municipality's exposure to climate risks as part of future credit rating evaluations. With this consideration in mind, staff also addressed the value of Green Infrastructure in demonstrating climate readiness to bond rating agencies.

This report summarizes the process, results and recommendations that emerged from the working group. In general, staff recommend the County direct further efforts and resources towards green infrastructure installations that includes both retrofit projects and new capital improvement

projects that would benefit from the addition of GI. This recommendation is based on existing literature and case studies and on the results of the analytical modeling using Autocase™ that quantified the triple bottom line costs and benefits of green infrastructure.

A detailed list of all recommendations can be found in Chapter 4 of the report starting on Page 26. At this time, we recommend the following next steps for the GI Action Plan:

1. Approve the List of Candidate GI Sites and direct staff to update the list annually.

2. Direct staff to select the top five to ten sites and develop a GI preliminary retrofit design. Use Autocase™ to analyze the triple, bottom-line costs and benefits by working with RFCD for each site. Departments responsible for these selected projects will identify funding sources each fiscal year for implementation of the top projects provided that funding is available. The experience gained from these projects will help inform future projects in the implementation process for GI/LID+Trees.

3. Direct staff to develop or update as needed Standard Details and Specifications for commonly constructed GI features. Develop a maintenance manual and an education and communication plan for staff to accompany the information.

4. Direct staff to develop an implementation plan to integrate GI/LID+Trees design features into County projects, where feasible, that include both retrofit and new capital improvement projects.

We appreciate your consideration of these recommendations, and we are available to discuss them further at your convenience. Once you have had the opportunity to review the report and its recommendations, we would be happy to develop a distribution list for the report and approved recommendations.

LM/UN/SS/vb

Attachments: GI Action Plan for Pima County
Appendix D, Autocase

Climate Adaptation Through Green Infrastructure Low Impact Development + Trees: A GI Action Plan for Pima County

PIMA COUNTY

August 3, 2018

Prepared in cooperation with:

Community Development and Neighborhood Conservation

Department of Environmental Quality

Department of Transportation

Development Services Department

Facilities Management

Health Department

Natural Resources, Parks and Recreation

Office of Sustainability, Conservation and Cultural Resources

Pima Association of Governments

Regional Flood Control District

Regional Wastewater Reclamation Department

Tucson Clean & Beautiful

TABLE OF CONTENTS

EXECUTIVE SUMMARY **1**
1. INTRODUCTION **3**
2. PILOT PROJECT DEMONSTRATION SELECTION PROCESS **8**
A. Description 8
B. Pilot Project Design & Methods 9
C. Evaluation of pilot project life-cycle costs and benefits 13
D. Comparison of Stationary Temperatures to Rising Temperatures 16
E. Value of the assessing GI benefits with Autocase™ 16
3. LIST OF ADDITIONAL COUNTY PROPERTIES FOR GI/LID + TREES INSTALLATIONS **18**
A. Criteria for selecting projects. 18
B. Candidate GI Sites to Install New Infrastructure 18
C. Prioritize Candidate GI List by heat and low canopy 20
D. Best Design and Installation Principles for GI/LID + Trees on County Parcels 20
E. Operation and Maintenance of Green Infrastructure 22
F. Communicate Green Infrastructure message to staff and public 23
G. Funding Sources for Green Infrastructure 24
H. Training and Recommended Future Tools 25
4. RECOMMENDATIONS **26**
REFERENCES 28

Appendices

A. Priority for selecting GI/LID + Trees projects
B. List of GI/LID + Trees Projects
C. Plant Materials Salvage and Selection for Pima County Projects
D. Triple Bottom Line Cost Benefit Analysis of Meander Bend Park and Southern Arizona Children's Advocacy Center (SACAC)

LIST OF FIGURES

Figure 1. Recent temperature trends in Pima County from the National Weather Service Tucson, AZ 3
Figure 2. Historic temperature trends in Pima County from National Weather Service Tucson, AZ 4
Figure 3. Annual Rainfall at Tucson International Airport from National Weather Service Tucson, AZ 4
Figure 4. Meander Bend Park Regional Temperature (left) and Tree Canopy Cover (right)..... 10

Figure 5. Preliminary Design of Meander Bend Park..... 11
Figure 6. Stormwater Harvesting Ramada and Cistern 11
Figure 7. SACAC Center Regional Temperature (left) and Tree Canopy Cover (right)..... 12
Figure 8. Preliminary Design of SACAC – GI irrigated with swales and stormwater..... 12
Figure 9. Preliminary Design of SACAC – Parking Lot 13
Figure 10. Candidate GI Sites..... 19
Figure 11. PAG's GI Prioritization Tool: Maps of regional surface temperature (left) and tree canopy (right)..... 20

LIST OF TABLES

Table 1. Meander Bend Park TBL-CBA, based on Autocase™ analysis 14
Table 2. SACAC TBL-CBA, based on Autocase™ analysis 15
Table 3. Urban Heat Island Benefit Comparison between Current Temperature and Predicted Temperature (RCP8.5)..... 16

Acknowledgements

The development of the Green Infrastructure (GI) Action Plan is the product of collaborative efforts between ten Pima County departments and subject matter experts from local governmental organizations, non-profits and consultants. This GI Action Plan continues the work begun in 2011 when the benefits of GI were identified for the desert Southwest and documented in the *Low Impact Development and Green Infrastructure Guidance Manual*. Initial activities began within Pima County Public Works and expanded as more departments recognized the benefits of GI to their respective missions. The 2017 Climate Change resolutions passed by the Board of Supervisors also generated enthusiasm within the team. The team is grateful to the Regional Flood Control District for funding and managing the contract to obtain the triple-bottom-line results quantifying the benefits of GI. Hearty thanks is extended to the participants providing their expertise including:

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Many other individuals, not mentioned above, including members of the LID Working Group, provided insights, contributions and inspiration for this action plan.

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EXECUTIVE SUMMARY

Moody's Investors Service, a leading provider of bond credit ratings, recently advised that a municipality's preparedness for the impacts of extreme weather patterns, including droughts and severe heat waves, will be weighed "when analyzing credit ratings" (Moody's Investors Service, 2017). Pima County has historically relied on bonds to fund large community infrastructure programs including flood control projects, historic preservation, parks and trails, and wastewater improvements. Bond projects provide tremendous benefits to the everyday lives of residents and visitors, and create thousands of construction-related jobs.

Extreme weather patterns could jeopardize the County's superior credit ratings and low interest rates. Climate scientists have expressed concerns to Pima County planners that surface temperatures in the southwestern United States could rise by another 8°Fahrenheit in undeveloped open space areas and 11°-16°F in urban areas (owing to the heat absorption and radiation properties of concrete and asphalt) by 2050, under current greenhouse gas emission scenarios. At the same time, winter rains will likely decrease and flooding associated with extreme storm events has been increasing. Pima County is currently in the midst of its twenty-first year of drought (Arizona State Climate Office, 2018), which has been compounded by elevated surface temperatures.

In addition to affecting the County's bond credit-worthiness, climate disruptions such as these can impose significant and unanticipated costs for infrastructure and road repairs resulting in a shadow on economic forecasts. Green infrastructure is a remedy, in part, to both of these problems. Green infrastructure (GI) is an engineered system mimicking natural water processes, which includes Low Impact Development and a continuous tree canopy of 20% (Tucson Clean and Beautiful, 2018). In fact, the County's Flood Control District and other departments have implemented GI projects for a number of years in order to restore riparian areas and watersheds.

This Green Infrastructure Action Plan builds on this previous work and fulfills several of the adaptation mandates outlined in the Board of Supervisors' Climate Resolutions 2017-39 and 2017-51. Specifically, this plan achieves three goals: identify additional candidate sites on County lands for GI and tree planting, evaluate the full range of costs and benefits of such work, and demonstrate climate readiness to credit rating agencies.

A team of county staff and external experts undertook the work effort. The process involved requesting departments to submit a list of parcels and right-of-ways that were candidates for GI based on their potential high return on investment to produce some or all of the following benefits: cool buildings and streets, reduce the urban heat island effect, sequester carbon, reduce ozone, conserve water, calm traffic, clean stormwater and abate flooding.

A total of 43 sites were catalogued and ranked by 2008 surface temperature and tree canopy cover using geospatial data shown on a GIS map (Pima Association of Governments, 2018). To clarify

the full range of respective advantages of green infrastructure, staff then collaborated with AutoCase™ developers to model the costs and benefits for two pilot projects selected from the list of candidate sites. Autocase™ is a cloud-based software calculating the costs and benefits of projects to quantify the financial costs as well as the social and environmental benefits, also known as triple bottom line analyses. Staff worked with the Autocase™ modelers to include specific climate projection data provided by the University of Arizona and to localize input data on property values and other considerations that affect outcome results.

In sum, the Autocase™ analysis for these two projects under future drought and elevated temperature scenarios, showed significant climate adaption benefits associated with urban cooling, air pollution reduction, recreation values, flood risk reduction, and in the case of the larger project (Meander Bend Park) an increase in surrounding property values. In undertaking the two pilot studies, staff were able to learn about the modeling tool, and the calculations and assumptions used in the analysis. Staff's takeaway impression was that while Autocase™ is a relatively new tool, training and special attention must be given to incorporate local data to achieve locally calibrated outputs. The tool offers great potential in generating triple-bottom line cost-benefit analyses, which have been difficult if not impossible to accomplish in the past.

The Green Infrastructure Action Plan deliverables completed to date include:

- A County GIS parcel overlay in the Green Infrastructure Prioritization Tool, an interactive GIS-based map produced by the Pima Association of Governments (PAG).
- A list of potential county parcels and Right-of-Ways (ROWs) identified by the team and rated using the PAG GI Prioritization Tool for future GI/LID + Tree installations.
- Selection of two candidate county projects and GI/LID + Trees designs to be assessed with Autocase™ for life-cycle costs.
- Report documenting the life-cycle costs for two county GI/LID + Trees projects.
- Training for key County staff to evaluate the triple bottom line (TBL) benefits of GI/LID + Trees installations.
- Acquisition of a one-year Autocase™ license to characterize life-cycle costs for projects.
- Recommendations for the county GI Action Plan

Ten Pima County Departments[1] represented the team led by PDEQ. RFCD has acquired a license to use Autocase™ for future GI projects. Next steps entail estimating the costs for projects to be built in 2019 using Autocase™. The GI/LID + Trees team will continue to meet and keep the candidate list updated as projects are completed and new projects are added each year.

[1] Community Development and Neighborhood Conservation (CDNC), Dept. of Transportation (DOT), Development Services Dept.(DSD), Facilities Management (FM), Office of Sustainability, Conservation and Cultural Resources (OSC), Pima Dept. of Environmental Quality (PDEQ), Regional Flood Control District (RFCD), Natural Resources, Parks & Recreation (NRPR), Regional Wastewater Reclamation Dept. (RWRD) and Health Department (PCHD).

1. INTRODUCTION

The Pima County Board of Supervisors passed Resolutions 2017-39 and 2017-51 in the summer of 2017 affirming the County's actions to meet the Paris Agreement's 2025 goals to reduce greenhouse gas emissions by 40% to 42% below current levels (Pima County OSC, 2017). Additionally, the County is exploring adaptation measures including the installation of green infrastructure, low impact development features and trees (GI/LID + Trees). These actions entail adding stormwater collection, water storage infrastructure and native plants. The goal of the GI/LID + Trees project is to cool buildings and neighborhoods, The Loop[2], pedestrian walking and gathering areas; sequester carbon; abate flooding and improve stormwater quality. Cooling occurs through increased shade and plant evapotranspiration. A team assembled from CDNC, DSD, FM, PCDOT, PDEQ, RFCD, NRPR, OSC, RWRD, PAG and Tucson Clean and Beautiful met to determine the best options and priorities for GI/LID + Trees on County property and ROWs. This report documents their findings and recommendations.

GI/LID + Trees is a recognized strategy for combatting rising surface temperatures. A recent snapshot of the last two years shows that average monthly air temperatures at night and during the day are higher than the monthly average of the daily low and high temperatures by 2.8°F (1.6°C) and 3.3°F (1.8°C), respectively (Figure 1). Air temperatures during seventeen of the 24 months in 2016 and 2017 set record highs. Elevated surface temperatures were widely reported in the news locally and on the west coast (Di Liberto, 2017).

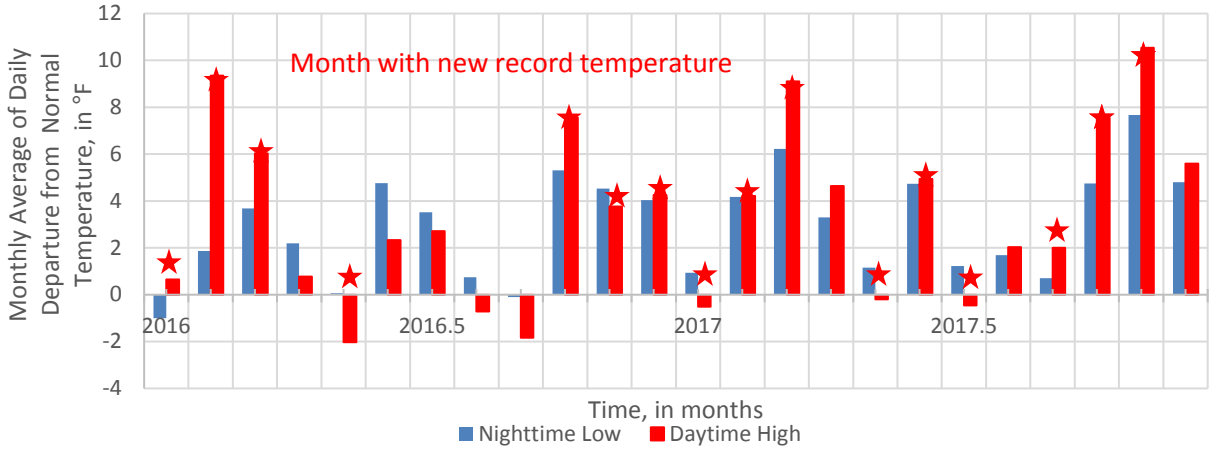

Figure 1. Recent temperature trends in Pima County from the National Weather Service Tucson, AZ

Long-term temperature patterns also show that Tucson has 22 more days with an air temperature above 100°F and seven fewer days below freezing in the last three decades as compared to the previous three decades of 1951 to 1980 (Figure 2). By adding shade trees, GI can help lower temperatures 4°F to 40°F, depending upon the tree's maturity and placement (NOAA, 2014).

[2] The Loop is a system of paved, shared-use paths and short segments of buffered bike lanes connecting the Rillito, Santa Cruz and Pantano River parks with the Julian Wash and Harrison Road Greenways.

Planting trees is recommended to begin as soon as possible to benefit from the shade of mature trees, which take 5 to 10 years to grow an effective canopy.

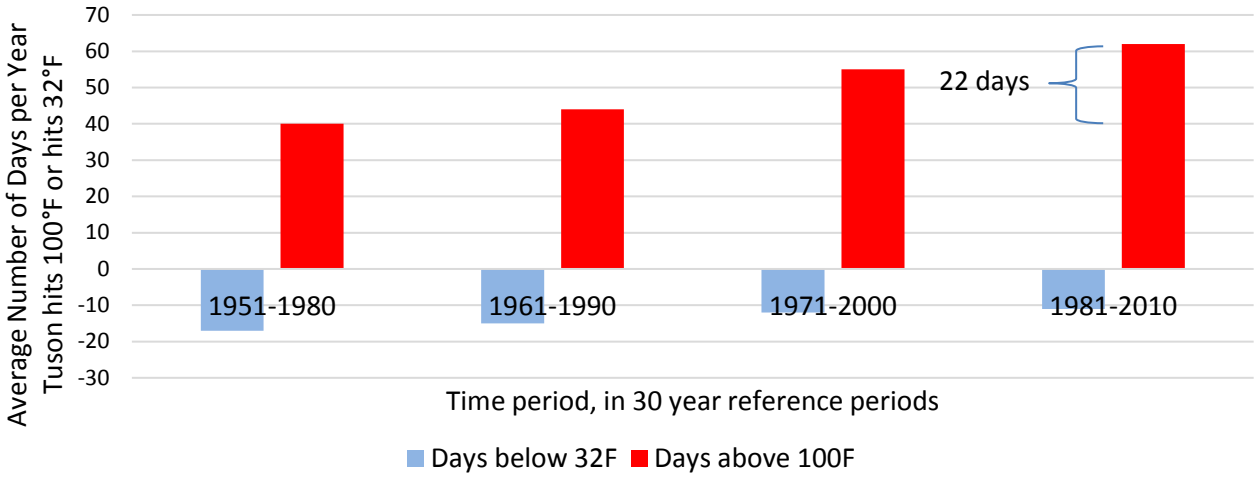

Figure 2. Historic temperature trends in Pima County from National Weather Service Tucson, AZ

Rainfall patterns have changed since the drought began in the mid-1990s. The normal rainfall is 11.6 inches per year and since the drought began, rainfall has met the average only four times (Figure 3). Within each year, rainfall has declined in winter and early spring while high intensity rains have been observed during monsoons and occasionally during the fall. Rainfall events are now less frequent and more intense, which increases the potential for localized flooding.

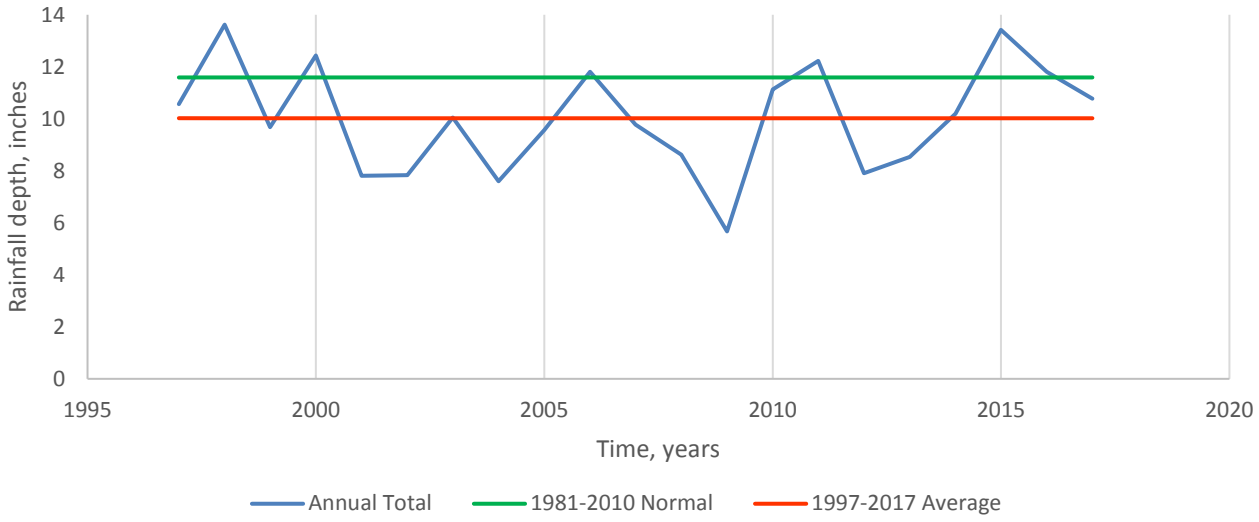

Figure 3. Annual Rainfall at Tucson International Airport from National Weather Service Tucson, AZ

Climate models for the Southwest predict increases in daytime and evening temperatures, persistent drought, increased flooding associated with the increased intensity of storm events and

early snowpack melt (Garfin *et al*, 2013). County residents have experienced these impacts, as noted above by increased air temperatures, persistent drought since 1994 (ADWR, 2017) and greater rainfall intensity. Atmospheric patterns altering local weather are also impacting the snowpack in the Rocky Mountains leading to lower flows on the Colorado River and lower water levels in Lake Mead. To protect Lake Mead from extensive drought conditions that could lead to a declared shortage on the Colorado River, Arizona water managers are negotiating the Lower Basin Drought Contingency Proposal (Arizona Daily Star, 2017). Utilizing stormwater in Pima County for landscape irrigation reduces dependence upon shrinking surface water from the Rockies.

Public Works departments recognized the mulitple benefits of GI and have been working collaboratively with the adhoc LID Working Group composed of government, private and non-profit stakeholders to develop green infrastructure. Specifically, the added impervious surfaces, such as roof tops and roads, associated with new development, increases runoff downstream (Atkins, 2015). Development techniques that modify this post-development hydrologic regime to mimic the pre-development hydrology can mitigate this increased runoff. The runoff from existing development can be collected at higher elevations in the watershed with the following actions and infrastructure:

- Collect runoff with curb cuts,
- Convey water with swales that are rock lined or vegetated rather than concrete,
- Infiltrate water using bioretention basins and cells, permeable paving, constructed wetlands, infiltration galleries and underdrains,
- Store harvested water in cisterns above ground or below ground, and
- Reuse the water for landscape irrigation.

The added vegetation removes air pollutants by intercepting particulate pollutants, namely the smaller sized $PM_{2.5}$, and absorbing gasesous pollutants like ozone, sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Lower ambient air temperatures reduce the photochemical reaction rates of ozone (Nowak et al, 2014). For every ton of carbon dioxide removed, plants release 0.71 tons of oxygen (Urban Forestry Network, 2017). Tucson he American Forests recommends a tree canopy of 20% (Tucson Clean and Beautiful, 2018). In addition to the air quality benefits, trees shading asphalt have been shown to reduce maintenance and repair costs and increase pavement durability (McPherson et al, 2005).

Health impacts include outdoor worker productivity and air quality. Elevated temperatures have been shown to reduce the productivity of outdoor workers (Watts, et al, 2017). Trees improve air quality by absorbing pollutants, intercepting particulates, releasing oxygen through photosynthesis, and transpiring water and shading surfaces to lower local air temperatures which lowers ozone levels (McPherson et al, 2004).

In 2017, Tucson experienced 68 days with temperatures greater than 100ºF and 7 days with temperatures in excess of 110ºF (The Southeast Regional Climate Center, 2018). Each year in Arizona, approximately 2,000 emergency room visits address heat related illness and almost 1,300 deaths occurred from exposure to excessive natural heat from 2005 to 2015 (ADHS, 2015). Visiters, occupational workers, children, elderly, border migrants and individuals with some pre-existing medical conditions are especially vulnerable to heat exposures. Elderly individuals have an additional risk of isolation stemming from elevated heat (Lopez, 2012). Limiting exposure to direct sunlight, limited air movement, high surface temperature, and radiant heat sources can help reduce risk (OSHA, 2018), which is supported by green infrastructure.

Studies have shown that proximity to vegetated land cover is associated with a 37% reduction in allostatic load, bodily wear and tear that results from chronic stress. People close to urban green spaces have significantly lower indicators of stress (blood chemistry with epinephrine and fibrinogen, vascular cell adhesion, depression) and higher indicators of wellness (blood chemistry with norepinephrine, dopamine and dehydroepiandrosterone) (Andrey, et al., 2017). Another study in a hospital following surgery showed patients with views of a small stand of trees left the hospital a full day sooner than those with a view of a brick wall and they required fewer doses of moderate to strong pain medication (Ulrich, 1984). Exposure to urban green spaces is consistent with prevention of depression, cardiovascular disease, premature mortality and quicker recovery from surgery (Sternberg, 2009). Moreover, the addition of green infrastructure is oftentimes associated with a reduction of crime and an increase in prosocial behaviors. These, in turn, can help contribute to social cohesion and an increased sense of wellbeing in the community (Suppakittpaisarn, 2017).

Property values increase by improving aesthetics, drainage, recreational opportunities and increased health outcomes. A Tucson study showed homebuyers had a consistent preference for green space as they were willing to pay almost $18,000 more for the greenest lot and a premium of over $12,000 to live near the greenest riparian corridor (Bark *et al.*, 2011). Landscaping and riparian restoration programs were associated with positive externalities that raised property value and, in turn, tax revenues (Bark-Hodgins, 2006).

Pima County has already begun implementing green infrastructure. For example, RFCD recently completed two water harvesting and tree projects that do not have a supplemental irrigation source and will rely solely on water harvested from the upstream watershed. The first project, in the Midvale Park neighborhood near the Santa Cruz River, will rely on runoff from the neighborhood. Runoff that once flowed direcly into the Santa Cruz will now slowly flow through about an acre of basins that have been re-vegetated. The second project, at Christopher Columbus Park, catches runoff that previously impacted The Loop path and now diverts it into re-vegetated basins that will further enhance The Loop system. The initial plantings were established with the use of water trucks and time released irrigation gel systems, rather than a conventional irrigation system.

Staff incorporated the cost effective methods noted above for GI in the county's long-range Comprehenive Land Use Plan, Pima Prospers. The sites on the Candidate GI List are consistent with the following elements, and their goals, policies and implementation measures:

- Environment: 3.4, Goal 2, Policy 1.b.
- Housing: 3.5, Goal 13, Policy 1.g and Goal 14, Policy 2.d.
- Water resources: 4.2, Goal 3, Policy 6.e.
- Flood control: 4.9, Goal 3, Policy 4.
- Health Services: 5.1, Goal 1, Policy 5, implementation measure i.
- Parks and recreation: 5.3, Goal 1, implementation measure e.

Additionally, Pima County's Sustainable Action Plan is being updated to also align with the climate resolutions and will track GI efforts.

2. PILOT PROJECT DEMONSTRATION SELECTION PROCESS

A. Description

The team's first initiative was to identify a pilot project and run two Autocase™ assessment to determine the triple bottom line benefits of GI/LID + Tree installations as well as evaluate the effectiveness of Autocase™ during the design phase. Autocase™ is a fee-based software and an industry accepted tool for running cost-benefit analyses to quantify the benefits of heretofore less tangible outcomes such as changes in air quality, property values, public health and recreational values. The triple bottom line (TBL) analysis from Autocase™ quantifies the environmental, social and economic costs and benefits of a project and produces an overall total cost called the Net Present Value (NPV), or a measurement "of the present-day value of benefits less present–day value of costs". The software calculates NPV by discounting cash flows over time and adding the discount values (Autocase™, 2017).

RFCD applied an Autocase™ analysis on a previous flood-control project for Airport Wash watershed to evaluate the relative benefits of four designs (Watershed Management, 2015). The four rain gardens selected for analysis by Autocase™ for comparison of best water harvesting in landscaping were 1) capturing rain water from rooftops, 2) use of runoff from streets and parking lots, 3) rain garden retrofits, and 4) Green Streets. Each design implemented water harvesting gravity flow grading techniques but differed in the numbers of trees planted and the areas and volumes of water-harvesting basins. Rain garden retrofits replace concrete and asphalt with porous pavement materials in streets, plazas and parking lots. Green Streets are roadways that include Green Infrastructure and include curb scuppers, curb depressions, core drills, water harvesting basins, swales, bio-retention basins, berms, check dams, infiltration trenches, and active water harvesting or storage systems. The cost benefit analysis provided line item capital expenses and maintenance costs. Benefits included water conservation, cleaner air, heating & cooling, street maintenance, stormwater runoff reduction, grey infrastructure avoided, improved property value, social value of water conservation, greenhouse gas emissions reductions, flood risk reduction, potable water pumping, stormwater pollution reduction and urban heat island effect reductions.

The comparison of the four designs showed that the rain garden retrofit had a negative net benefit due to increased labor, design, excavation, hauling, demolition and concrete costs, as compared to the other designs. Retrofits in roads and parking lots will need a benefit with significant value to have a positive life cycle cost. The other three designs that are typical for new developments held great promise with payback periods ranging between six to ten years and positive net benefits for the 40-year project life (Watershed Management Group, 2015). The comparison method enables managers to evaluate which of the selected design features will yield the best results for the site. The granularity of the results shows the strengths and weaknesses of a particular design as compared to other designs.

In addition to comparing the costs and benefits of different designs, Autocase™ can also quantify the absolute costs and benefits of a particular project. This method compares one design to a do-nothing option. The value of an absolute Autocase™ analysis is quantification of the direct economic values, such as air quality improvement or property value increases, and indirect economic values, such as urban heat island effect.

B. Pilot Project Design & Methods

A subcommittee, led by RFCD, identified the two sites with different structure and use, for cost benefit analyses. One site had no development and the other was adjacent to a Pima County building. Wheat Design was contracted to develop the designs and Autocase™ prepared the triple bottom line analysis for each site (Appendix C).

Autocase™ was customized to reflect local conditions and costs (see Appendix C, pages 37-54). The software included the following information to assess costs and benefits:

- construction costs,
- operation and maintenance costs from county departments and contracts,
- watering costs for plant establishment and occasional watering during emergency drought conditions,
- surface temperature projections from RCP8.5[3] climate models,
- property value increases,
- rate of using recreational areas,
- public health benefits from exercising,
- native food benefits from mesquite and prickly pear harvests,
- air pollution and carbon capture by vegetation,
- reduced energy costs for both natural gas and electricity, and
- habitat restoration and pollination.

Staff selected the two most favorable sites by winnowing a group of potential sites with a field inspection. The field inspection of the potential sites revealed that one site had extensive subsurface utility lines that would be too expensive to move. The second site was too small to show a meaningful benefit. Inspection of nearby properties showed the Southern Arizona's Children's Advocacy Center would have good capacity for expanding the planted area and provide a recreational area for the children. Sites under consideration along The Loop all had high favorability. One site on The Loop had the added benefit of having a remnant pit that was near a new project with excess sediment. The pit resulted when a meander to the Santa Cruz River was isolated after a bank protection installation; staff solved the operational need of filling a pit on one project with the operational need to dispose of extra sediment from another project.

[3] RCP 8.5 is a climate scenario representing 8.5 Watts per square meter applied by the Intergovernmental Panel on Climate Change (IPCC) in global climate models. The data from the global climate model was downscaled to an area representing the Tucson International Airport.

The site on The Loop is called Meander Bend Park and is about ½ mile north-northeast of the intersection of Grant Road and Silverbell Road. The tree canopy cover is 0% and the regional surface temperatures show as an orange hotspot adjacent to cooler neighborhoods making this a high priority project for adding green infrastructure (Figure 4). Additionally, the area is immediately adjacent to The Loop making the installation of a park highly attractive to both the neighborhood residents and Loop users. The 18-acre park design includes contoured berms directing stormwater flow from higher elevations through the park to two detention basins, vegetated swales, enhancement of an existing recreational trail, additional trees and shrubs (Figure 5) and an innovative ramada demonstrating stormwater harvesting (Figure 6).

Figure 4. Meander Bend Park Regional Temperature (left) and Tree Canopy Cover (right)

The building site is called Southern Arizona Children's Advocacy Center (SACAC) and is located about ½ mile due east of the intersection of South Kino Parkway and Ajo Way. The tree canopy cover is 8% and the regional surface temperature is moderately low and shows as a turquoise color (Figure 7). The low tree canopy and open vacant lot proximal to two types of users, namely people traveling along the Loop and people attending SACAC indicated this would be a good location to add more shade for a rest area. The 0.3 acre property will include a gate to access The Loop, a pedestrian trail, rock-lined swales carrying water from the building scuppers to three new infiltration basins, and vegetation comprising trees, shrubs, and cacti (Figure 8). A second alternative was developed to compare the cost of installing an irrigation system that would supply potable water, in lieu of irrigating the site with stormwater. The green infrastructure projects were compared to a parking lot (Figure 9).

The analysis enabled staff to quantify the operational costs for each irrigation method. The results enabled staff to compare the flexibility and cost of an irrigation system with the less flexible green infrastructure and low water costs.

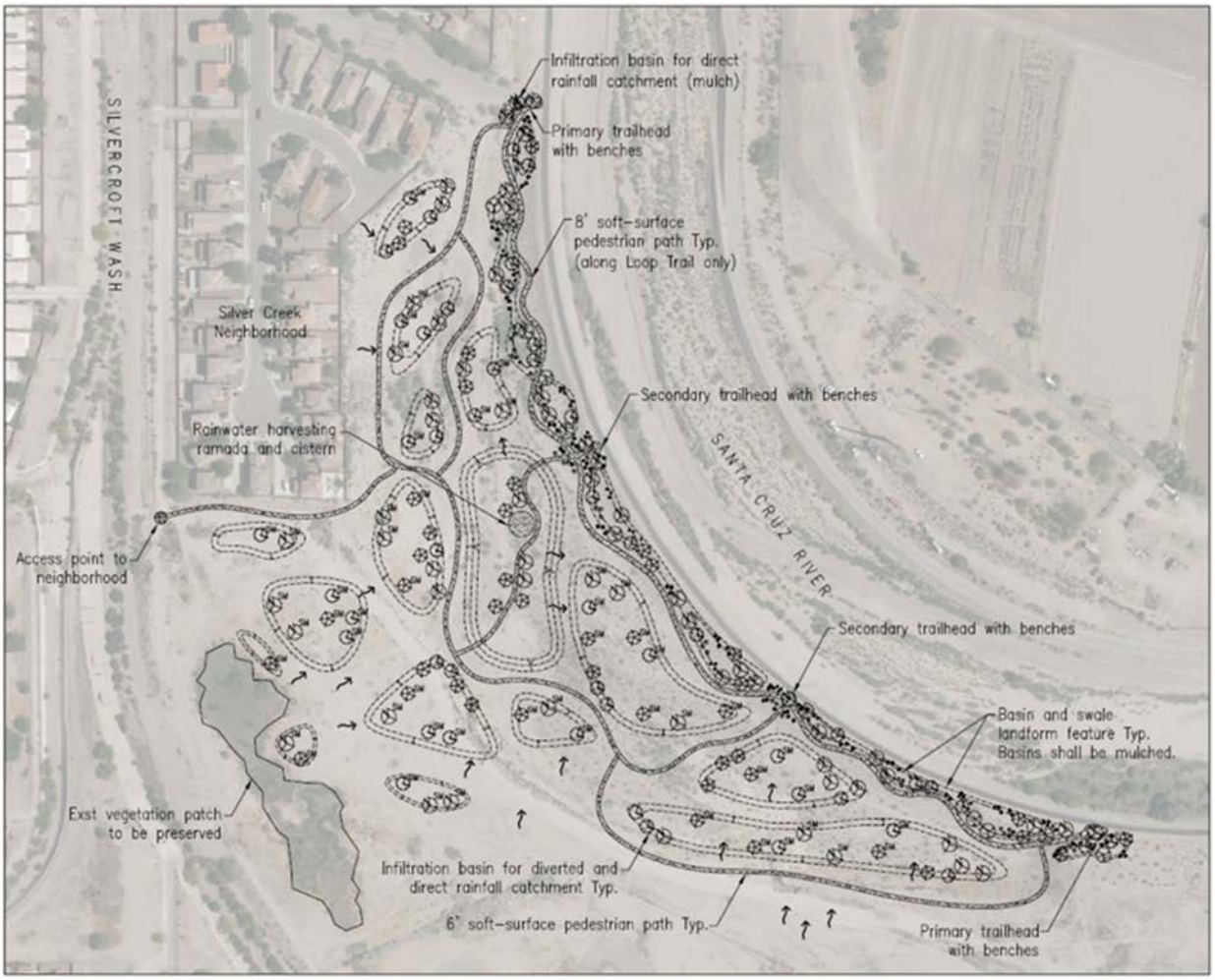

Figure 5. Preliminary Design of Meander Bend Park

Figure 6. Stormwater Harvesting Ramada and Cistern

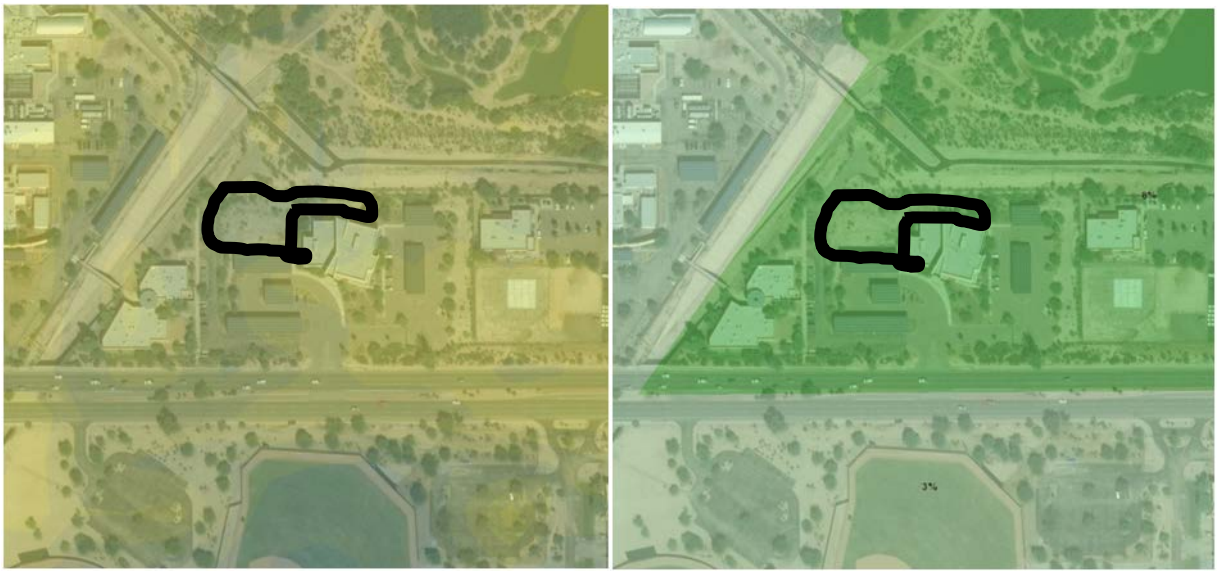

Figure 7. SACAC Center Regional Temperature (left) and Tree Canopy Cover (right)

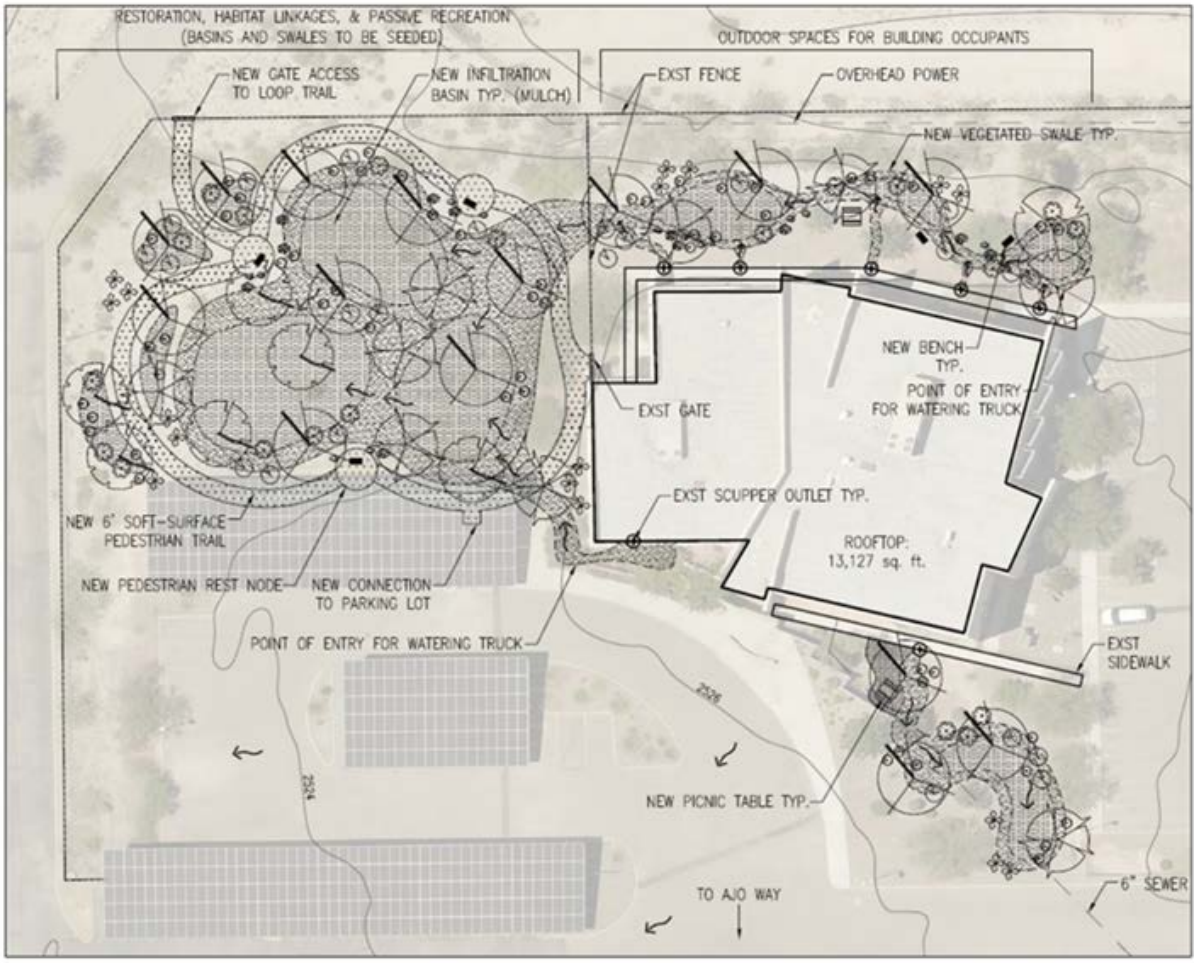

Figure 8. Preliminary Design of SACAC – GI irrigated with swales and stormwater

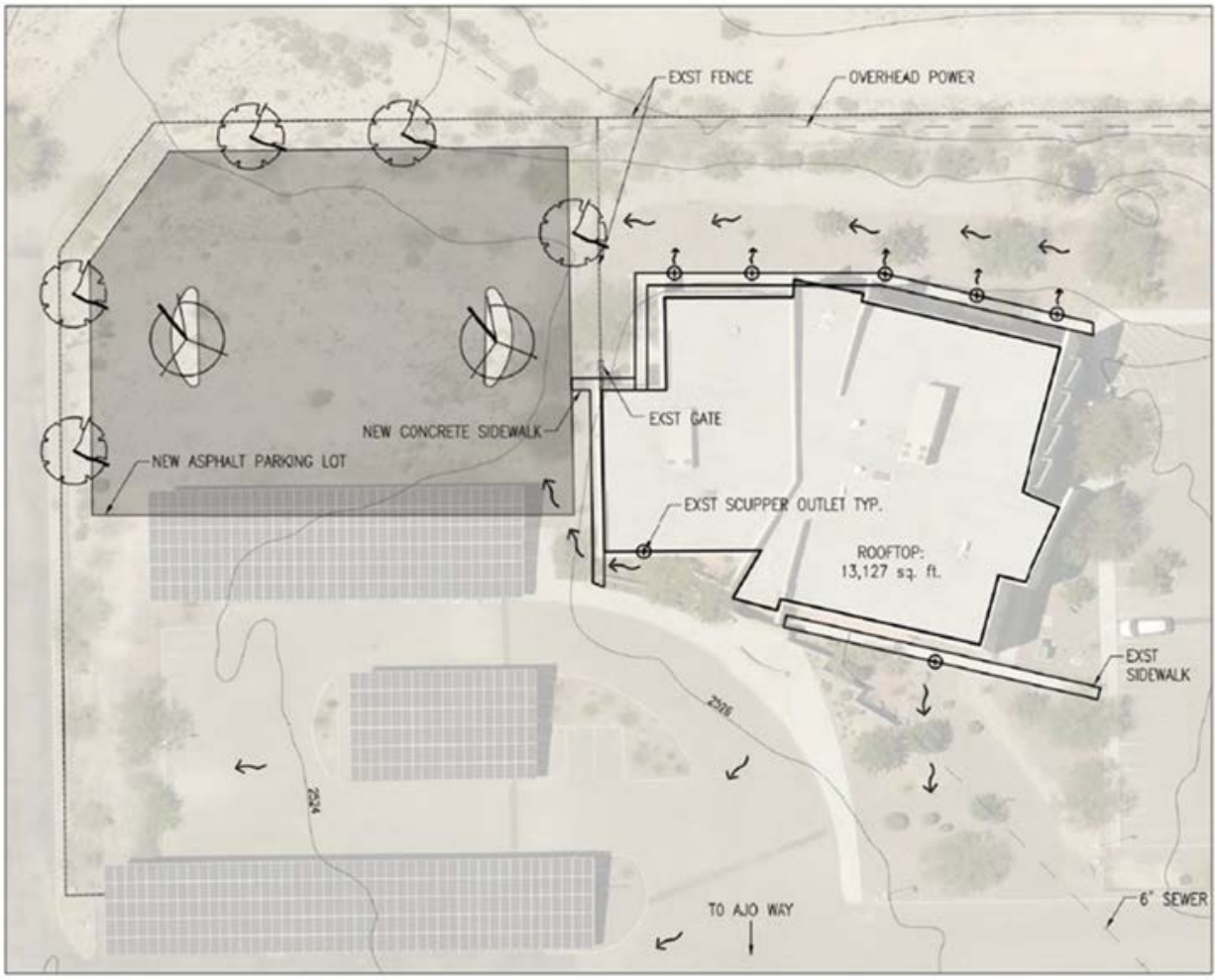

Figure 9. Preliminary Design of SACAC – Parking Lot

The project leads organized an Autocase™ training session for the team with a software representative. The designers met with team members from PDEQ and RFCD to review the preliminary results and verify that the project was accurately characterized for the Autocase™ assessment. The software representative presented the preliminary results and the group discussed the outcomes and requested clarification of input information. Where the default assumptions were not applicable to the project, the software developers integrated additional data from staff to obtain more precise results (Refer to Appendix C for details).

C. Evaluation of pilot project life-cycle costs and benefits

The preliminary design for Meander Bend Park was compared to a do-nothing alternative. Meander Bend Park has a net present value[4] of $9,781,159, using a discount rate of 3%, a rate commonly applied by governmental agencies, over 50 years (Table 1). The total discounted cost

[4] **Net Present Value** (NPV) is the difference between the **present value** of cash inflows and the **present value** of cash outflows over a period of time, in this case 50 years. NPV is used in capital budgeting to analyze the profitability of a projected investment or project. https://www.investopedia.com/terms/n/npv.asp

to build and operate the project is -$1,687,488 while the total benefit for both social and environmental aspects is $11,468,647. The largest benefits include the recreational value ($3.7M), carbon emissions from reduced energy use ($3.1M), heat island effect ($1.8M) and property value ($1.2M).

Impact Type	Cost/Benefit	Mean Value	95% Confidence Interval
Financial	Capital Expenditures	($867,681)	($987,988) to ($ 738,031)
Financial	Operations & Maintenance	($690,662)	($786,432) to ($ 587,455)
Financial	Replacement Costs	($201,735)	($320,647) to ($ 122,882)
Financial	Residual Value of Assets	$ 72,590	$ 9,476 to $ 124,283
Financial	Water Savings	$ 0	$ 0 to $ 0
Social	Heat Island Effect	$1,826,645	$1,255,961 to $ 2,374,508
Social	Flood Risk	$ 100,913	$ 100,913 to $ 100,193
Social	Property Value	$1,159,372	$ 651,931 to $ 1,708,405
Social	Education	$ 16,149	$ 9,388 to $ 24,516
Social	Recreational Value	$3,721,554	$3,721,554 to $ 3,721,554
Social	Public Health	$ 38,012	$ 6,879 to $ 86,165
Social	Food	$ 523,563	$ 314,602 to $ 735,216
Social	Social Value of Water	$ 0	$ 0 to $ 0
Environmental	Stormwater Quality	$ 55,889	$ 55,889 to $ 55,889
Environmental	Carbon emissions from concrete	$ 0	$ 0 to $ 0
Environmental	Air pollution Reduction by Vegetation	$ 328,524	$ 243,049 to $ 414,799
Environmental	Carbon reduction by vegetation	$ 20,154	$ 7,906 to $ 35,648
Environmental	Air pollution from energy use	$ 25,970	$ 13,270 to $ 41,597
Environmental	Carbon emissions from energy use	$3,132,994	$1,223,733 to $ 5,553,594
Environmental	Habitat	$ 385,145	$ 385,145 to $ 385,145
Environmental	Pollination	$ 133,763	$ 133,763 to $ 133,763
	Triple Bottom Line Net Present Value	$9,781,159	$6,038,392 to $14,047,627

Table 1. Meander Bend Park TBL-CBA, based on Autocase™ analysis

The two preliminary designs for the SACAC Green Infrastructure were compared to building a parking lot, using a discount rate of 3% over 50 years (Table 2). The SACAC GI project irrigated with stormwater is compared to the parking lot project and the result is a net present value of $1,127,666; the relative cost to build and operate is $196,349 whereas the social and environmental benefits add to $931,317. The positive relative cost occurs because building and maintaining green infrastructure is less expensive than building and replacing a parking lot over the same period. The largest benefits include the recreational value ($0.7M), heat island effect ($91K), food ($47K), and public health ($20K).

The comparison of SACAC GI irrigated with potable water to the parking lot project has a net present value of $1,067,314 (Table 2); the relative cost to build and operate was $144,996 whereas

the social and environmental benefits add to $922,318. This analysis shows irrigation with stormwater less expensive than potable water by about $60K.

Impact Type	Cost/Benefit	Green Infrastructure irrigated with Stormwater	Green Infrastructure irrigated with potable water
Financial	Capital Expenditures	$145,667	$136,667
Financial	Operations & Maintenance	($45,560)	($52,581)
Financial	Replacement Costs	$120,681	$100,481
Financial	Residual Value of Assets	($10,560)	($10,560)
Financial	Water Savings	($13,879)	($29,011)
Social	Heat Island Effect	$90,915	$90,915
Social	Flood Risk	$8,431	$8,431
Social	Property Value	$0	$0
Social	Education	$0	$0
Social	Recreational Value	$732,336	$732,336
Social	Public Health	$20,255	$20,255
Social	Food	$46,735	$46,735
Social	Social Value of Water	($104)	($9,103)
Environmental	Stormwater Quality	$1,371	$1,371
Environmental	Carbon emissions from concrete	$2,176	$2,176
Environmental	Air pollution Reduction by Vegetation	$12,832	$12,832
Environmental	Carbon reduction by vegetation	$907	$907
Environmental	Air pollution from energy use	$3,362	$3,362
Environmental	Carbon emissions from energy use	$2,589	$2,589
Environmental	Habitat	$7,060	$7,060
Environmental	Pollination	$2,452	$2,452
	Triple Bottom Line Net Present Value	$1,127,666	$1,067,314

Table 2. SACAC TBL-CBA, based on Autocase™ analysis

Based on the results of the Autocase™ analyses, both projects, the Meander Bend Park and the SACAC GI Project are recommended for construction and maintenance. The Meander Bend Park increases property values for both Pima County and the adjacent neighborhood. Additional amenities and shade along The Loop increase benefits to the public's health and education. The SACAC GI project significantly outweighs the value of adding a parking lot. The high benefit of Meander Bend Park compared to SACAC GI is related to the size of the project. Green infrastructure also ties to other departments' goals related to flood control, and improving stormwater, air quality and habitat (supportive of Pima County's Multi-species Conservation Plan). The comparison of gravity irrigation with stormwater with an installed irrigation system using potable water showed there was an additional cost of $37,450 over a 50-year period related

to capital expense for installation ($9,000), maintenance ($7,000), replacement costs ($20,200) and water cost ($1,250).

D. Comparison of Stationary Temperatures to Rising Temperatures

An additional analysis was conducted to quantify benefits for the Urban Heat Island Effect based on predicted changes in temperature (Table 3). One analysis evaluated benefits with stationary temperatures over a 30-year period and the other analysis evaluated the benefits for predicted temperature increases based on the Representative Concentration Pathway (RCP) 8.5 adopted by the Intergovernmental Panel on Climate Change in the Fifth Assessment Report (IPCC, 2014). Both projects showed a positive benefit under stationary temperature conditions. If temperatures increase as predicted by RCP8.5[5], the UHI benefit doubles. The doubling of benefits by accounting for increased temperatures shows the importance of long-term planning to adapt to climate change.

Project	Low UHI	Med UHI	High UHI
Meander - Stationary	$653,006	$948,074	$1,226,916
Meander - RCP8.5	$1,255,961	$1,826,645	$2,374,508
Increased benefit	92%	93%	94%
SACAC – Stationary	$33,320	$46,673	$60,826
SACAC - RCP8.5	$64,905	$90,915	$118,482
Increased benefit	95%	95%	95%

Table 3. Urban Heat Island Benefit Comparison between Current Temperature and Predicted Temperature (RCP8.5)

This type of analysis enables staff to effectively plan for climbing temperatures, and provide evidence to a credit rating agency weighing a municipalities' preparedness for extreme weather patterns (Moody's Investors Service, 2017).

E. Value of the assessing GI benefits with Autocase™

Autocase™ is a tool that quantifies hidden social and environmental benefits of GI. The results reveal the complete life-cycle costs and enable departments to plan for operation and maintenance costs. The table of results (Table 1 or Table 2) illustrate where the benefits and costs occur, which enables a manager to adjust the design to lower costs and maximize benefits. These results may also be communicated to the public during outreach activities to provide information relevant to their interests, such as the value of recreational amenities. The structure of the tool enables the user to use default inputs common within the United States to obtain a quick result or to add parameters specific to a municipality, making it highly versatile.

[5] Air surface temperature data were collected from the Climate Explorer website: monthly average between 2035 and 2065 of the daily high within the month. Predicted average monthly high values: Jan=69.1, Feb=72.1, Mar=77.4, Apr=86.0, May=94.6, Jun=103.6, Jul=103.7, Aug=101.6, Sep=99.3, Oct=91.1, Nov=78.4, and Dec=70.0.

The high customization an Autocase™ analysis limits scaling results from one project to another. For instance, each site has unique variables, such as land temperature and canopy cover, that strongly influence surface temperature. The key benefit for Urban Heat Island effect changes at thresholds associated with the body's response to heat. Where fatigue is possible below 90°F, heat stress is *possible* above 90°F and *likely* above 105°F while in the shade. Hence, if a GI feature lowered the surface temperature a few degrees and crossed below a threshold, a benefit would be achieve; however, if the feature lowered 6°F without crossing a threshold, the coolness would not change the health outcome.

3. LIST OF ADDITIONAL COUNTY PROPERTIES FOR GI/LID + TREES INSTALLATIONS

A. Criteria for selecting projects.

The team discussed criteria for selecting candidate projects. The top criteria is the location within a county regional river park system. The next three temperature goals (potential to decrease air temperature, reduce urban heat island effects and building cooling) are grouped into the second criteria to reduce urban heat island (UHI) effects. This was important to the team as climate scientists have expressed the concern that temperatures in the southwestern United States will rise to 8°F in undeveloped open spaces and 11°F to 16°F in urban areas by 2050. The urban temperatures increase more because of the heat absorptive and radiative properties of concrete and asphalt by 2050. The third criteria groups the avoided costs for water, energy and maintenance. The fourth criteria improves air quality for both public health and the economy. Abating flooding and improving stormwater quality are the fifth and six criteria (Appendix A).

B. Candidate GI Sites to Install New Infrastructure

The forty-four candidate GI sites include Pima County public buildings, parks, reaches of The Loop, rights-of-way, pocket parks, bus stops, and open spaces (Figure 10, Appendix B). Engineered design work and site assessment of the candidate GI sites are necessary to determine topography, earth moving requirements and cultural assessments to obtain project capital expenditures. Future engineering designs that transport stormwater by gravity are key to building low maintenance projects. The List of Candidate GI Sites is expected to change during site assessment and the design process.

The team recommends that the preliminary design plans for the pilot projects Meander Bend Park and SACAC GI be developed into final designs and built by RFCD in 2019. Planting trees is one of the most beneficial ways to reduce UHI effect. Facilities Management identified five county buildings that could benefit from cooling by trees planted adjacent to the building or by modifying parking lots to add trees and porous concrete as a means of reducing parking lot temperatures. Natural Resources, Parks and Recreation identified eight parks where trees could be added. In addition to the two pilot projects, RFCD identified twenty projects with 12 sections along The Loop, six riparian restoration projects, one park and one flood mitigation project. PCDOT identified eight projects with seven in the right-of-way and one at a school. The transportation projects are part of currently planned projects, except for one at a bus stop. All projects require a cultural evaluation, topographic survey, engineering design that shows the capture and transport of stormwater on a landscape plan. Many DOT projects already utilize an LID approach so those increases in vegetation were added to our potential progress towards goals. Where trees are a safety or irrigation concern, hydro seeding, native cacti and succulents are used as alternatives. It would be worth exploring the carbon and shading benefits of native shrubs, yucca, agave and cacti.

The Pima County Native Plant Nursery will partner with each department to grow the plants for each project. Depending upon the species selected, 8 to 18 months are needed to grow a tree from a seedling into a tree that can be planted. Additionally, transplants from construction projects can be planted and the owners will still receive credit for them as part of the NPPO process.

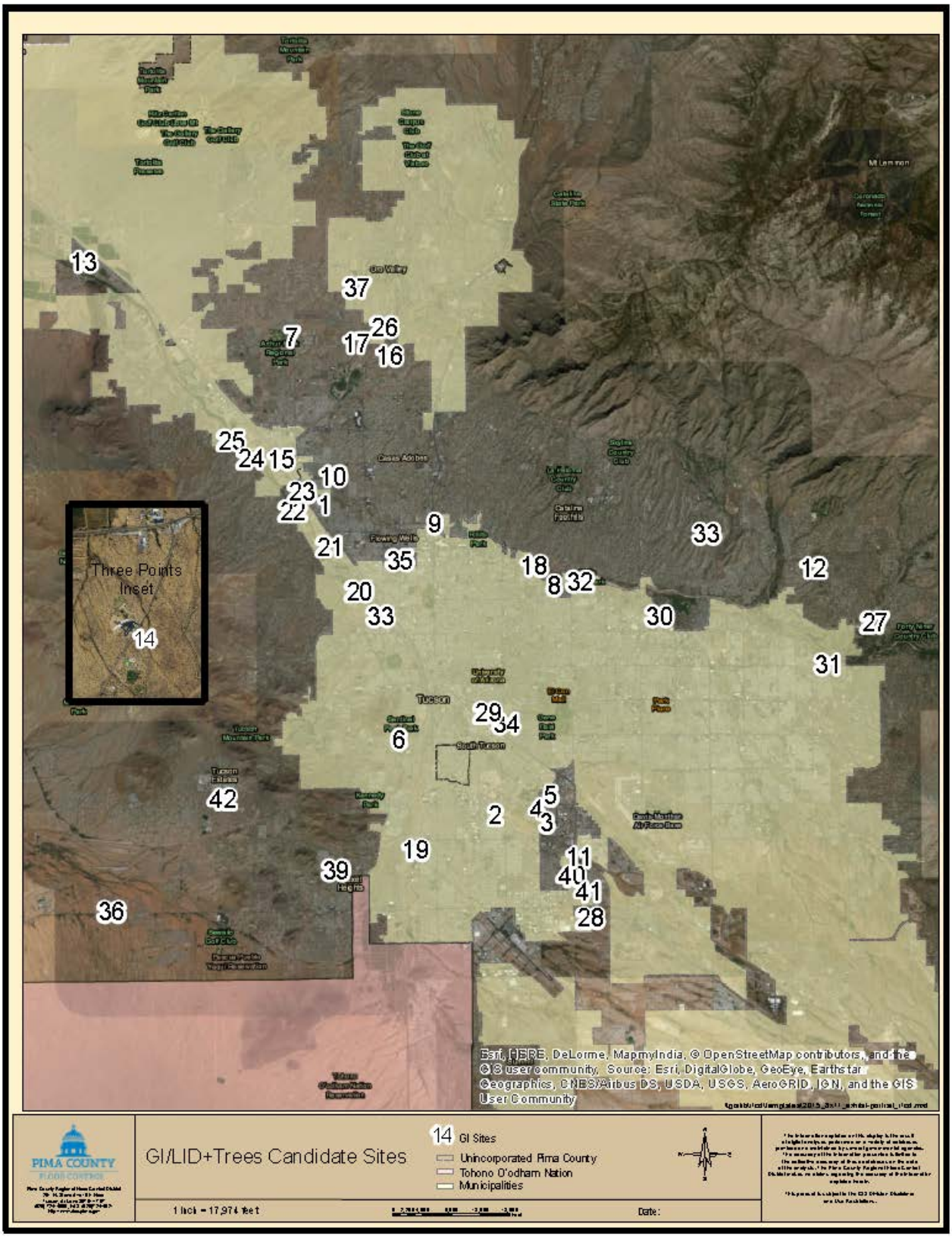

Figure 10. Candidate GI Sites

C. Prioritize Candidate GI List by heat and low canopy

Staff prioritized the candidate GI sites using the 2008 remote sensing data illustrating the regional surface temperate at 10:00am as well as the tree canopy percentage, as illustrated by PAG's GI Prioritization Tool (Figure 11). The surface temperature with warmer colors of yellow to red are above the average temperatures and the low tree canopy areas are shown in pale green areas.

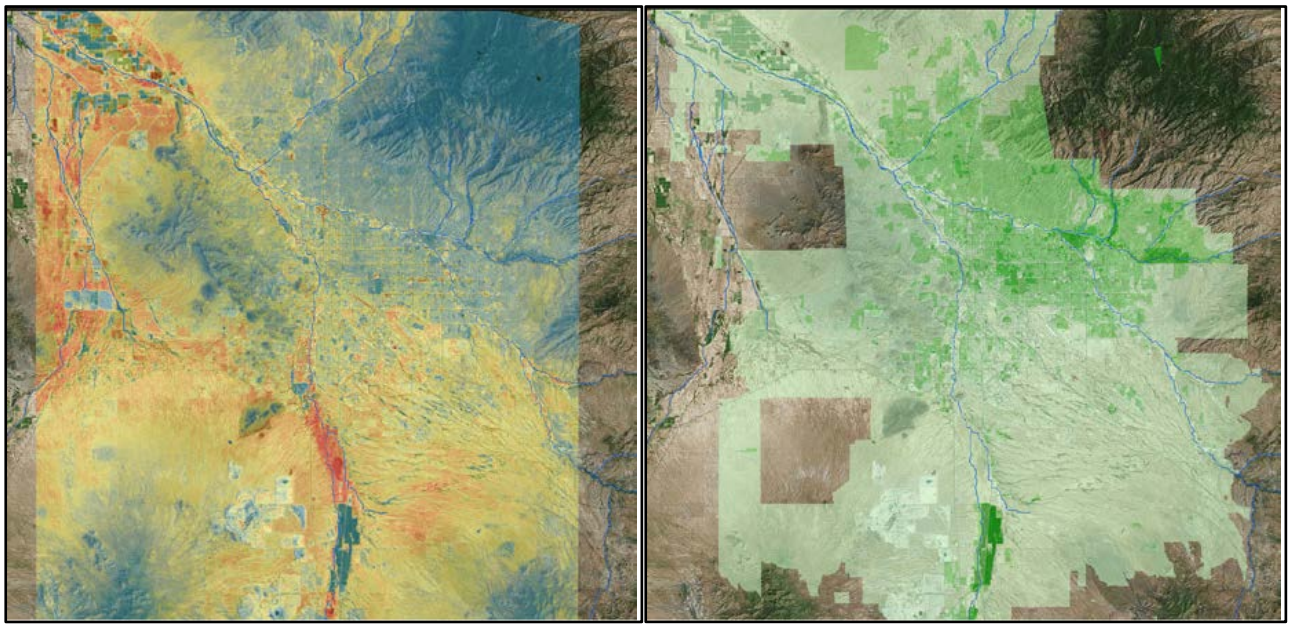

Figure 11. PAG's GI Prioritization Tool: Maps of regional surface temperature (left) and tree canopy (right).

The first step characterized the range of temperatures and percent of tree canopy coverage. The heat and canopy scores were synthesized to obtain a rating for each site. The scores were then ranked such that the sites with highest temperatures and lowest canopy had the highest priority of 1 to the sites with the lowest temperatures and highest tree canopy with the lowest priority of 33.

The top third of the candidate GI sites had tree canopy coverage below 5% and associated high temperatures. The lower third of the priority candidate GI sites include the parks, which have higher tree canopies than the surrounding land uses. These sites need additional trees to increase the tree canopy. Two sites had tree canopy coverage between 15% and 20% and have a low priority for green infrastructure benefits.

D. Best Design and Installation Principles for GI/LID + Trees on County Parcels

Pima County departmental design guidelines should be followed while designing GI/LID features and selecting plant materials. The most important design guidance documents include the following:

- GI-LID Guidance Manual (Pima County *et al*., 2015),

- Design Standards for Stormwater Detention and Retention (Pima County Regional Flood Control District, 2015),
- LID Tool Kit (City of Mesa, 2015),
- PAG Standard Specifications and Details for Public Improvements, and
- Administrative Procedure No 51-3 (Appendix C) for plant material selection.

County staff are currently developing additional details and modifications to existing details in cooperation with local jurisdictions and Phoenix jurisdictions to create a common set for the construction industry. The important designs include gravity flow, basin ingress and egress, sediment traps and public uses. Good gravity flow designs are recommended to collect water at a high point on the property and use gravity to transport the water from that elevation to the point of storage or use, and include elevations or amount of fall between grade controls for installation clarity. Additionally, add a "flow check" to the Department Close Out Checklist. A flow check consists of verifying water flows in the right direction, ponds in the designed locations, and can flow through stabilized overflow points without erosion. Most sites have a shallow grade and visual checks are inadequate to verify proper function. Easy ingress and egress from retention/detention basins for maintenance vehicles reduce the cost of transporting supplies and removing waste materials. Sediment traps are best located at the entrance to the basin and where they are easily cleaned out.

Properly GI design are recommended to factor in all uses of public space. For example, roundabouts containing sewer manholes and green infrastructure need to allocate space for ingress and egress for sanitary sewer maintenance crews as well as space for vegetation to be enjoyed by the residents. Design details can specify minimum areas needed for maintenance to set expectations with the residents. A method of demarcation, such as addition of bollards, could keep the designated areas separate. The design details would become a part of the PAG Standard Specifications and Details for Public Improvements.

The LID Working Group is also considering how to ensure trees have adequate soil aeration, soil composition and space to grow. Typically, the root zone of a mature desert tree in a natural habitat is at minimum double the size of the canopy. This is rarely available in urban areas. It should be recognized that with smaller soil spaces, the resulting tree canopy will be considerably smaller than is typical for the species. When spaces are tight such as near curbs, sidewalks and parking spaces, porous pavers or porous concrete can be an effective alternative to support healthy root and trunk growth as well as tree canopy for shade. Where parking lot slopes direct runoff to tree wells or low-planted areas, retrofits may be added around the trees; however, existing parking lots without these types of slopes are not recommended for retrofitting due to the high cost of regrading and repaving the area.

The Pima County Native Plant Nursery will provide as many plants as possible, within the constraints of growing season and project schedule. The Pima County Native Nursery currently

can provide trees in 30" tall pots, 24" tree pots, 5 gallon or 15 gallon. These sizes may be supplemented with larger trees from commercial nurseries, when required. Trees will be low to medium biogenic Volatile Organic trees. Reduced ozone concentrations can be accomplished through planting species native to the southwest and which have low biogenic Volatile Organic Compounds (BVOC) emissions. The plants available from Pima County Native Plant Nursery include acacias, hackberry (*Celtis*), palo verdes (*Parkinsonia*), ironwoods (*Olneya*), desert willows (*Chilopsis*), ashes (*Fraxinus*), elders (*Sambucus*), and redbuds (*Cercis*). Plant selection, as well as salvage, shall follow Pima County Administrative Procedure 51-3 (Appendix C), which directs staff to use plants native to a Pima County project's site and region.

Landscape is preferably installed in late fall through early spring to minimize supplemental watering. While larger size trees provide a more favorable appearance upon planting, smaller sized trees generally appear to establish more easily. Smaller trees, when protected against vandalism and predators, tend to have a higher survival rate and quicker growth to maturity. Supplemental water is typically required for up to 3 years. More drought tolerant plants may require less supplemental water, while plants with higher water needs may require more water.

E. Operation and Maintenance of Green Infrastructure

A maintenance manual is currently being created in cooperation with members of the LID Working Group composed of local municipalities, Pima Association of Governments, University of Arizona researchers, consultants and non-profit organizations. This manual addresses key needs for GI success, namely awareness, communication, cost-effective implementation, and innovative maintenance techniques. The topics addressed include planting techniques, watering, pruning, fertilizing, plant replacement, soil amendment, mulching and sediment removal. For example, as additional curb cuts are constructed, additional maintenance work will be required to remove the accumulating sediment in sediment traps that would have normally been swept up by sweepers. Alternatively specially designed street sweepers with suction hoses can be used to clean sediment traps.

Lessons learned from early installations of this new infrastructure include proper plant establishment, proper pruning, trash and sediment removal, maintenance level scaled to public visibility, maintenance of irrigation systems and drought condition alternatives. Manual watering is required during plant establishment, which may last up to three years. Less time may be needed in years with abundant seasonal rains, while more time may be required when drought occurs in concurrent years.

Proper pruning addresses a tree's growth characteristics from a seedling through attainment of a full canopy. Sparse pruning in the early years encourages trunk and root growth. Minor pruning may be needed to minimize potential storm damage and falling debris as well as to remove dead or diseased branches.

The level of pruning can be adjusted according to the remoteness of the site or by proximity to areas of high public use. Areas adjacent to a path or with sight lines near intersections of a neighborhood entrance will require more maintenance, while areas hidden from view will require less. Likewise, the level of trash and sediment removal can be customize by level of use.

Additional planning is needed to address extended severe drought conditions that are expected in the foreseeable future. The period of greatest vulnerability occurs between May and June when rainfall is low and temperatures are high. Options to address these stressful conditions include manual watering or a backup irrigation system. Water can be manually added to tree wells, with a water truck and hose. Local landscaping companies and the City of Tucson Department of Transportation (Gary Wittwer, 2017) use this approach. The installation of a backup irrigation system is often not warranted or possible, due to high installation and maintenance costs (See Part 2.C, Project Assessment). Maintenance tasks associated with conventional irrigation systems are also frequently overlooked. For instance, controllers may not be seasonally adjusted, resulting in higher water use than required and increasing monthly water bills. Areas with vandalism require equipment replacement at a high rate. However, the benefit of installing a backup irrigation system is that, during periods of extended drought, staff can manually open a valve instead of arranging for a water truck and staff to deliver the water. This would be an asset if it were not possible to manually water the county's entire tree inventory thereby avoiding die back and canopy loss. On a project-by-project basis, each department will need to weigh the cost of installing an irrigation system activated as a back-up with the cost of losing a portion of the tree infrastructure.

F. Communicate Green Infrastructure message to staff and public

Proper GI design, staff training and signage are recommended to address common losses with green infrastructure. Newly installed green infrastructure is often removed, severely pruned or altered by those unfamiliar with its design or purpose. Inadequately trained maintenance personnel and the public often perceive green infrastructure plantings as "weedy". Often native plantings, which may be less manicured than the public is used to, are not perceived as "landscape", so are driven over or removed by contractors working in public areas. These actions result in additional expenditures to grow new seedlings, replant and irrigate a young plant until it is re-established. County departments also lack consistency in their approaches to landscape maintenance. Personnel supervising landscape maintenance often are assigned multiple maintenance tasks; landscape may be just one component of their duties. Staff training, as described in Section H, is recommended to addressed these issues.

Signage at newly installed green infrastructure can be used to inform both the public and staff to minimize tree pruning in the early years as well as inform the public about the function of green infrastructure such as ground stabilization and collecting water into irrigation areas. The team recommends they coordinate with the Communications Office and Community Relations divisions

of departments to assemble a consistent message for outreach signs and social media. The DOT Sign Shop and FM Sign Shop can prepare the signs.

Consistency can also be facilitated by creating a GI Team to aid department managers in advancing GI/LID, similar to the City of Raleigh's work plan (City of Raleigh, 2016). The GI Team functions could include ensuring essential county operations, assessing long-term cost effectiveness and sustainability, coordinating strategic timing or phasing of implementation, balancing multiple objects, educating county staff and educating the public on public GI projects.

G. Funding Sources for Green Infrastructure

Utilize Tucson Conserve 2 Enhance (C2E) funds throughout the entire Tucson Water service area including in unincorporated Pima County. This program is funded by donations on PC RWRD and Tucson Water utility bills is set up to benefit the public through community grants such as green streets with stormwater harvesting in neighborhoods and wash habitat in community parks. Partnerships with community groups would allow the County to apply for the C2E grants and ensure volunteer-based maintenance. The program has years of successful implementation and includes long-term maintenance commitment by project volunteers with support from C2E coordinators and funds. Projects are eligible anywhere within the Pima County wastewater or Tucson Water service area. Grants applications are received and reviewed by an independent non-profit; their Advisory Council is composed of jurisdictional, business, and non-profit representatives. PAG's Green Infrastructure Prioritization tool is used to direct projects to areas of greatest need, such as riparian benefit. C2E is open to and capable of administering any additional Pima County funds for similar projects.

Apply for grants from state and federal agencies. EPA's Environmental Justice Grant program provides support to communities so they develop solutions addressing public health issues associated with elevated temperatures. EPA's Urban Waters Small Grants Program awards up to $60,000 every two years to groups working collaboratively to improve urban water quality and which have multiple benefits. EPA's Office of Sustainable Communities Greening America's Communities Program funds a team of designers to visit communities to produce schematic designs and exciting illustrations intended to catalyze or complement a larger planning process for a pilot neighborhood that would incorporate innovative green infrastructure and other sustainable design strategies. The Water Infrastructure Finance Authority of Arizona fund provides low interest rate loans with no closing costs to enable wastewater utilities to plan, design and construct green infrastructure.

The City of Tucson Water Department currently partners with Tucson Clean and Beautiful to administer the Neighborhood Scale Stormwater Harvesting Program, which will be awarding grants to install GI to city wards. Currently, the Tucson City Council utilizes Ward offices to receive the applications for the Neighborhood Scale Stormwater Harvesting Program funds and selects the most favorable projects. This program began in 2017 and can be extended throughout

Tucson Waters Service Area within unincorporated Pima County. The Board of Supervisors could implement a similar program to building a green infrastructure project within their district each year. Tucson Clean & Beautiful manages the design-construct project and trains the neighborhood members to maintain the installations. Tucson Clean and Beautiful Trees for Tucson Program collaborates with neighborhood community groups and corporate partners to make trees available for ROWs, parks and public properties throughout eastern Pima County.

H. Training and Recommended Future Tools

Proper plant care is essential. The landscape industry has a high turnover rate, requiring continual retraining. All personnel performing or supervising landscape maintenance who work on Pima County property are recommended to be trained in plant care. This includes County staff (NRPR, DOT, RFCD, and FM), landscape contractors performing work on County properties, and volunteers. The SmartScapes program run by the University of Arizona Cooperative Extension provides training in plant care at minimal cost. An often cited problem is early and aggressive tree pruning, which inhibits both root and trunk growth resulting in a small canopy. With minimal landscape maintenance budgets and a potentially larger landscape inventory to maintain in Pima County, there may be a need to rely upon the public to assist in maintaining an increased tree canopy. Tucson Clean and Beautiful is an organization that could train volunteers through its Trees for Tucson community tree tender program.

Local jurisdictions around the U.S. and Arizona typically employ urban foresters or arborists to manage tree populations as a collective resource, on both public and private land. To increase the tree canopy to 20%, it is recommended that an Urban Forester/Arborist position be instituted. An urban forester or arborist working across departments could provide uniform guidance to County staff and contractors hired by Pima County. The position of County Arborist or Urban Forest Manager could be created anew, or a current Pima County staff member with the appropriate qualifications could be re-assigned to this position.

Tree inventories and tree ordinances are tools used by the urban forester in maintaining tree canopy. A tree inventory is critical for the urban forester to manage tree populations. Tree ordinances regulate tree planting, removal, and maintenance on public and private property within a jurisdiction to maintain this public health infrastructure's purpose of cooling the environment and improving air quality. There is also potential for Pima County to increase partnership with Trees for Tucson/Tucson Clean and Beautiful in achieving these goals.

The average tree canopy within metropolitan Tucson is 8%. A regional tree and shade master plan is recommended to achieve the 20% tree canopy coverage at tree maturity.

4. RECOMMENDATIONS

Green infrastructure can help to solve two potential problems facing Pima County. As a climate adaptation measure, green infrastructure reduces urban temperatures, flooding risks and the impacts on roads and infrastructure, while creating green, healthy and climate resilient neighborhoods. These actions also reduce air and water pollution while capturing and storing carbon.

Green infrastructure can also demonstrate climate readiness to bond rating agencies, like Moody's, thereby helping to future-proof the County's superior credit ratings under climate threat tests by demonstrating awareness and action to maintain and increase property values.

Within this context, staff offer the following recommendations:

- Approve the List of Candidate GI Sites and direct staff to evaluate cultural clearances and environmental requirements and then develop site plans defining the green infrastructure features.
- Direct departments to quantify the triple bottom line benefits using the Autocase™ license available in RFCD for each GI Site with a preliminary design. Look into enhancing this effort by making the locally calibrated tool available to local partners.
- Direct staff in each department to develop capital expenditures, including maintenance costs, for GI sites with preliminary designs.
- Dedicate $250,000 from the General Fund each year to support GI projects through 2025. The funding will support earthwork to lay drainage and the installation of plant materials and associated infrastructures.
- Approve a countywide policy that CIP plans, programs and projects incorporate LID features and GI strategies, where conditions are feasible. Align the use of stormwater with Detention Retention first-flush guidelines and other adopted policies for consistency and ease of compliance.
- Work with utility companies to create polices for best placement of utility lines that will not restrict GI opportunities.
- Direct staff to complete the Green Infrastructure Care Manual in cooperation with local jurisdictions.
- Approve development of a GI Outreach program, including signage, staff trainings in coordination with PDEQ, RFCD and PCDOT, and in-house brownbag presentations.
- Build the Meander Bend GI Project and the Southern Arizona Children's Advocacy Center GI Project.
- Create a GI Team to help department managers, inspectors and plan reviewers to make important green infrastructure decisions and to annually report work progress and successes in Pima County's Sustainable Action Plan Report Card.
- Coordinate with other jurisdictions to develop Standard Details and Specifications for commonly constructed GI features for addition to PAG's Standard Specifications Update.

- Develop safe, reliable, and efficient management strategies to use stormwater as a resource in the arid southwest.
- Identify dedicated funding sources for future GI-LID capital projects and maintenance of GI-LID projects.
- Plant trees to increase tree canopy cover from 8% to 20%.

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Appendix A. Priority for selecting GI/LID + Trees projects

No.	Resolution 2017-51
1	Location within County Regional River Park System
2	Reduce Urban Heat Island (Potential to decrease $temperature_{air,}$ building cooling, potential to increase canopy)
3	Avoid utility costs for water, energy and maintenance
4	Air quality benefits to improve public health costs, improve productivity and benefit the economy
5	Abate flooding
6	Improve stormwater quality
7	Reduce CO_2 emissions
8	Sequester carbon
9	Avoid capital improvement costs
10	Reduce flood insurance costs

Appendix B. List of GI/LID + Trees Projects

No	Dep	Land Use Category	Location	Address/parcel	Trees (#)	Basin area (acre)	Additional structures	Temperature * Tree Canopy	Priority
1	CDNC	ROW	Shannon Gardens LID Project	Shannon Rd/ Palmyra-Sahara	50	1.2	pipeline, rocked channel	1.08	25
2	FM	Public building	Documents and Micrographics Facility	1640 E Benson Hy	10		trees, porous concrete	0.54	17
3	FM	Public building	Forensics	2825 E District St	5		trees porous concrete	0.28	10
4	FM	Public building	Kino Service Center	2797 E Ajo Wy	5		trees, porous concrete	0.08	2
5	FM	Public building	Kino Veterans' Workforce Center	2801 E Ajo Wy	2		trees, porous concrete	1.04	24
6	FM	Public building	Road Maintenance	1313 S Mission Rd	5		trees, swales	0.45	13
7	NRPR	Park	Arthur Pack	9101 N. Thornydale	10		Install in walk-ups in the 4-plex, evaluate removal of 2 existing mature mesquites	0.92	23
8	NRPR	Park	Brandi Fenton	3482 E. River Road	6		Remove and replace dead/dying trees only, irrigation available	0.35	11
9	NRPR	Park	Children's Memorial	4875 N. 15th Place	5		Irrigation available	2.1	31
10	NRPR	Park	Dan Felix	5790 N. Camino De La Tierra	30		Remove and replace dead/dying trees and add additional trees, irrigation available but design required	0.6	19
11	NRPR	Park	Los Ninos	5432 S. Bryant Avenue	10		Spread through park, irrigation available	1.76	29
12	NRPR	Park	McDonald	4100 N. Harrison Road	5		Along fence line north of field #4, irrigation available	1.92	30
13	NRPR	Park	Rillito Vista	8820 W. Robinson St	5		Various locations, irrigation	1.68	28
14	NRPR	Park	Three Points	10211 S. Sasabe Rd*	10		Various locations, irrigation	unk	unk
15	RFCD	The Loop	CDO	Thornydale to I-10	100		No irrigation, water harvesting/cocoon	0.39	12
16	RFCD	The Loop	CDO	Overton to La Canada	300		East bank, no irrigation, water harvesting/cocoon	0.8	21

No	Dep	Land Use Category	Location	Address/parcel	Trees (#)	Basin area (acre)	Additional structures	Temperature * Tree Canopy	Priority
17	RFCD	The Loop	CDO	La Cholla to La Canada	200		No irrigation, water harvesting/cocoon	0.56	18
18	RFCD	The Loop	Rillito	South bank Country Club West of bridge	10		Irrigation available	0.52	16
19	RFCD	The Loop	Santa Cruz	Irvington to Drexel	100		West bank, no irrigation, water harvesting/cocoon	0.6	19
20	RFCD	The Loop	Santa Cruz	Grant to Sweetwater	50		No irrigation, water harvesting/cocoon	0.15	5
21	RFCD	The Loop	Santa Cruz	Sweetwater to El Camino Del Cerro	100		No irrigation, water harvesting/cocoon	0	1
22	RFCD	The Loop	Santa Cruz	Diamond to Sunset	100		No irrigation, water harvesting/cocoon	0	1
23	RFCD	The Loop	Santa Cruz	Sundt Entrance to Sunset	50		No irrigation, water harvesting/cocoon	0.28	10
24	RFCD	The Loop	Santa Cruz	Orange Grove to Ted Walker	50		No irrigation, water harvesting/cocoon	0.2	6
25	RFCD	The Loop	Santa Cruz	Ted Walker to Ina	100		East bank, no irrigation, water harvesting/cocoon	0.21	7
26	RFCD	Riparian restoration	Canada Del Oro - The Oasis (separate from NRPR project noted above)	Overton to La Canada	50	0.6	potential project partnering with WMG to install water harvesting basins. Potential for future irrigation, water truck, or use driwater to establish trees and seed mix that includes tree species.	0.8	21
27	RFCD	Riparian restoration	Agua Caliente Wash - Desert Willow	ACW at Tanque Verde Road	25	0.6	Potential project partnering with WMG to install water harvesting basins, no irrigation, possibly use driwater to establish trees and seed mix that includes tree species.	2.4	32
28	RFCD	ASLD/District	140-41-1400	4175 E Cameo Point Dr	?		469.4 ac disturbance over most area	0	1
29	RFCD	Riparian restoration	Arroyo Chico - 2b Park Ave Basins	Park to Kino	20	15	In basin, irrigation available or water harvesting	0.27	9
30	RFCD	The Loop	Pantano - Phase 3	Grant to Fort Lowell Park	100		In-channel floodplain and overbank, irrigation available or water harvesting	0.88	22
31	RFCD	Park	Tanque Verde Creek - Isabella Lee	Bonnza	20	2	No irrigation, water harvesting/cocoon	2.88	33

No	Dep	Land Use Category	Location	Address/parcel	Trees (#)	Basin area (acre)	Additional structures	Temperature * Tree Canopy	Priority
32	RFCD	Riparian restoration	Rillito - Sparrow Patch at Swan Wetlands	Columbus Road, south bank	20	2	No irrigation, water harvesting/cocoon	1.54	27
33	RFCD	Riparian restoration	Santa Cruz River -Silver Creek	Silver Creek to Jackrabbit Ave	20	0.2	No irrigation, water harvesting/cocoon	0.14	4
34	RFCD	Flood control	Arroyo Chico - Phase 3 Upstream	Campbell to Parkway Terrace	100	15	In basin, irrigation available or water harvesting	0.64	20
35	DOT	ROW	Talisman/Flowing Wells LID (bus stop)		4		basins, trees, bench	1.21	26
36	DOT	ROW	Valencia Far West: Ajo to Wade		662		Water harvesting	0.12	3
37	DOT	ROW	La Cholla: Overton to Tangerine		2063		Water harvesting	0.5	15
38	DOT	ROW	Kolb Rd: Sabino to Sunrise - 3 lane section				Water harvesting	0.49	14
39	DOT	School	White - Pister				Water harvesting	0	1
40	DOT	ROW	Benson Hy at Drexel Rd		31		Water harvesting	0.12	3
41	DOT	ROW	Benson Hy at Columbus		39		Water harvesting	0.24	8
42	DOT	ROW	Bopp Rd: Sarasota Blvd at Kinney Rd		212		Water harvesting	0.52	16
43	CDNC	Park	Barrio Nopal Neighborhood Association	329 E Elvira Rd				0.75	21

Summary	Trees	Basins
Public buildings	27	
Parks	101	
The Loop	1260	
ROW	3061	
Riparian restoration	135	
Other	100	
Total	4684	36.6

ADMINISTRATIVE PROCEDURES

Procedure No. 51-3

Effective Date: July 15, 2016
Revision Date:

County Administrator

SUBJECT: **Plant Materials Salvage and Selection for Pima County Projects**

DEPARTMENT(S) RESPONSIBLE: All Public Works, Facilities Management

PURPOSE

The purpose of this Administrative Procedure is to establish a consistent procedure for plant selection and salvage for projects constructed by Pima County and Pima County Regional Flood Control District (District) to ensure compliance with state and local requirements, and to provide a unified approach for use of native plants.

Pima County is characterized by unique biological and cultural resources that define its strong regional identity. The Sonoran Desert Conservation Plan and the Comprehensive Plan, Pima Prospers promote planning to preserve this identity. The Pima County Native Plant Nursery was established in 2003 to provide native plants to Pima County projects. The Arizona Native Plant Law restricts some activities affecting native plants, as do other state, federal and local authorities under which County departments may operate when plant materials are removed, salvaged, or planted.

The Native Plant Preservation Ordinance (Chapter 18.73 in the Pima County Code), enforced by Development Services and applied to private development, does not apply to County or District projects. The Environmentally Sensitive Roadway Design Guidelines applies only to Pima County Department of Transportation. Therefore, these new procedures will provide a consistent and unified approach to selection of plants across all County departments, including facilities or improvements constructed and operated by Pima County. All departments shall follow these procedures for new construction, whether or not there is any "landscaping" planned.

PLANT MATERIAL SALVAGE AND SELECTION

1. Site Design:

When planning for Pima County facilities and projects, practices to preserve-in-place native plants on the site shall be implemented to the maximum extent practicable through:
a. avoidance and minimization of impacts by such practices as conserving natural areas,
b. preservation or avoidance of natural drainage flow in site design, and
c.minimization of disturbed areas.

Contact the Pima County Department of Transportation for guidance in applying the Environmentally Sensitive Roadway Design Guidelines on transportation projects.

2. Regulated Riparian Habitat:
Review limits of disturbance for your project to avoid Regulated Riparian Habitat. (These can be determined on PimaMaps.) If there are Regulated Riparian Habitats, contact RFCD for compliance requirements.

3. Compliance with other Jurisdictions:
If this a County- or District-managed project that is to be maintained, owned or operated by another jurisdiction, contact that jurisdiction regarding any requirements. If there are conflicting requirements between the jurisdiction and this procedure, contact Pima County Office of Sustainability and Conservation.

4. Prohibited Plants:
The Pima County Health Department prohibits the following vegetation: Texas mulberry and fruiting olive trees. These shall not be used under any circumstance.

5. Arizona Native Plant Law:
Regardless of jurisdiction, if there is potential for native plants to exist currently on site and there will be removal of the plants or plant parts from the site, compliance with the Arizona Native Plant law is required. Landowners must provide notice of any destruction or removal of protected native plants, as required by Arizona Department of Agriculture.

6. Plant Salvage:
If any native plants exist onsite, the Pima County Native Plant Nursery shall be contacted for potential plant salvage. Salvage of native plants to be transplanted on site, or relocated to the Pima County Native Plant Nursery or other location is encouraged.

7. Plant Selection:
When plant materials are to be specified as part of a new Pima County project or facility, the priority of plant specification shall be as follows:

- First Choice: Plants native to project site
- Second Choice: Sonoran Desert Plants
- Third Choice: Chihuauhuan Desert Plants
- Fourth Choice: ADWR Tucson Active Management Area Category 1 and 2 plants

The use of plants not native to the Sonoran and Chihuahuan deserts may be unavoidable in some locations, due to a lack of native species with the required plant characteristics. Unless the elevation of the site is greater than 5000 feet or there is a need to maintain an historic landscape, consider species from outside the Sonoran desert only after consideration of native or Sonoran Desert plants. For historic landscapes, see the "Historical Plantings" list at Pima County Native Plants .

Contact the Pima County Native Plant Nursery in order to provide native plants to Pima County projects. While it may not be able to provide all the plants for Pima County facilities, particularly large size trees, it shall be the first source used. The Native Plant Nursery shall be consulted at the initial stages of landscape plan development in order to make recommendations regarding availability of plants, costs and sizes to specify, and to coordinate a schedule.

Regardless of the plant materials supplier, Sonoran Desert native plants shall be selected to the maximum extent practicable.

Some resources that can be used in plant selection are:

Pima County Native Plant Tool can assist in selecting appropriate native plants for the site, even where the original plant community has been largely altered or removed..
For the Pima County Native Plant Nursery, contact the manager at Natural Resources, Parks and Recreation Department, or phone 724-5000.

The Low-Impact Development Guidance Manual has an excellent plant list for Pima County facilities.

Grow Native: Don't Plant a Pest brochure suggests plants to avoid and appropriate substitutes.

For historic landscapes, see the Pima County Native Plant Tool for a list of historically appropriate plant material.

8. Invasive Species Management:
Management and control of invasive species, particularly buffelgrass, fountain grass, and Sahara mustard are of critical concern. These species are to be identified and managed per Public Works Standard Operating Procedure 2009-02 or its sucessor.

9. Low Impact Design and Plant Irrigation
Rather than relying solely on supplemental irrigation, County and District projects using plant materials shall be designed to incorporate water harvesting principles. For additional guidance consult the Low-Impact Development Guidance Manual.

RESPONSIBILITIES

Office of Sustainability and Conservation shall review the effectiveness of this procedure with its practitioners every two years, and serve as a clearing house for questions.

Appendix D. Triple Bottom Line Cost Benefit Analysis of Meander Bend Park and Southern Arizona Children's Advocacy Center (SACAC)

Autocase

Triple Bottom Line Cost Benefit Analysis of Green Infrastructure for a Proposed Meander Bend Park and the Southern Arizona's Children Advocacy Center for Pima County

Prepared by Autocase

2018-03-09

Contents

Executive Summary 3
Project Overview 4
Project 1: Meander Bend Park Site Design 5
1a. Meander Bend Park Base Case Alternative 5
1b. Meander Bend Park Stormwater Alternative 5
Project 2: Southern Arizona Children's Advocacy Center Site Design 8
2a. SACAC Base Case Alternative 8
2b. SACAC GI with Stormwater Alternative 10
2c. SACAC GI with Irrigation Alternative 10
Results 12
Project 1: Meander Bend Park Project TBL-CBA Results 12
Project 2: SACAC Project TBL-CBA Results 16
Urban Heat Island: A Comparison of Static versus Rising Future Temperatures 20
Appendix A: Methodologies 21
A.1 TBL-CBA Framework 21
A.2 Base case 21
A.3 Valuation Methodologies 21
A.3.1 Financial Impacts 21
A.3.2 Social Impacts 23
A.3.3 Environmental Impacts 27
Appendix B: Inputs and Assumptions 29
Inputs 29
Inputs for Meander Bend Park Project 29
Inputs for Southern Arizona Children's Advocacy Center Project 29
Assumptions 31
Appendix C: Pima County Regional Flood Control District Derivation of Inputs 36
References 42

Executive Summary

A Triple Bottom Line Cost Benefit Analysis (TBL-CBA) using Autocase for two proposed green infrastructure/low impact development (GI/LID)[1] sites for Pima County demonstrated how capturing and quantifying the often hidden social and environmental benefits of GI/LID is important. Moreover, these hidden benefits become increasingly pronounced under future climate change scenarios of hotter temperatures. The projects chosen for these analyses are illustrative of different sizes and uses: one site is for a proposed new park on restoration land and the other is a smaller site around an existing County-owned building. Both sites are in areas with low tree canopy and high regional surface temperatures.

The TBL-CBA for GI installations for both projects (compared to do-nothing or gray base scenarios) showed substantial financial value to the County under an assumption of long-term historical temperature trends. Significantly, these values increased substantially under the assumption of rising temperatures based on models provided by University of Arizona climate scientists. These findings indicate that GI is a valuable strategy for these two sites now, and will be even more valuable to the community as temperatures continue to rise.

The first project, Meander Bend Park compared a Green Infrastructure designed 18-acre park adjacent to the Santa Cruz River vs. a do-nothing scenario. The Autocase results of the GI design showed environmental and social benefits that are over six times the costs of capital expenses and operation and maintenance. The park design also enhanced an existing recreational trail and provided recreational and property value benefits to residents. The park also provides other social benefits such as food harvesting value, reduction in the urban heat island, as well as flood and water quality benefits. The carbon reduction benefits and air quality improvements add to the overall value of the park vs. a do-nothing scenario.

The smaller 0.3-acre Southern Arizona Children's Advocacy Center (SACAC) compared a gray infrastructure (parking lot) to a GI designed outdoor space with access to a recreational trail. Further, two irrigation scenarios were compared as part of the GI design: 2a) stormwater irrigation, and 2b) traditional irrigation practices. In Autocase, the recreational, cooling and public health benefits along with the cleaner air added to the positive TBL net benefits of the GI design, and even with irrigation included, both scenarios were still less expensive than the parking lot. The stormwater scenario (2a) produced essentially the same benefits as the irrigation scenario (2b), at significant savings in capital and O&M costs and therefore represents a better value for the County.

Using Autocase, we are able to demonstrate that the GI/LID scenarios for the two projects: the proposed Meander Bend Park and the Southern Arizona Children's Advocacy Center provided social, environmental and economic value that contributed to overall net positive benefits associated with green infrastructure installations. The Autocase analysis further demonstrated these values increased significantly under increasing urban temperatures associated with modeled climate change scenarios for the southwestern United States that were provided by University of Arizona climate scientists.

[1] Green Infrastructure/Low Impact Development is a term used to describe engineered systems that mimic natural processes and flow paths to reduce flooding, conserve water, curb urban heat island effects and reduce both air and stormwater pollution.

Project Overview

Wheat Design Group and Autocase were engaged by Pima County to assess the triple bottom line impacts of two potential green infrastructure (GI) projects in Tucson, AZ. The first project, Meander Bend Park, is an 18-acre desert restoration project adjacent to the Loop on Santa Cruz River. The second project, Southern Arizona Children's Advocacy Center (SACAC), is a 0.3-acre site providing shaded outdoor space for building occupants and the Loop users.

These sites were chosen to be illustrative of the use of triple bottom line cost benefit analysis (TBL-CBA) to create a business case for Green Infrastructure/Low Impact Development (GI/LID). The TBL-CBA approach is proposed as way to evaluate and prioritize future GI/LID + Trees projects in Pima County. The intent of TBL-CBA is to determine the social and environmental net benefits (benefits minus costs), in addition to the lifecycle financial costs and avoided costs that arise from projects.

The TBL-CBA business case was conducted in Autocase - a cloud-based software tool, to provide insights into the net present value of costs and benefits of the two projects to Pima County, as well as the broader societal and environmental impacts over a 50-year time horizon using a 3% discount rate to convert all future cash flows into a present value.

The project is driven by Pima County's commitment to the Paris Climate Agreement. As part of this initiative the Pima County Board of Supervisors adopted resolutions "which state that County government will align its operational efforts to meet the United States' commitment to the Paris Agreement on Climate Change that seeks to reduce global carbon emissions by 26% to 28% below 2005 levels by the year 2025" (Pima County, 2017). In order to evaluate future conditions, the climate model for this analysis considered projected temperature in 2050 as well as under stationarity assumptions (i.e. future climate will be like past climate).

Project 1: Meander Bend Park Site Design

The site for the proposed Meander Bend Park is a bend in the Santa Cruz River about ½ mile north-northwest of the intersection of N. Silverbell Road and W. Grant Road in Tucson. The site is a meander bend, which has been cut off from the main channel by a bank protection resulting in a pit, which will be filled from a project that removes sediment from the Santa Cruz River. The newly graded site will be the starting point for Meander Bend Park. Scenario 1 for this project assesses the costs and benefits of a Base Case Alternative (do-nothing) versus Meander Bend Park, a multi-benefit restoration alternative using GI and vegetation supported by stormwater, as described below.

1a. Meander Bend Park Base Case Alternative

The base case is the filled-in and graded site and is a "do nothing" alternative. Activities from Phase One of the sediment removal project are expected to begin in March 2018.

1b. Meander Bend Park Stormwater Alternative

Meander Bend Park incorporates green infrastructure (GI) and recreation opportunities within a sediment deposit site adjacent to the Santa Cruz River. The concept builds upon the planned earthworks of the graded fill by adding native vegetation, infiltration basins, vegetated swales, and a rainwater harvesting ramada and cistern. An extensive pedestrian pathway system allows for connections to and from the Loop Trail and adjacent neighborhoods, making Meander Bend Park a recreation destination. The landscaping will be supported with harvested stormwater off the adjacent watershed and from on-site sources. Dry H_2O (a natural, non-toxic alternative to water in the form of a gel) will be used to improve the water holding capacity in plantings, extending the time required between watering by stormwater. The site will be seeded, and a significant component of the projected vegetation will come from seeds growing and maturing in basins. The alternative consciously included food-producing desert vegetation including prickly pear cactus and velvet mesquite trees.

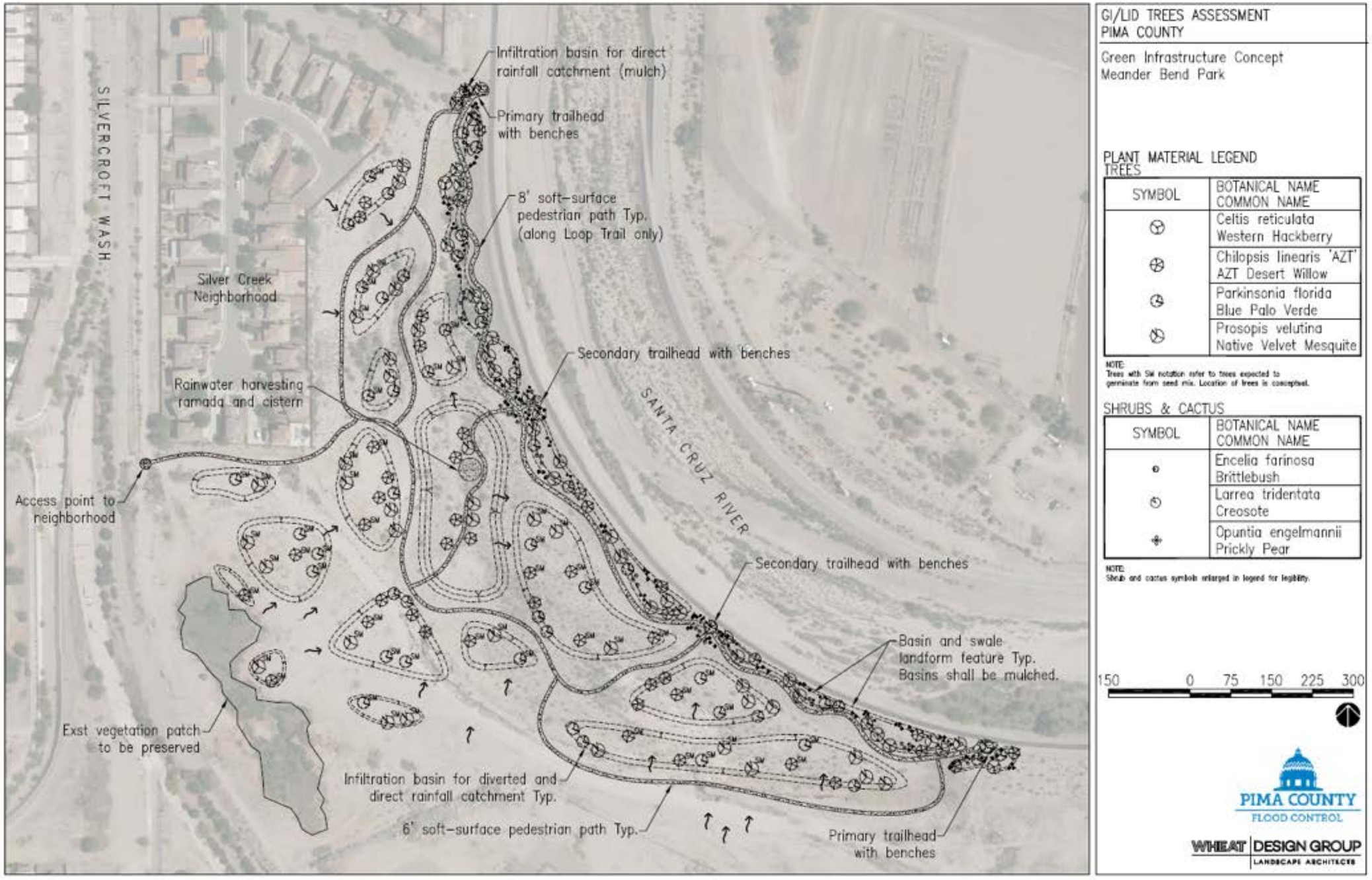


Figure 1: Site Design for Meander Bend Park

Figure 2: Existing Site Looking North. Source: Google, retrieved Feb 27th 2018

Project 2: Southern Arizona Children's Advocacy Center Site Design

The Southern Arizona Children's Advocacy Center (SACAC) is located at 2337 E. Ajo Way, Tucson, about ½ mile due east of South Kino Parkway and Ajo Way where two scenarios were evaluated. Scenario 2a assesses the costs and benefits comparing a Base Case alternative (a parking lot) to a green infrastructure (GI) alternative with a multi-use landscaped area irrigated with stormwater. Scenario 2b assess the same design replacing stormwater irrigation with standard practice irrigation.

2a. SACAC Base Case Alternative

The gray infrastructure concept for the SACAC presents an alternative to the green infrastructure concept. This design features a parking lot for an estimated 50 cars, sidewalk connections to the building, and seven new trees. It is assumed that no improvements are made for the landscape north and south of the building.

Figure 3: Existing Site Looking North. Source: Google, retrieved Feb 27th 2018

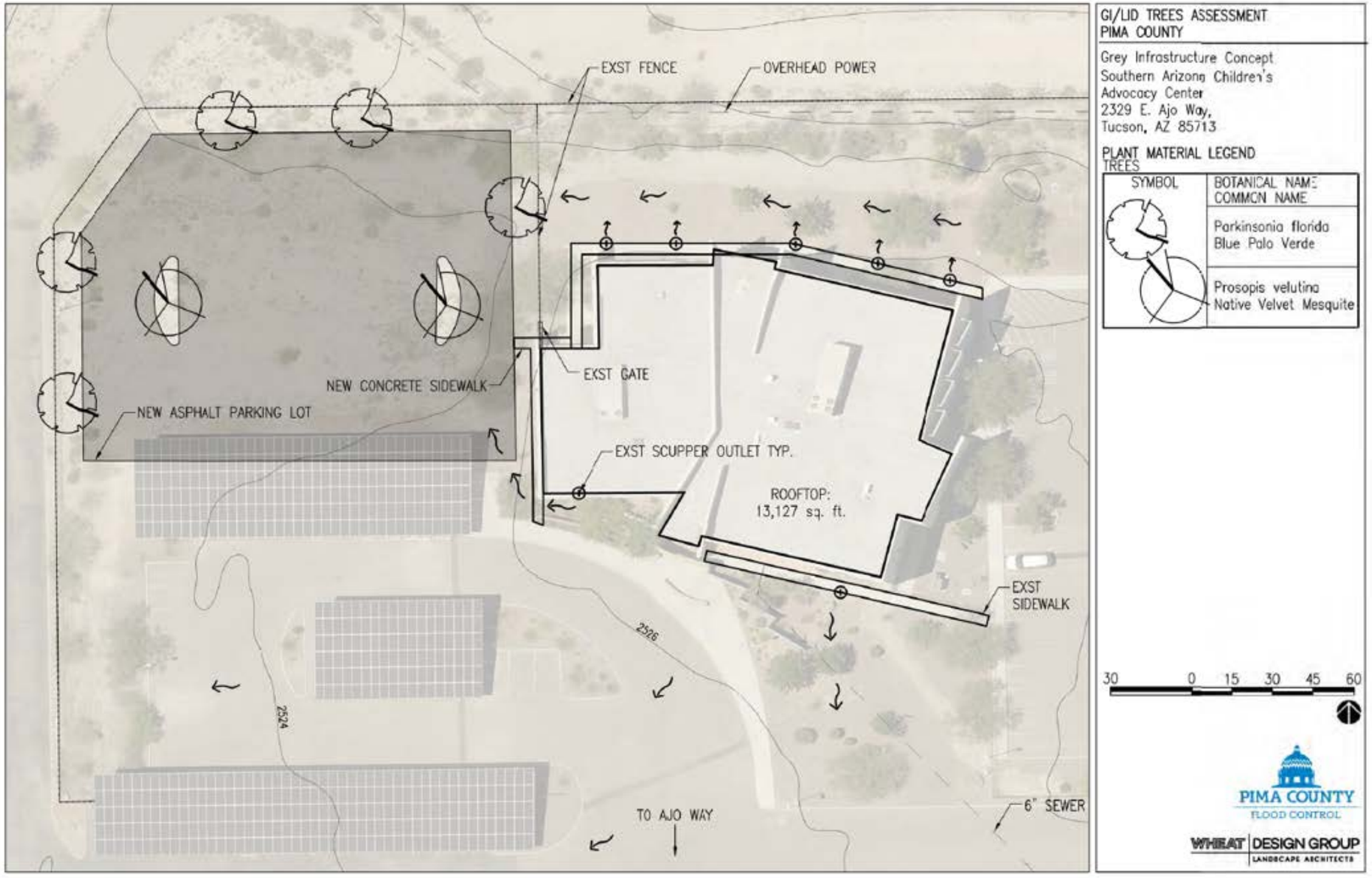


Figure 4: SACAC Base Case Design

2b. SACAC GI with Stormwater Alternative

The concept for the SACAC leverages green infrastructure techniques to create outdoor spaces for building occupants and for the Loop users. An interconnected series of vegetated swales and infiltration basins slowly transport water from building scupper outlets to the landscape, which supports trees, shrubs, and seed mix. The site's proximity to the Loop and to adjacent natural resources makes it an important habitat area and recreation outlet. Since water use is a major drought consideration and cost for Pima County, both on-site and off-site stormwater sources were utilized with water being harvested off rooftops and parking lots. Periodic watering with a water truck was assumed for the first five years during the vegetation establishment period and then, once every three years in the early summer months before the monsoon arrives to account for potential extreme drought conditions. For Scenario 2a, the results of the Base Case Alternative were compared to the SACAC Stormwater Alternative for the Stormwater Scenario.

2c. SACAC GI with Irrigation Alternative

For comparison, Autocase also assessed a second irrigation alternative for the SACAC design: assuming that the watering needs of the vegetation would be met by an irrigation system, instead of stormwater and delivery truck as proposed above. For Scenario 2b, the results of the Base Case Alternative are compared to the results of the SACAC Irrigation Alternative.

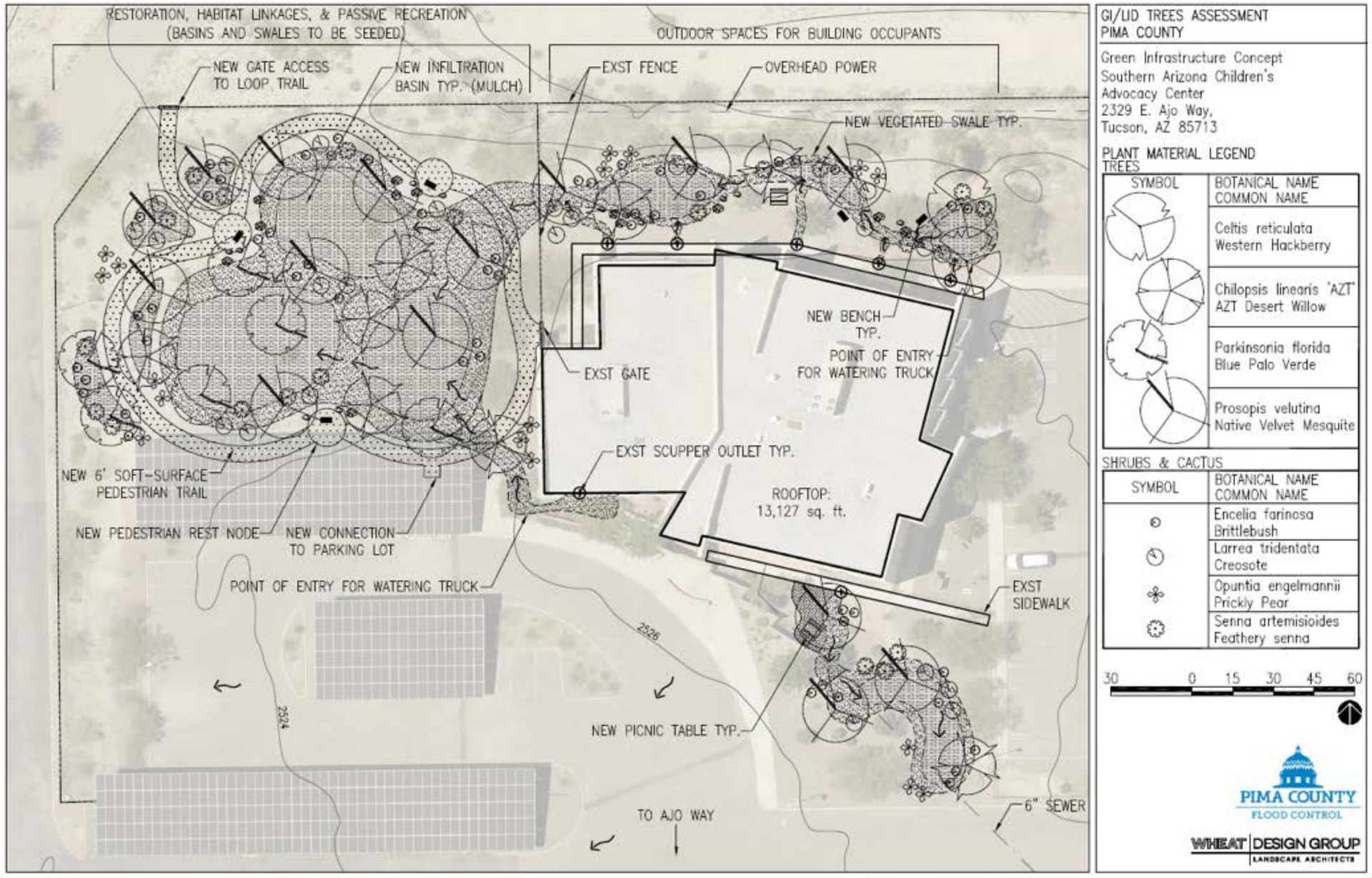


Figure 5: Southern Arizona Children's Advocacy Center Site Design

Results

The intent of these analyses is to determine the social and environmental benefits (and disbenefits), in addition to the lifecycle financial costs and avoided costs that arise from projects. The following sections provide triple bottom line results for the two projects in net present value (NPV) over a 50-year time horizon using a 3% discount rate as is commonly applied by governmental agencies with long-term investment strategies. NPV is the present value of benefits net of present value of costs over the entire project's life -- essentially showing the entire value of the project over 50 years in today's dollars.

Project 1: Meander Bend Park Project TBL-CBA Results

The Autocase analysis for Meander Bend Park Project shows an estimated $9.8m (95% confidence interval of $6.0m to $14.0m) in triple bottom line net present value (TBL-NPV) over a 50-year time horizon relative to the base case alternative of a new parking lot, with -$1.7m created from financial costs, $7.4m from social impacts, and $4.1m from environmental impacts. The negative financial impact derives from the fact we are comparing to a 'do-nothing' alternative design, which would involve no capital expenditure, O&M or replacement costs.

Table 1: TBL-CBA Results for Meander Bend Park

	Meander Bend Park Project (Base Case – Stormwater)
Financial	-$1,687,488
Social	$7,386,208
Environmental	$4,082,439
Triple Bottom Line NPV	**$9,781,159**

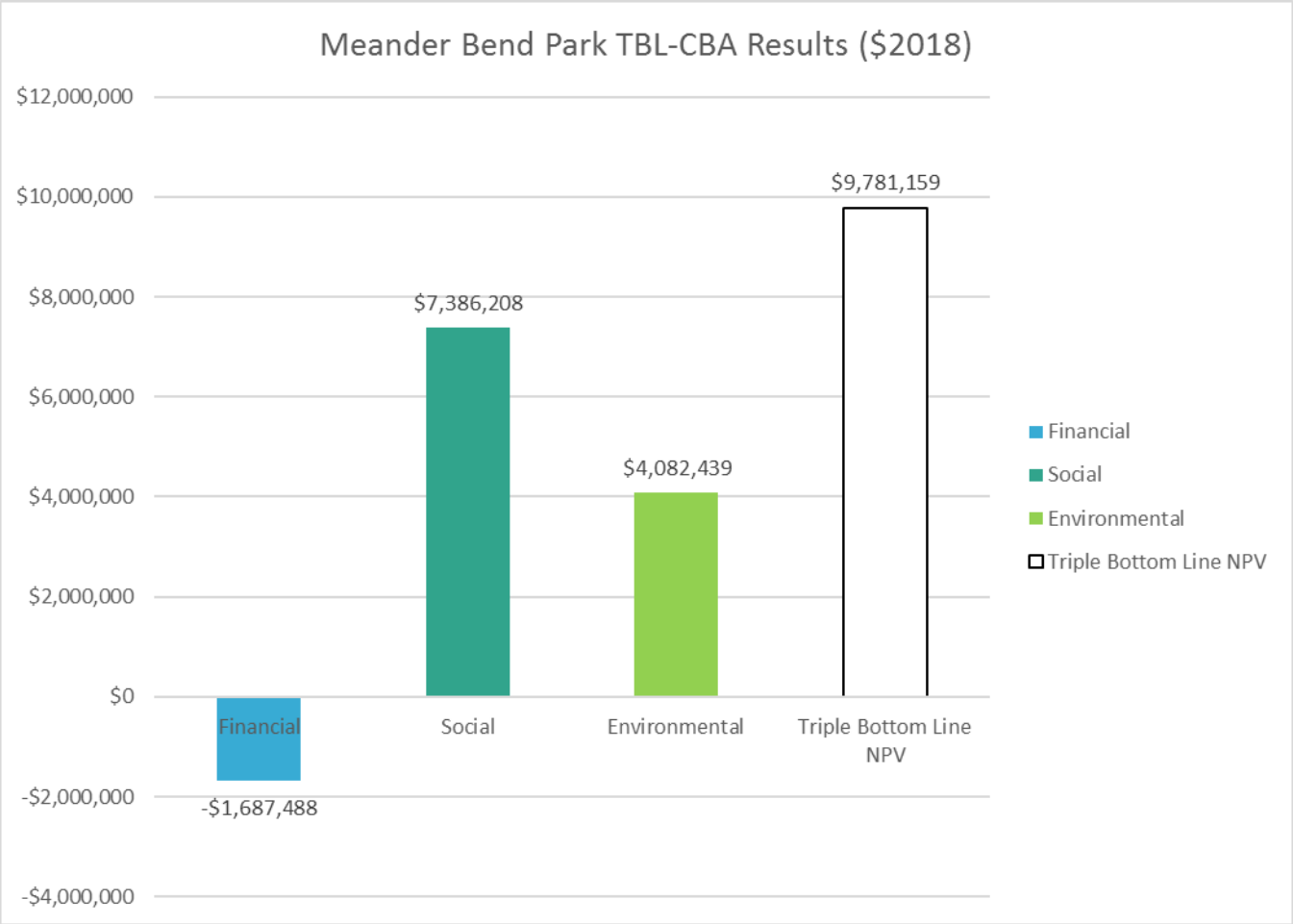


Figure 6: TBL-CBA Waterfall Results for Meander Bend Park

Both the results (Table 2) and the waterfall chart (Figure 7) illustrate this in more detail. On the chart, green represents value being created, whereas red represents a cost, relative to the parking lot base case. The most dis-benefit is created by high capital expenditures (-$868,000) and O&M Costs (-$691,000). Heat Island Effect ($1.8m), Property Value Uplift ($1.2m), Recreation ($3.7m), and Food ($0.5m) impacts generate the most social value. Finally, Air Pollution Reduced by Vegetation ($0.3m), Carbon Emissions from Energy Use ($3.1m), and Habitat ($0.4m) create the biggest environmental benefits.

The urban heat island impacts under RCP8.5[2] are significant at $1.8m ($1.3 to $2.4m 95% confidence interval). If we were to use a stationary temperature projection (current temperature going out 50 years), the urban heat island impacts would be $0.9m ($0.7m to $1.2m 95% confidence interval). Although still large, the benefits of GI under higher temperatures has almost double the benefit.

[2] Representative Concentration Pathway 8.5 is one of four greenhouse gas concentration trajectories adopted by the Intergovernmental Panel in the Fifth Assessment Report in 2014.

Table 2: Detailed TBL-CBA Results for Meander Bend Park Project

Impact Type	Cost/Benefit	Mean Value	95% Confidence Interval		
Financial	Capital Expenditures	**-$867,681**	-$987,988	to	-$738,031
Financial	Operations and Maintenance	**-$690,662**	-$786,432	to	-$587,455
Financial	CapEx on Additional Detention	**$0**	$0	to	$0
Financial	O&M on Additional Detention	**$0**	$0	to	$0
Financial	CapEx on Additional Piping	**$0**	$0	to	$0
Financial	O&M on Additional Piping	**$0**	$0	to	$0
Financial	Replacement Costs	**-$201,735**	-$320,647	to	-$122,882
Financial	Residual Value of Assets	**$72,590**	$9,476	to	$124,283
Financial	Water savings	**$0**	$0	to	$0
Social	Heat Island Effect	**$1,826,645**	$1,255,961	to	$2,374,508
Social	Other Benefits	**$0**	$0	to	$0
Social	Flood Risk	**$100,913**	$100,913	to	$100,913
Social	Property Value	**$1,159,372**	$651,931	to	$1,708,405
Social	Education	**$16,149**	$9,388	to	$24,516
Social	Recreational Value	**$3,721,554**	$3,721,554	to	$3,721,554
Social	Public Health	**$38,012**	$6,879	to	$86,165
Social	Food	**$523,563**	$314,602	to	$735,216
Social	Social Value of Water	**$0**	$0	to	$0
Environmental	Water quality	**$55,889**	$55,889	to	$55,889
Environmental	Carbon Emissions from Concrete	**$0**	$0	to	$0
Environmental	Air Pollution Reduced by Vegetation	**$328,524**	$243,049	to	$414,799
Environmental	Carbon Reduction by Vegetation	**$20,154**	$7,906	to	$35,648
Environmental	Air Pollution from Energy Use	**$25,970**	$13,270	to	$41,597
Environmental	Carbon Emissions from Energy Use	**$3,132,994**	$1,223,733	to	$5,553,594
Environmental	Habitat	**$385,145**	$385,145	to	$385,145
Environmental	Pollination	**$133,763**	$133,763	to	$133,763
Total:	**Triple Bottom Line NPV**	**$9,781,159**	$6,038,392	to	$14,047,627

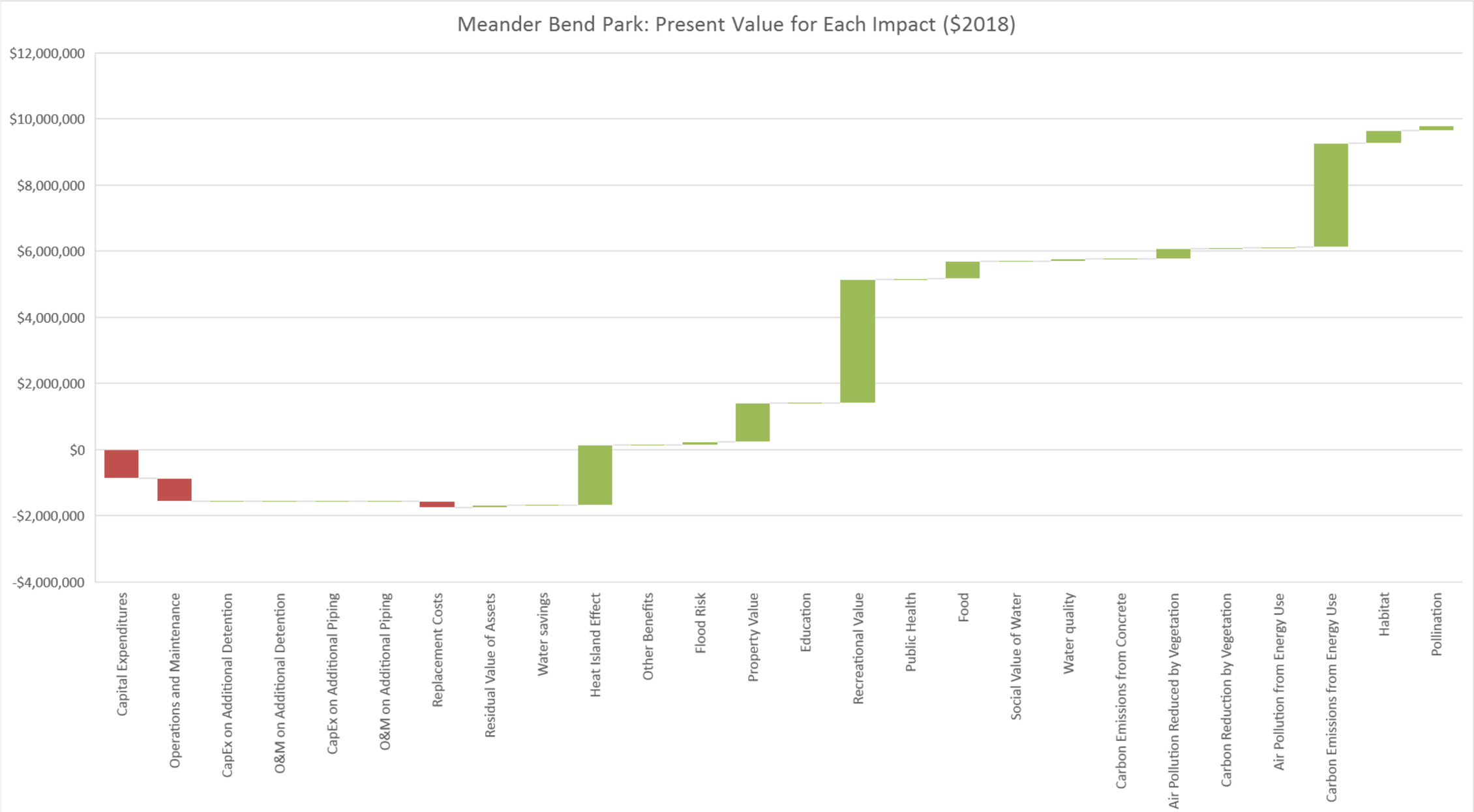


Figure 7: Detailed TBL-CBA Waterfall Results for Meander Bend Park Project

Project 2: SACAC Project TBL-CBA Results

Scenario 2a: Base Case Alternative to Stormwater Alternative

When we assess the GI design for SACAC using stormwater against a gray infrastructure alternative, the Southern Arizona Children's Advocacy project generates an estimated $1.13m (95% confidence interval of $0.87m to $1.44m) in triple bottom line net present value (TBL NPV) over a 50-year time horizon relative to the base case alternative of a new parking lot. Compared to the totals costs of a parking lot under the same scenario and conditions, a GI installation irrigated with stormwater provides the following benefits: $196,000 in financial benefits, $0.9m in positive social impacts, and $33,000 from beneficial environmental impacts.

It is important to note that the positive financial impact derives from the fact that Autocase compared it against a new parking lot with a higher capital outlay ($206,000 vs. $60,000), and replacement costs (~$125,000 vs. ~$13,400) over 50 years. Even though the parking lot involves a lower O&M cost ($0 vs. $46,000), this is outweighed by the positive financial benefits provided by the stormwater design.

Scenario 2b: Base Case Alternative to Irrigation Alternative

When we assess the SACAC GI site assuming that vegetation is irrigated through a newly-built irrigation system, the SACAC project delivers a lower – but still positive – TBL NPV of $1.08m (95% confidence interval of $0.83 to $1.41m) relative to the base case of a new parking lot. On the financial side, these differences arise from an additional $9,000 in capital expenditure, $7,000 in O&M, $20,200 on replacement costs, and $1,250 on water costs (-$13,879 vs. -$15,132 present day value) that can be attributed to the irrigation system. The social difference is created by the $9,000 social cost of water arising from the additional 147,600 gallons of potable water being used on site.

Table 3: TBL-CBA Results for SACAC Project

	SACAC (Base Case – Stormwater)	SACAC (Base Case – Irrigation)
Financial	$196,349	$158,875
Social	$898,569	$889,673
Environmental	$32,749	$32,749
Triple Bottom Line NPV	**$1,127,667**	**$1,081,297**

While both Scenarios generate a positive Net Present Value to the County, it is important to note that the Stormwater Scenario (2a) saves around $40,000 (in present value) over 50 years. Essentially, while generating slightly more social benefit through lower water use, the Stormwater Scenario also costs less (71% of the irrigation scenario: -$127,815 vs. -$179,168).

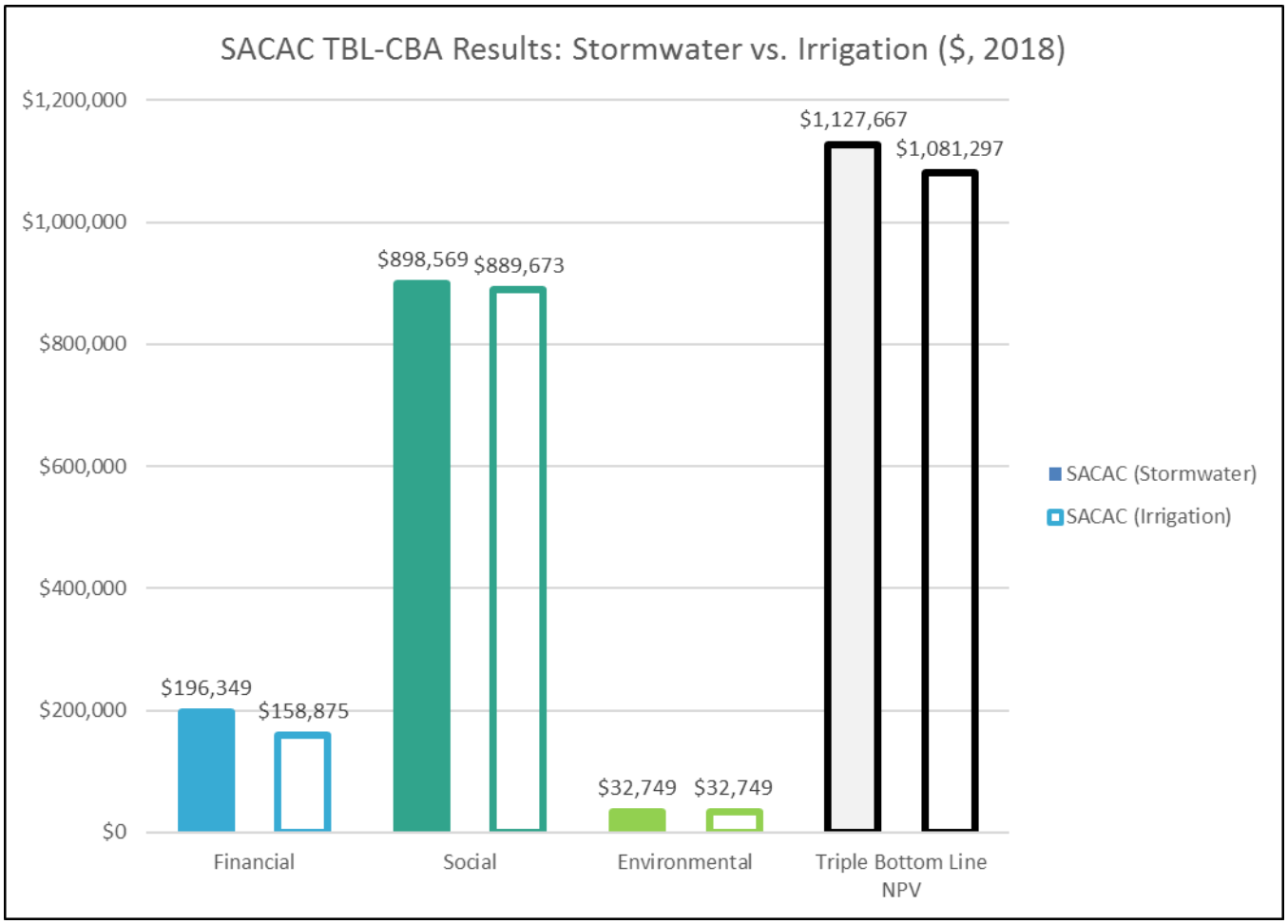


Figure 8: TBL-CBA Results for SACAC Project

Both the table and the waterfall chart below illustrate this in more detail. In the table, note that results specific to the irrigated design alternative are shown as indented and italicized (Table 4). On the chart, green represents value being created, whereas red represents a cost, relative to the parking lot base case (Figure 9). The solid bars represent Alternative 1 (Base Case to Stormwater), whereas hollow bars represent Alternative 2 (Base Case to Irrigation). On the financial perspective, we can see the most value is created by lower Capex ($146,000 & $137,000) and Replacement Costs ($121,000 & $100,000). Heat Island Effect ($91,000), Recreation ($732,000), and Food ($47,000) impacts generate the most social value. Finally, Air Pollution Reduced by Vegetation ($13,000), and Habitat ($7,000) create the biggest environmental benefits.

The urban heat island impacts under RCP8.5[3] are significant at $91,000 ($65,000 to $118,000 95% confidence interval). If we were to use a stationary temperature projection (current temperature going out 50 years), the urban heat island impacts would be $47,000 ($33,000 to $61,000 95% confidence interval). Although still large, the benefits of GI under higher future temperatures has almost double the benefit.

[3] "The Representative Concentration Pathways (RCPs) form a set of greenhouse gas concentrations supporting impacts and policy responses to climate change (Moss et al. 2010; van Vuuren et al. 2011a)." RCP8.5 corresponds to the pathway with the highest greenhouse gas emissions based on assumptions of modest technological change and energy intensity improvements leading to long-term high energy demand and GHG emissions in absence of climate policies. (Riahi, 2011, pp. 33-34).

Table 4: Detailed TBL-CBA Results for SACAC Project (Stormwater vs. Irrigation)

Impact Type	Cost/Benefit	Mean Value	95% Confidence Interval		
Financial	Capital Expenditures	**$145,667**	$114,974	to	$174,148
Financial	*Additional Irrigation CapEx*	***-$9,000***	*-$10,800*	*to*	*-$7,200*
Financial	Operations and Maintenance	**-$45,560**	-$42,454	to	-$34,486
Financial	*Additional Irrigation O&M*	***-$7,021***	*-$10,511*	to	*-$4,065*
Financial	CapEx on Additional Detention	**$0**	$0	to	$0
Financial	O&M on Additional Detention	**$0**	$0	to	$0
Financial	CapEx on Additional Piping	**$0**	$0	to	$0
Financial	O&M on Additional Piping	**$0**	$0	to	$0
Financial	Replacement Costs	**$120,681**	$20,531	to	$273,452
Financial	*Additional Irrigation Replacement Cost*	***-$20,200***	*-$20,200*	*to*	*-$7,742*
Financial	Residual Value of Assets	**-$10,560**	-$34,387	to	$8,221
Financial	Water savings	**-$13,879**	-$23,133	to	-$6,593
Financial	*Irrigation water savings*	***-$15,132***	*-$17,312*	*to*	*-$13,087*
Social	Heat Island Effect	**$90,915**	$34,013	to	$65,681
Social	Other Benefits	**$0**	$0	to	$0
Social	Flood Risk	**$8,431**	$8,431	to	$8,431
Social	Property Value	**$0**	$0	to	$0
Social	Education	**$0**	$0	to	$0
Social	Recreational Value	**$732,336**	$732,336	to	$732,336
Social	Public Health	**$20,255**	$2,554	to	$55,672
Social	Food	**$46,735**	$22,433	to	$69,486
Social	Social Value of Water	**-$104**	-$104	to	-$104
Social	*Irrigation Social Value of Water*	***-$8,999***	*-$10,798*	*to*	*-$7,199*
Environmental	Water quality	**$1,371**	$1,371	to	$1,371
Environmental	Carbon Emissions from Concrete	**$2,176**	$850	to	$3,854
Environmental	Air Pollution Reduced by Vegetation	**$12,832**	$8,779	to	$16,498
Environmental	Carbon Reduction by Vegetation	**$907**	$172	to	$1,787
Environmental	Air Pollution from Energy Use	**$3,362**	$1,136	to	$6,193
Environmental	Carbon Emissions from Energy Use	**$2,589**	-$106	to	$6,026
Environmental	Habitat	**$7,060**	$7,060	to	$7,060
Environmental	Pollination	**$2,452**	$2,452	to	$2,452
Total:	**(Alt 1) Triple Bottom Line NPV (Base - Stormwater)**	**$1,127,667**	**$877,207**	**to**	**$1,441,793**
Total:	***(Alt 2) Triple Bottom Line NPV (Base - Irrigation)***	***$1,081,297***	***$830,822***	***to***	***$1,413,261***

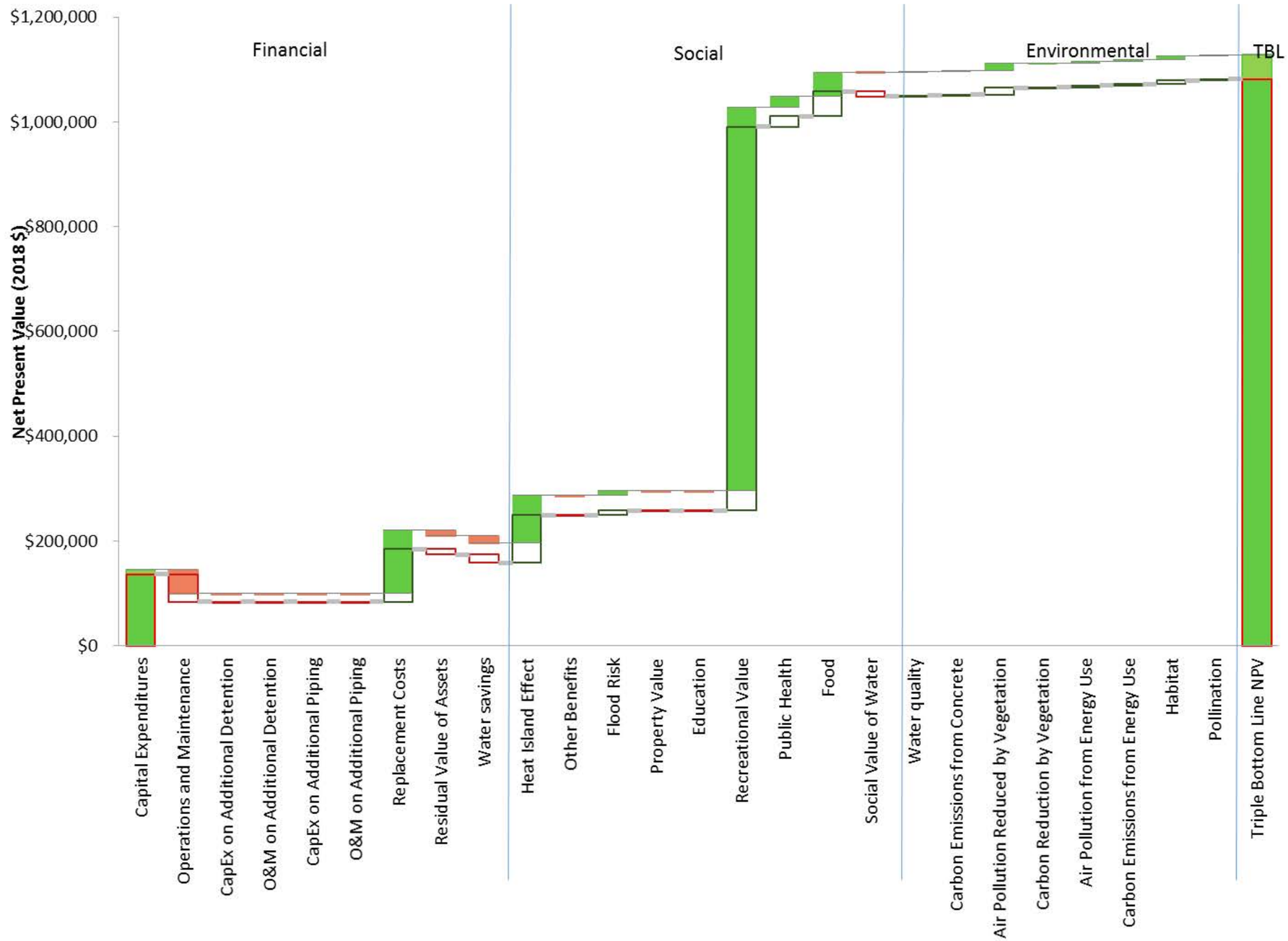


Figure 9: Detailed TBL-CBA Waterfall Results for SACAC Project

Note: Solid bars represent Alternative 1 (Base to Stormwater). Hollow bars represent Alternative 2 (Base to Irrigation).

Urban Heat Island: A Comparison of Static versus Rising Future Temperatures

Urban Heat Island (UHI) is an important consideration for Pima County under current and future climate scenarios. This analysis used RCP8.5 (high emissions projection for a 30-year period based around 2050) to quantify the value of reduced temperature brought about by GI. However, a comparison between static current temperatures versus RCP8.5 reveals interesting results. Under the static temperature, each project still yields significant UHI benefits (Meander = $0.9m, and SACAC = $47,000). However, these benefits almost double when assessing a higher future temperature[4] for the area.

Table 5: Urban Heat Island Comparison Between Future Predicted Temperature (RCP8.5) and Current Temperature

Project	Low UHI	Med UHI	High UHI
Stationary Meander	$653,006	$948,074	$1,226,916
RCP8.5 Meander	$1,255,961	$1,826,645	$2,374,508
Stationary SACAC	$33,320	$46,673	$60,826
RCP8.5 SACAC	$64,905	$90,915	$118,482

[4] Temperatures used to calculate UHI impact within Autocase from RCP8.5: Jan = 69.1, Feb = 72.1, Mar = 77.4, Apr = 86.0, May = 94.6, Jun = 103.6, Jul = 103.7, Aug = 101.6, Sep = 99.3, Oct = 91.1, Nov = 78.4, Dec = 70.0

Appendix A: Methodologies

A.1 TBL-CBA Framework

This project was conducted using a Triple Bottom Line Cost Benefit Analysis (TBL-CBA) framework. TBL-CBA provides an objective, transparent, and defensible business case framework to assess investments in stormwater infrastructure. The proposed analysis broadens traditional financial analysis to incorporate, and value social and environmental factors within an expanded CBA framework. The intent of these analyses is to determine the net social and environmental benefits (net benefits means costs minus benefits), in addition to the lifecycle financial costs and avoided costs that arise from projects.

CBA is a conceptual framework that quantifies in monetary terms as many of the costs and benefits of a project as possible and converting them all into a present day dollar value. In CBA, a "base case" (the existing conditions) is compared to one or more alternatives (which have some significant improvement compared to the base case). The analysis evaluates incremental differences between the base case and the alternative.

To incorporate uncertainty into the analysis, Autocase runs a Monte Carlo based simulation[5] of the possible outcomes and final project value. Low, most likely, and high values are taken from both user inputs and values in literature to reflect the underlying uncertainty in the values used in the CBA. These values are then defined by a distribution and applied to the benefit-cost analysis. This process is then repeated thousands of times to create a probability distribution of the results in the CBA – or 95% confidence intervals, allowing for a more nuanced assessment of project risks.

A.2 Base case

The cost-benefit analysis is conducted relative to a base case. The proposed project is the alternative. In the context of Autocase, the base case is maintaining the status quo. Put another way, it is the "do nothing" option. If a "do nothing" option is not feasible, the best approach is to create two alternatives that can be compared to one another; the comparison results is called a scenario.

The base case for Meander Bend Park Project is a do-nothing option. For the Southern Arizona Children's Center, the base case is a new asphalt parking lot. An additional consideration was also built in for the SACAC design alternative whereby a new irrigation system was assessed in place of the combination of water truck deliveries and stormwater.

A.3 Valuation Methodologies

For this assessment, Autocase was used to value:

- Capital expenditure;
- Operations and maintenance costs;
- Replacement costs;
- Residual value of assets;
- Avoided piping and detention costs (both CapEx and O&M);
- Water savings;
- Heat island effect on mortality risk;
- Flood risk;
- Property value uplift;
- Education;
- Recreation;
- Public health;
- Food;
- Social value of water;
- Water quality;
- Avoided carbon emissions from concrete;
- Air pollution and carbon emissions reduced by vegetation;
- Air pollution and carbon emissions reduced by energy savings
- Habitat; and
- Pollination.

A.3.1 Financial Impacts

A.3.1.1 Capital Expenditure

The capital costs for each of the features were based off Pima County's historical costs and Wheat Design Group estimates, thus representing a local picture of the upfront costs of each of these feature types. Low, expected, and high estimates are put in for each site to allow for a risk assessment.

A.3.1.2 Operations and Maintenance

Operations and maintenance (O&M) costs are those that accrue throughout the life of the project. In Autocase, they are discounted to produce a present value of the costs. As with capital costs, local O&M costs were provided by Pima County and Wheat Design Group. Again, low, expected, and high estimates were put in for each site to allow for a risk assessment.

A.3.1.3 Replacement Costs and Residual Value of Assets

Whether the infrastructure is a tree, an infiltration basin, a green or traditional roof, or plain concrete, all elements of an infrastructure project need to be replaced at some point. All feature types have different lifespans, as well as different costs of replacement at the end of their operating lives. Autocase quantifies these costs as the lifetime "Replacement Costs" of each feature. Replacement costs for features are estimated whenever the expected operating duration of the project exceeds the lifespan of a feature. Replacement costs are then combined with the expected lifespans of each feature type and the operating life of the project to quantify the expected total replacement costs.

Autocase estimates replacement costs as a percentage of initial capital expenditure (using the values listed above). The percent replacement costs are gathered from the EPA's SUSTAIN database. As for useful lives, they are estimated from a number of sources. These sources are used to create a distribution

[5] Monte Carlo simulation models probabilities of different outcomes, and is a process that cannot easily be predicted due to the intervention of random variables. This is used to understand the impact of risk and uncertainty.

in duration of useful life for each feature type. Sources used include Center for Neighborhood Technology (2006), Toronto and Region Conservation Authority (2013), and City of Toronto (Belanger, 2008).

Table 6: Replacement Costs and Useful Life of Features

Feature	Replacement Cost (% of original)			Useful Life (years)		
	Low	Expected	Max	Low	Expected	Max
Parking lot	31%	63%	100%	8	17.2	30
Sidewalk	24%	62%	100%	20	31	50
Swale	41%	64%	90%	20	35	50
Infiltration basin	41%	64%	90%	5	10	15
Tree	100%	100%	100%	25	50	75
Shrub	100%	100%	100%	5	5	20
Unmanaged turf	41%	64%	90%	20	35	50

When a project's operating life comes to an end, many assets may still have an implicit residual value. Depending on the remaining useful life of the asset for each alternative, at the end of the study period, some site elements have a "residual value". The residual value was calculated by determining the assets' useful lives remaining at the end of the period, and determining an appropriate value of the asset based on its remaining useful life. Autocase estimates this residual value by assuming straight-line depreciation in the value of all assets/design features. This value is then discounted into present value terms.

A.3.1.4 Water Savings

Water is saved due to water efficiency investments that thereby reduce the consumption of potable water. Water efficient investment can include cisterns, rain barrels etc. To value these quantity savings, Autocase uses the local average water rate from a dataset of city-level water prices from the latest American Water Works Association's (AWWA) Water and Wastewater Rate Survey (AWWA, 2014b) in the United States. These rates are forecasted forward based on historical price increases in the AWWA Rate Trends in Survey Years (AWWA, 2014a). For this project, we used a delivery truck rate of $0.76/gallon and a reclaimed irrigation rate of $0.004/gallon.

A.3.2 Social Impacts

A.3.2.1 Heat Island Effect

Heat waves are an increasing danger across North America, occasionally resulting in large numbers of premature deaths (e.g., over 100 deaths in Philadelphia in the summer of 1993). These events may be more frequent and severe in the future due to climate change. GI/LID can reduce the severity of extreme heat events by creating shade and reducing the amount of heat absorbed by pavement and rooftops. Even a small cooling effect can be sufficient to reduce heat stress-related fatalities during extreme heat wave events.

This analysis accounts for climate change by using temperature projections from RCP8.5 temperature data (high future emissions pathway for 30-year period centered around 2050). The expected increase in temperature affects the Urban Heat Island impacts and results in an increased benefit from using greener land uses and green infrastructure features.

The Urban Heat Island (UHI) effect compromises human health and comfort by causing respiratory difficulties, exhaustion, heat stroke, and heat-related mortality. Various studies have estimated that trees and other vegetation within building sites can reduce temperatures by 5 °F when compared to outside non-green space. At larger scales, variation between non-green city centers and rural areas has been shown to be as high as 9 °F during the day and up to 22 °F during the night.

To quantify heat risk mitigated in Autocase, the first step is determining reduced temperatures in the area because of the project. Figure 10 shows various land cover types and the average temperature reduced caused by changing a hypothetical city of all asphalt to that specific land cover instead. Using this link, the reduction in temperature is then used to determine avoided death over the life of the project. The reduction in the average annual mortality rate is based on local weather, the local mortality rate, and the local temperature threshold at which the impacts of heat on mortality can be detected (referred to as the Minimum Mortality Temperature, or MMT). Finally, the Value of Statistical Life, is used to quantify the benefit of reduced heat mortality rates.

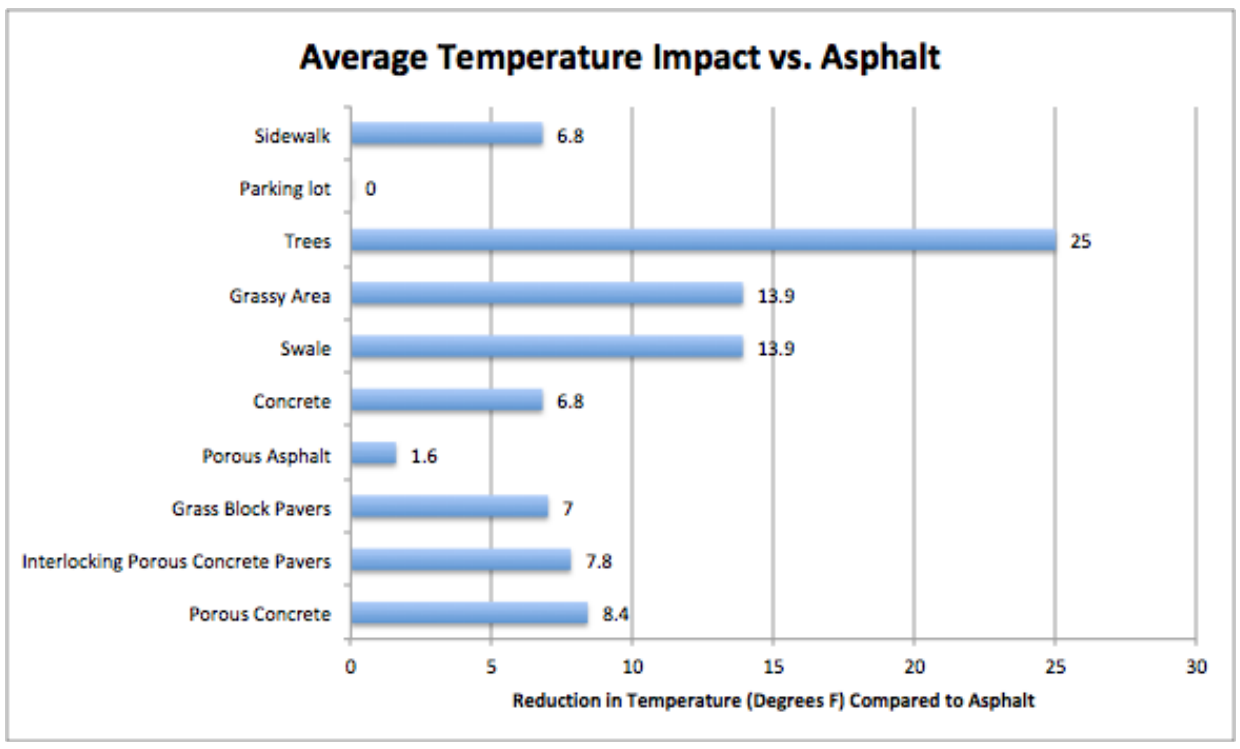


Figure 10: Temperature Changes from Land Cover Change

Value of Statistical Life

The value of a statistical life (VSL) is used when analyzing the risk and reward trade-offs people make. Economists often estimate the VSL by looking at the risks that people take, or say they will take, and how much they are - or must be - paid for taking them. The VSL is widely used in the regulatory impact analysis and cost benefit studies for federal government cost benefit analyses (e.g. safety improvements in rail and roadways). A range of $5-$13 million with a median around $9 million seems to be accepted. These values are in 2012 US Dollars and are adjusted for inflation depending on the year they are realized.

VSL is not intended to be the value of a specific life. It is the value placed on changes in the likelihood of death, not the price someone would pay to avoid death. Autocase does not place a dollar value on individual lives. Rather, the benefit-cost analysis of infrastructure uses estimates of how much people are willing to pay for small reductions in their risks of dying from adverse health conditions that may be caused or improved by the infrastructure.

References Used

(Anderson e Bell, 2011), (Basu *et al.*, 2008), (Curriero *et al.*, 2002), (Mercado *et al.*), (Medina-Ramon e Schwartz, 2007), (Sailor, 2003), (Zanobetti e Schwartz, 2008), (Voorhees *et al.*, 2011).

A.3.2.2 Avoided Flood Risk

Flood risk is quantified by estimating the percent flood risk mitigated as a result of the project design. As climate change has progressed and rainfall events in some regions have become more extreme, flood risk has become an important consideration in infrastructure development. Autocase quantifies the value of reduced flood risk due to a smaller volume of runoff from the project's property during storm events. Runoff can be reduced by increased green acreage, stormwater storage capacity, stormwater drainage capacity, or reducing the surface area covered by impervious land.

Flood risk is quantified in Autocase by estimating the percent flood risk mitigated in the city because of the project design. The components to this methodology are explained as follows:

1. The first is estimating the total flood risk damage in any given year.
    - Flood risk is estimated based on historical property value and historical flood damage in each state in the United States.
2. The second component to the flood risk methodology is determining the flood risk mitigated because of the project.

- This uses historical rainfall data from over 6,000 weather stations across the United States and Canada, enabling location-specific rainfall data to estimate the rainfall amounts in large storm events each year. Precipitation trends from climate change predictions are also incorporated into the modeling.
- Estimated flood risk mitigated by the design is equal to the change in retention and infiltration capacity beyond the site's base capacity, divided by the approximate city-wide flood volume in storm events.
- The overall flood risk mitigated each year is calculated by multiplying total city property value by the flood risk mitigated.

Although the value at risk increases linearly when compared with storm repeat rate, this actually implies that risk increases exponentially as rainfall depth goes up. This is due to the fact that rainfall levels off as the storm repeat rate goes up. In other words, going from a 10-year storm to a 40-year storm may double rainfall depth from 2.5 inches to 5 inches, but that same doubling from 5 inches to 10 inches may be extremely improbable, even in a 10,000-year storm. In short, for each extra 0.1 inches of rainfall, flood damage is exponentially costlier.

The Autocase flood risk methodology is a dynamic simulation, meaning that for every year in each iteration of the simulation, it produces different risk values. For example, flood risk mitigated due to a decrease of impervious surfaces might be zero for most years. However, in some years there may be rainfall events that are extraordinarily large, at which point there could be massive flooding and the value of reduced flooding due to higher infiltration rates on the site may have value. This is reflected in the Autocase methodology, as there is an element of randomness applied to the rainfall estimates for each year. This means that Autocase's analysis is a better reflection of reality than assuming constant maximum storm strength each year or simply estimating reduced damage value from synthetic design storms, such as 10-, 20-, 50-, and 100-year storms.

References Used

(Hanson e Vogel, 2008); (Nowak e Greenfield, 2012); (Pielke *et al.*, 2002); (Cronshey *et al.*, 1985)

A.3.2.3 Property Value Uplift

High quality landscape design will improve the aesthetic quality of the surrounding area, creating a more desirable neighborhood. The literature tells us that it is highly likely that property values – not only adjacent to the low impact development (LID) – but beyond, will increase as a result.

To estimate this impact, we use a US EPA meta-analysis of 35 hedonic property valuation studies on the benefits of general open space and low impact development (Mazzotta *et al.*, 2014). Autocase estimates the percent change in a home's value for an observed percent change in open green space, while factoring in other influencing characteristics, such as existing house prices (at the zip code-level for USA, and city-level for Canada), existing green space within 500m, the distance of the property from the LID, and whether there are recreational facilities, among others.

The types of features we use to estimate the increase in market value of properties include:
Trees; Bioretention; Dry detention pond; Infiltration basin; Infiltration trench; Lawn or grassy area; Retention pond; Green roof; Wetlands.

Our model assumes that properties within 250m of the LID will be impacted to a greater extent than properties 250m-500m from the LID. Based on the literature, we assume that properties more than 500m from the LID amenity will not be affected, which is consistent with the distance people are generally willing to walk for local amenities.

Once the percentage increase in property value is calculated for the two distance bands (within 250m and 250m-500m), we convert the total increase in value to an "annual rental equivalence" i.e. a yearly benefit, since we do not know what year the property will be sold. Essentially this estimates the yearly increase in rent that would be gained, if this property were to be rented out, since the price of a home can be thought of or represented as the sum of the discounted future annual rental-equivalent values of living in that home.

We multiply this yearly increase in value per property by the number of properties in each distance band (within 250m, and 250m-500m) to calculate the total yearly benefits for all properties within 500m of the LID. These yearly benefits are then discounted according to the time horizon of the project to create a present value of the benefits.

References Used

(Mazzotta *et al.*, 2014) (Braden e Johnston, 2004); (Anderson e Cordell, 1988); (Mcpherson *et al.*, 2006); (Ward *et al.*, 2008); (Wachter e Wong, 2008).

A.3.2.3 Education

Green space and LID/BMPs often offer a unique opportunity to promote eco-literacy and environmental education for children and adults alike. Some green spaces may be specifically designed to encourage school trips and improve educational opportunities, but in many cases they may just be positive unintentional by-products.
Ultimately, we use the cost of educating a child to monetize the educational benefits of the LID assuming that education within the classroom is equivalent to education at the LID. We multiply the estimated number of student hours spent at the green space by the cost of educating a student per hour to give us the educational value for the time students spend at the green space.

Using 2014-2016 field trip survey data from Sonoma, CA – which gave data on student hours spent at each park based off park size and whether it is rural or urban – we estimate the anticipated number of annual student hours. We then calculate the hourly cost of educating a student by dividing each state's total per-student spending by the number of hours each student attends in school.

Multiplying the cost of one student-hour by the estimated number of student-hours spent at the park (e.g. a class of 30 students spending 2 hours at the park equals 60 student-hours) enables us to determine the educational value associated with the green space.

The data only reported educational use hours that occurred during the school day, such as class field trips. Therefore, this value may be underestimating the overall educational value of the green infrastructure. For example, value that is not accounted for include: 1) the time and cost it took to travel to the park, 2) time spent by children outside of school hours where they are absorbing knowledge informally, 3) adult and infant eco-literacy, and 4) the wider long-term benefits of a future generation with improved eco-literacy.

References Used
(Nces, 2008), (Census.Gov, 2014)

A.3.2.4 Recreation

Green infrastructure has been shown to increase recreational opportunities (e.g., walking the dog, walking or jogging on sidewalks, bench sitting or picnicking) when increased vegetation and treed acreage is added within a community. The value of added recreational opportunities is measured by the increase in recreational trips or user days gained from urban greening. Use values can then be assigned to the various recreational activity trips. Although the protection of public space and the provision of recreational amenities are typically not priced, they nevertheless have significant value to society, and economists have developed sophisticated analytical techniques to derive monetary values for these types of goods.

Autocase uses a methodology developed by the US Army Corps of Engineers to quantify this benefit, while also incorporating low and high ranges into the analysis. The range used in the risk analysis is important because the valuation of how much people are willing to pay for a recreational experience is uncertain. The approach uses a points-to-dollars system that has been developed by the US Army Corps of Engineers, producing a range of willingness-to-pay (WTP) values that are largely based on the responses to "Recreation Use" questions in Autocase.

The approach taken in Autocase involves estimating the increased total user days expected after the project is constructed, then multiplying this value by the estimated WTP of users. The WTP value is calculated using the US Army Corps of Engineers methodology, which evaluates qualitative responses into points, then translates points into dollars.

References Used
(Kitch, 2012)

A.3.2.5 Public Health

Low impact development (LID), parks, and greener streets are more attractive for exercise. The economic benefits of improved health from engaging in regular physical activity can be valued as the prevented – or avoided – reduction in productivity that results from that activity. Lost economic output from people being out of work or not engaged while at work represents the social cost in this model.

In order to determine this value, we need to estimate 1) the amount of time adults spend at the park exercising, and 2) the cost per minute – in terms of lost productivity – of not exercising. By multiplying the two, we find the avoided cost due to engaging in physical activity.

To determine the amount of time spent at the site, we estimate the expected number of adult visitors to the green infrastructure site (be it a park or a street with LID along it), and assume they spend 15 minutes exercising at the area – thus attributing 15 minutes of their American Heart Association-recommended 30-minute exercise routine to the site.

To estimate the cost per minute of inactivity (or avoided cost of a minute's activity), we use a study that showed the lost productivity (absenteeism i.e. being away from work, and presenteeism i.e. not being able to work well even when you are present at work) in percentage terms of inactivity. Multiplying these productivity losses by the GDP per capita, we can establish the annual per person cost of lost productivity from inactivity. Given there are 7,800 minutes (150 minutes a week) of exercise needed in a year to avoid lost productivity, we work out the per-minute avoided cost of activity by dividing the cost of lost productivity by 7,800.
Multiplying the per-minute avoided cost of activity by the estimated number of minutes on the park gives us an estimate of the avoided productivity losses due to inactivity that can be attributed to the park.

References Used
(Aha, 2018), (Boles *et al.*, 2004), (Cohen *et al.*, 2007)

A.3.2.6 Food Provisioning

Both sites will house plants that have the opportunity to be harvested for food. The two plants in question are Mesquite trees (*Prosopis velutina*), and Prickly Pear cactus (*Opuntia* spp.).

Mesquite:
One mature velvet mesquite tree 15-30 height can yield 10 lbs of pods. 10 lbs pods yields approximately 7.5 lbs of flour. The retail value for 1 lb of flour (less milling costs of $3/lb.) is $15. The retail value of harvest from one mature tree (7.5 lbs flour) is $112.50/yr. A low estimate assumes each pod produces 2.5 lbs of flour = $37.3 per tree per year. A high estimate assumes 10 lbs of flour = $150 per tree per year.

Prickly pear plants:
Prickly pear plants produce both pads and fruit that can be harvested, so we estimate their value separately.

- Pads - A well-kept plant can be harvested up to six times a year for pads, with each plant generating 20-40 half-pound pads per harvest (Uc.Davis, 2018). For the medium estimate, we assume two harvests a year, with each plant producing 10 half-pound pads at each harvest. The value of the pads is $1.70/lb, resulting in a value per plant of $17/yr (10 lbs of produce x $1.70/lb). The low estimate is $8.5/yr per plant (i.e. 5 lb yield assuming one harvest a year). The high estimate is $34/yr per plant (i.e. 20 lb yield assuming two harvests and 20 half-pound pads per plant).
- Fruit - Eight to 16 fruit to be found on each pad is common. The yield for fruit is 8.36 times less than that of pads (0.5lbs per meter vs. 4.18lbs per meter). We assume one harvest of fruit per year valued at $14/lb of fruit. Each plant is estimated to produce 0.6 lbs of fruit per harvest, which results in a value of $8.4/yr per plant. The low estimate = $4.2/yr per plant (assuming half the yield). The high estimate = $16.8/yr per plant (assuming 0.6 lbs per harvest, but two harvests).

References Used
(Uc.Davis, 2018)

A.3.2.7 Social Value of Water

This model estimates the benefits of collecting rainwater or greywater to offset potable water use used for irrigation. Benefits in this model include:

1. A social value of water associated to keeping water in the ground, lakes, streams.
2. A social value of reduced carbon emissions and air pollution from less electricity needed to supply and treat water.
3. The financial aspect of increased or decreased water use is found in the Financial section under "Water Savings".

Social Value of Water:

- Autocase uses the county-level United States Geographical Survey water census data to determine what percentage of streamflow and groundwater is used as the water supply, and thus estimate the amount of each water source the project is using. The social values for groundwater and streamflow are then multiplied by their respective amounts used More information can be found here (https://sites.autocase.com/docs/methodologies.html#social-value-of-water).
- The social value of water is inflated over the project period using American Water Works Association historical growth rates of water.
- A social value of water will be applied to any water taken out of the water table. For instance, using water from a utility or capturing water from a well will imply water being taken out of the water table or a body of water, hence a social value of water will be applied.
- By reducing the amount of potable water in a project and increasing rainwater capture, the social value of water will also be saved, hence a benefit will come from the project in question.

Air Pollution and Carbon Emissions:

- The entire process from sourcing, treating, and supplying water to treating wastewater requires significant amount of electricity. By reducing the amount of water required on-site, it is assumed that there will be a reduction in electricity usage by the utility.
- Based on available literature, Autocase has estimates of electricity usage per gallon of water for different locations in the US and Canada, as well as for the source of water.
- We apply emission factors for carbon emissions and air pollution to the electricity saved by reducing water consumption. Electricity emissions per amount of electricity generated can be found in EGRID or 2014 National Emissions Inventory (NEI) Data, both from the EPA.
- These emissions will be monetized using the emissions' respective social cost of emissions.

A.3.3 Environmental Impacts

A.3.3.1 Water Quality

Increased acres of vegetation, including forests or wetlands, can positively influence the water quality in a local area by reducing surface runoff of pollutants into local waters. In addition, using LID for stormwater management can reduce the stormwater volume that must be managed by gray infrastructure, reducing the frequency and volume of overflowing sewer systems in large storm events. This leads to improved water quality in local waters.

The improvement is valued using an avoided treatment cost approach. Autocase values changes in pollutant loadings by estimating the changes in pollutant loads compared to a base case (Schueler, 1987) and then applying a social cost of water pollutants to these values (Hernandez-Sancho et al., 2010, Hernandez-Sancho et al., 2015).

The components involved in this analysis include the following:

1. Pollutant reduction determined by site design
2. Social cost of water pollutants
    a. Total Suspended Solids (TSS)
    b. Nitrogen
    c. Phosphorous
    d. Fecal Coliform

A.3.3.2 Carbon Emissions

Newly planted trees, shrubs, grass, and plants can sequester carbon from the atmosphere, reducing the impacts of climate change. Additionally, growing trees, shrubs, grass, and plants can act as carbon 'sinks', absorbing carbon dioxide from the air and incorporating it into their stems or trunks, branches, and roots, as well as into the soil. As with air pollution, plant life often requires maintenance which emits carbon into the atmosphere.

Avoided CO_2 emissions, as well as increased CO_2 sequestration, is a benefit of investing in green infrastructure development. Relative to traditional gray infrastructure (e.g. pipes and water treatment infrastructure), LID may also have less embodied energy. In particular, the use of concrete is a large contributor to net embodied energy in gray infrastructure projects. However, in some cases - notably for green roofs - the net embodied energy may be higher than for traditional infrastructure due to differences in materials used or because more materials are needed.

Autocase quantifies the carbon sequestration rate for all design features in the software, given the available literature on carbon sequestration. It will then value this reduction in carbon emissions by applying the social cost of carbon to the change in total tonnes of avoided CO_2e emissions due to the project. The social cost of carbon used in this assessment follows the Interagency Working Group on Social Cost of Carbon and is valued at $ 41.68 per tonne.

References Used

(Cai, Wang, Elgowainy, & Han, 2012), (European Comission, 2005), (Mike Holland, 2002), (Friedrich, Rabl, & Spadaro, 2001), (Matthews & Lave, 2000), (G. E. McPherson, Nowak, & Rowntree, 1994), (Muller & Mendelsohn, 2010), (U.S. Environmental Protection Agency, 2014), (G. McPherson et al., 2004).

A.3.3.3 Air Pollution

For the purposes of this study, Criteria Air Contaminants (CACs) are considered air pollutants emitted by combustion engines, which affect the health of people immediately in their vicinity. Air pollution, or CACs, is removed from the environment by trees and shrubs. As these grow throughout the life of the project they capture air pollutants at an increasing rate.

The air pollutants reduced on site include mono-nitrogen oxides (NOx), sulphur dioxide (SO2), volatile organic compounds (VOCs), and particulate matter smaller than 2.5 micrometers (PM2.5). The air pollution is valued by multiplying by the social cost of each pollutant ranges from $6,730/tonne for NOx to $14,190/tonne for PM2.5. PM10 (Dust) was also considered in this study, using a McPherson (2004) study.

References Used

(Cai, Wang, Elgowainy, & Han, 2012), (European Commission, 2005), (Mike Holland, 2002), (Friedrich, Rabl, & Spadaro, 2001), (Matthews & Lave, 2000), (G. E. McPherson, Nowak, & Rowntree, 1994), (Muller & Mendelsohn, 2010), (U.S. Environmental Protection Agency, 2014).

A.3.3.4 Avoided Air Pollution and Carbon Emissions due to Reduced Energy Use

Trees modify climate and conserve building energy use in three principal ways:

1. Shading—reduces the amount of radiant energy absorbed and stored by built surfaces.
2. Transpiration—converts liquid water to water vapor and thus cools by using solar energy that would otherwise result in heating of the air.
3. Wind speed reduction—reduces the infiltration of outside air into interior spaces and conductive heat loss, especially where thermal conductivity is relatively high.

Trees provide greater energy savings in the Desert Southwest region than in milder climate regions because of the long, hot summers. Trees near buildings can reduce the demand for heating and air conditioning, thereby reducing emissions associated with electric power production. Autocase then uses the same principle as above to calculate the avoided emissions and the resulting social benefit from that.

The work by (G. McPherson et al., 2004) estimate that public trees save 77-181 kWh per year in electricity and around 229 kBTU in natural gas.

References Used

(G. McPherson et al., 2004)

A.3.3.5 Habitat

Autocase uses a habitat value taken from a FEMA mitigation policy document: "Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs", which states that FEMA will allow the inclusion of environmental benefits in benefit-cost analysis to determine cost effectiveness of projects.

References Used

(Fema, 2013)

A.3.3.6 Pollination

Autocase uses a pollination value taken from a FEMA mitigation policy document: “Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs”, which states that FEMA will allow the inclusion of environmental benefits in benefit-cost analysis to determine cost effectiveness of projects.

References Used

(Fema, 2013)

Appendix B: Inputs and Assumptions

Inputs

The tables in the section below outlines the inputs for each feature within the two sites that were used for the assessment in Autocase.

Inputs for Meander Bend Park Project

The design assumptions for the concept design were:

1. Planted vegetation that is not already contained within a basin or swale shall be planted within a depressed planting area, which shall include organic mulch.
2. Infiltration basins along the Loop Trail and 8' pedestrian path shall include organic mulch.
3. All areas that are not planted shall be seeded with a desert scrub seed mix. Seed mix shall include species of trees, shrubs, forbs, and grasses.
4. Proposed plant material includes food-producing and pollinator species.
5. Trees and shrubs shall be planted and seed mix broadcast immediately prior to summer monsoon season for successful landscape establishment.
6. Dry H_20 shall be used for planted trees. Stormwater will be used as the irrigation source for seeded areas and for planted vegetation after the use of Dry H_20.
7. Rainwater harvesting ramada and cistern will be a similar structure as the ramada used on the Julian Wash Greenway.
8. Bottom of vegetated swales shall be 3" deep with side slopes 4: 1-6: 1.
9. Bottom of infiltration basins shall be 5" deep with side slopes 4:1-6:1.
10. Pedestrian pathways shall be raked earth.
11. Location of design features to be field-adjusted as needed.

Input	Unit	Expected value	Notes
Meander Bend Park Project - General Inputs			
Dominant soil type		B	
24-hour design storm	Inches	4.23	
Stormwater model		TR-55	
Operations duration	Years	50	
Construction duration	Years	1	
Discount rate	%	3	
Meander Bend Park Project – Stormwater Scenario Inputs			
New vegetated swale	sqft	22,139	
New infiltration basin	sqft	252,226	
New unmanaged turf	Acre	17	
New shrubs	#	174	
New trees	#	420	112 planted, and 308 from seed mix after 25 years
Meander Bend Park Project - Base Case Scenario Inputs			
Existing undisturbed land	Acre	18	

Inputs for Southern Arizona Children's Advocacy Center Project

The assumptions for the concept design are:

1. All areas that are not planted within basins and swales within the 'restoration' zone of the site shall be seeded with a desert scrub seed mix. Seed mix shall include species of trees, shrubs, forbs, and grasses.
2. Proposed plant material includes food-producing and pollinator species.
3. Trees and shrubs shall be planted and seed mix broadcasted immediately prior to summer monsoon season for successful landscape establishment.
4. A watering truck will irrigate vegetation. The quantity of water used during each watering shall meet a 5 gallon requirement per tree. The water truck schedule is as follows: 1 x/month March-April; 1 x/week May-June annually for the first 5 years, then again every 3 years. Stormwater will be used as the irrigation source for the remainder of the year.
5. Bottom of vegetated swales shall be 3" deep with side slopes 4: 1-6: 1.
6. Bottom of infiltration basins shall be 5" deep with side slopes 4:1-6:1. Basins shall contain organic mulch.
7. Pedestrian pathways shall be decomposed granite.
8. Location of design features to be field-adjusted as needed.

The assumptions for the SACAC Base Case Scenario are:

1. The parking lot scenario presents an alternative to the green infrastructure concept.
2. It is assumed that no improvements are made to the landscape north and south of the building, and that these areas of the property remain undisturbed.

3. One tree is provided for every 10 parking spots (number of parking spots estimated and not depicted on plan.)

Input	Unit	Expected value	Notes
Southern Arizona Children's Advocacy Center Project - General Inputs			
Dominant soil type		D	
24-hour design storm	Inches	4.26	
Stormwater model		TR-55	
Operations duration	Years	50	
Construction duration	Years	1	
Discount rate	%	3	
Southern Arizona Children's Advocacy Center Project – Stormwater Inputs			
New vegetated swale	sqft	7,357	
New unmanaged turf	sqft	10,103	
New shrubs	#	114	
New trees	#	31	
New infiltration basin	sqft	7,687	
Existing swale	sqft	246	
Existing roof	sqft	13,127	
Existing sidewalk	sqft	1,200	
Southern Arizona Children's Advocacy Center Project - Base Case Scenario Inputs			
New parking lot	sqft	18,269	
New shrubs	#	21	
New trees	#	7	
New sidewalk	sqft	340	
Existing roof	sqft	13,127	
Existing sidewalk	sqft	1,200	

Assumptions

The table below details the assumptions that were made for each impact category that exogenous customizations/calculations were made within each of the two sites. Missing impact categories indicate that no customizations were made, essentially saying Autocase defaults were used.

Impact category	Site	Notes
Capital Expenditure	Meander Bend Park Design	$872,070 +/- 20% as low and high
	Meander Bend Park Base	None
	SACAC Design	$60,000 with 20%+/- as low and high
	SACAC Design w/ irrigation	Same as above, plus an additional $9,000 (+/- 20%) for irrigation system, assuming it is possible to tap into the existing irrigation system.
	SACAC Base Case	$206,485 +/- 20% as low and high
Operations and Maintenance	Meander Bend Park Design	$41,669/yr for first 10 yrs (which includes a cost for irrigation water for establishment of about $13,000/yr). $23,311/yr for years 10 to 50. On an annual basis = $26,983 +/- 20% as high/low. Numbers are based on habitat restoration.
	Meander Bend Park Base	None
	SACAC Design	$1,800/yr for 0.33-acre site ($125/1,000sf). High: Using Watershed Management Group costs for Phoenix of $150/1,000 sqft = $2,160/yr. Low: Using $90/1,000 sqft = $1,289/yr.
	SACAC Design w/ irrigation	Same as above plus additional O&M for irrigation as set out below. Low Annual Cost: $127 Average Annual Cost: $253 High Annual Cost: $512 These costs include labor and materials for Pima County projects. Labor is assumed to include two people to make repairs at 5%, 10% or 15% of their time on a weekly basis. Low costs are associated with new irrigations systems, least hard water and low critter chomping. Medium costs are associated with dilapidated irrigation systems, moderately hard water and moderate critter chomping. High costs are associated with vandalism prone irrigation systems, hard water that clogs the emitters and poly line attacked by critters heavily.
	SACAC Base Case	None
Replacement costs	Meander Bend Park Design	See 'replacement cost' in methodologies section
	Meander Bend Park Base	None
	SACAC Design	See 'replacement cost' in methodologies section
	SACAC Design w/ irrigation	Same as above, plus assume irrigation system needs replacing every 10 years. Low = replace every 20 years. High = every ten years.
	SACAC Base	See 'replacement cost' in methodologies section
Water Savings	Meander Bend Park Design	Stormwater-only.
	Meander Bend Park Base	None
	SACAC Design	Truck Water Calculations: 31 trees x 5 gallons per tree = 155 gallons per watering. 10 waterings a year (1x/month in March and April, 1x/week in May and June). Cost of water = $.76/gallon. Annual water cost = 155 gallons x 10 waterings = 1,550 gallons x 0.76 = $1,178/yr. Water once a year for 5 years for establishment. And then once every 3 years. Low = Four waterings ($471/yr) under same schedule as above. High = 10 waterings ($1,178) a year every year.
	SACAC Design w/ irrigation	Use irrigation instead of water truck. Total estimated annual mature water use is 147,600 gallons. Cost of water = $1,300/AF for reclaimed water ($0.0040/gallon). Gallons used = 147,600 Total cost/yr = $589 Low = 20% less water needed = $471/yr High = 20% more water needed = $707/yr
	Meander Bend Park Design	

Impact category	Site	Notes
Heat Island Effect	Meander Bend Park Base	In order to reflect the local impact GI features have in lowering temperature, we updated the temperature reduction factors within the code for each feature type, based on research done at Arizona State University (see UHI methodology section for details). We used temperature projections from RCP8.5 temperature data (high future emissions pathway for 30-year period centered around 2050) to reflect climate change in the area and the impact GI would have with these higher temperatures.
	SACAC Design	
	SACAC Design w/ irrigation	
	SACAC Base	
Flood risk	Meander Bend Park Design	We used the PC-Hydro values for the 2, 5, 10, 25, 50, 100, and 200 year 24 hour design storms.
	Meander Bend Park Base	Same as above
	SACAC Design	Same as above
	SACAC Design w/ irrigation	Same as above
	SACAC Base	Same as above
Property value	Meander Bend Park Design	Surrounding area already has ~ 40 acres of open public 'green' space within 500m of the site. Current property value is $190,000. Annual uplift from park is $44,536/yr. Low = $15,945/yr High = $75,055/yr
	Meander Bend Park Base	None
	SACAC Design	Given the site is adjacent to a major recreation area (used to be Diamondback spring training), soccer fields and restoration site (total ~200 acres), there was no impact on property value.
	SACAC Design w/ irrigation	Same as above
	SACAC Base	None
Education	Meander Bend Park Design	50 students per year for 2 hours each = 100 student hours. Annual benefit = $580.45. Low = $290/yr High = $1,160
	Meander Bend Park Base	None
	SACAC Design	None
	SACAC Design w/ irrigation	None
	SACAC Base	None
Recreation	Meander Bend Park Design	7,300 user days (20 ppl per day * 365 days).
	Meander Bend Park Base	None
	SACAC Design	18 ppl for 200 days = 3,600 (30 staff in building, 270 working days per year). 5 x 365 days = 1,825 user days from Loop visitors. Total = 5,425 user days.
	SACAC Design w/ irrigation	Same as above
	SACAC Base	None
Public Health	Meander Bend Park Design	7,300 user days. 16% of visitors getting exercise in site for 15 minutes. Annual benefit = $897/yr. Low = $60/yr High = $5,094/yr
	Meander Bend Park Base	None
	SACAC Design	5,425 user days. 16% of visitors getting exercise in site for 5 minutes each. Annual benefit = $229/yr. Low = $45/yr High = $3,785/yr
	SACAC Design w/ irrigation	Same as above
	SACAC Base	None
Food	Meander Bend Park Design	Planted: 65 mesquites Med = $7,312.50 per year ($112.50 per tree per year); Low = $2,424.5/yr High = $9,750/yr

Impact category	Site	Notes
		82 prickly pear plants Pads: = $1,394 per year ($1.70/lb and 820 lbs). Low = $697. High = $2,788. Fruit: = $686 per year ($14/lb and 49 lbs of fruit). Low = $343. High = $1,372. Total prickly pear. Low = $1,040, Med = $2,080, High = $4,160. From seed mix: We assume the plants from seed mix start generating food after 25 years, so half the time period. 518 prickly pear plants and 308 mesquites generating the same value as those planted today from years 26-50. Total: Low = $7,708/yr Med = $20,697/yr High = $31,203/yr
	Meander Bend Park Base	None
	SACAC Design	15 Mesquite Trees: Med = $1,687.50 ($112.5 per tree per year) Low = 2.5 lbs of flour = $37.3 per tree = $559.5 High = 10 lbs of flour = $150 per tree = $2,250 17 prickly pear plants: Pads: Med = $289 per year. Low = $144.5. High = $578. Fruit: = $140 per year. Low = $70. High = $280. Total: Low = $774 per year. Med = $2,116.5 per year. High = $3,108 per year.
	SACAC Design w/ irrigation	Same as above
	SACAC Base	2 Mesquite Trees: Med = $225/yr. Low = $74.6/yr. High = $300/yr.
Social Value of Water	Meander Bend Park Design	Stormwater-only irrigation.
	Meander Bend Park Base	None
	SACAC Design	1,550 gallons of potable water from a truck delivery.
	SACAC Design w/ irrigation	Total estimated annual mature water use is 147,600 gallons, or 0.453 acre-feet.
	SACAC Base	None
Air Pollution and Carbon Reduced by Vegetation	Meander Bend Park Design	For PM10 (Dust) Planted: High = 112 trees at 0.42lbs removal per year (Mesquite tree) at $8.03/lb (inflated from $6 in 2004) = $377.7 per year. Medium = 65 mesquite at 0.42 lbs removal per year and 47 trees at 0.16 lbs removal per year = $219 + $60 = $279. Low = 112 trees at 0.16lbs removal per year at $8.03/lb = $143.9. Seed mix: Additional 308 trees from seed mix that bring benefits starting in year 26 through to year 50. Med = $183/yr Low = $94.15/yr High = $247.9/yr Total: Med = $462/yr Low = $238/yr High = $625/yr Autocase defaults used for other air pollutants from vegetation.
	Meander Bend Park Base	None
	SACAC Design	PM10 (Dust) 31 trees: 15 Mesquite trees at 0.42 lbs PM10 removal per tree per year at $8.03/lb PM10 (inflated from $6 in 2004) = $50.6/yr. 16 trees at 0.16 lbs PM10 removal per tree per year = $20.6/yr. Total = $71.2/yr.

Impact category	Site	Notes
		Autocase defaults used for other air pollutants from vegetation.
	SACAC Design w/ irrigation	Same as above
	SACAC Base	PM10 (Dust) 7 trees Two mesquite trees at 0.42lbs removal per year at $8.03/lb = $6.7/yr. 5 trees at 0.16 lbs removal per year = $6.4/yr. Total = $13.1/yr. Autocase defaults used for other air pollutants from vegetation.
Air pollution and Carbon from Energy Use (Natural Gas)	Meander Bend Park Design	112 public trees at 229 kBTU savings per year = 25,648 kBTU savings per year. From seed mix = additional 308 trees in 25 years. So saving 35,266 kBTU (essentially divided by two, as 25 years, not 50 years). Total = 60,914 kBTU/yr
	Meander Bend Park Base	None
	SACAC Design	11 private trees and 20 public trees (Mesquite). Natural gas savings from Private trees: Low = -116 kBTU/yr, Med = 2 kBTU, High = 24 kBTU. For 11 private trees: Low = -1,276 kBTU. Med = 22 kBTU, High = 264 kBTU 20 public trees at 229 kBTU savings = 4,580 kBTU. Total savings: Low = 3,304 kBTU/yr, Med = 4,602 kBTU/yr, High = 4, 844 kBTU/yr
	SACAC Design w/ irrigation	Same as above
	SACAC Base	2 private trees and 5 public trees Natural gas savings from Private trees: Low = -116 kBTU/yr, Med = 2 kBTU, High = 24 kBTU. For 2 private trees: Low = -232 kBTU. Med = 4 kBTU, High = 48 kBTU 5 public trees at 229 kBTU savings = 1,145 kBTU. Total savings: Low = 913 kBTU/yr, Med = 1,149 kBTU/yr, High = 1,193 kBTU/yr
Air pollution and Carbon from Energy Use (Electricity savings)	Meander Bend Park Design	Planted: High = 112 Mesquite at 180 kWh savings = 20,160kwh total yearly savings. Medium = 65 Mesquites at 180 kWh/tree saving and 47 small trees at 77 kWh/tree savings = 15,319kwh savings per year. Low = 112 small trees at 77 kWh savings per tree per year = 8,624 kWh savings per year. From seed mix: 308 additional trees in 25 years. Med = 15,319 kWh for 112 trees = 136.78 kWh per tree per year. For 308 trees in 25 years = 21,064 kWh per year (divide by 2 for 25 years instead of 50 years). Low = 77 kWh per tree for 100 trees in 25 years = 3,850 kWh High = 180 kWh per tree for 308 trees in 25 years = 27,720 kWh Total savings: Low = 12,474 kWh, Med = 36,382.6 kWh, High = 47,880 kWh
	Meander Bend Park Base	None
	SACAC Design	11 private trees and 20 public trees (Mesquite). Private tree = 167-388 kWh savings = 277 kWh Public tree = 77-180 kWh savings = 128.5 kWh 11 private trees = Low = 1,837, Med = 3,047 kWh, High = 4,268 20 public trees = Low = 1,540, Med = 2,570 kWh, High = 3,600 Total savings = Low = 3,377 kWh, Med = 5,617 kWh, High = 7,868 kWh
	SACAC Design w/ irrigation	Same as above
	SACAC Base	2 private trees and 5 public trees Private tree = 167-388 kWh savings = 277 kWh Public tree = 77-180 kWh savings = 128.5 kWh 2 private trees = Low = 334, Med = 554 kWh, High = 776 5 public trees = Low = 385, Med = 642.5 kWh, High = 900 Total saved = Low = 719 kWh, Med = 1,196 kWh, High = 1,676 kWh
Habitat	Meander Bend Park Design	$835/acre per year (FEMA). 18 acres x $835 = $15,030 per year.

Impact category	Site	Notes
	Meander Bend Park Base	None
	SACAC Design	$835/acre (FEMA) at 0.33 acres = $275.5/yr
	SACAC Design w/ irrigation	None
	SACAC Base	None
Pollination	Meander Bend Park Design	$290 per acre per year for open green space. 18 acres of site = 18 x $290 = $5,220
	Meander Bend Park Base	None
	SACAC Design	$290/acre per year for green open space. 14,327 sqft = 0.33 acres = $95.7/yr
	SACAC Design w/ irrigation	Same as above
	SACAC Base	None

Appendix C: Pima County Regional Flood Control District Derivation of Inputs

Background:

The AutoCASE assessment required Pima County to Provide inputs for calculating Net Present Value. This memo provides the derivation of those inputs

Summary:

1.) **Operation and Maintenance Costs:**

a. Southern Arizona Children's Advocacy Center Site Design (estimate from similar site)

Name	**Cortaro Ridge Basin #2**
Size (ac)	mostly mowing 0.21
Vegetation	
Cost/visit	$ 558
Frequency per year	2
Staff number	4
Hours/visit	2
Mowing	
Cost/visit	30
Frequency per year	2
Staff number	2
Hours/visit	1
Spraying	
Cost/visit	82
Frequency per year	1
Staff number	1
Hours/visit	1
Total cost per year	$ 1,258
$/sq-ft	$0.14
Area SACAC (sf)	13,068
Annual Cost	**$ 1,797**

b. ***Meander Bend Park:*** Tom Helfrich, Division Manager for RFCD Water Resources Division provided values based on many years implementing habitat restoration projects on Pima County Lands. Tom calculated O &M costs for the first 10 years of operation during the vegetation establishment period and maturation period, and then for the maintenance costs following establishment in years 10 to 40.

Short Term Operation & Maintenance Costs (Year 1 to Year 10)

Activity	**Unit**	**Cost / Unit**	**#**	**Cost**
Site Inspection (Wages, Salary & Overhead for an employee paid $30/hr)	hrs	$90	48	$4,320
Trash Removal	ls	$500	1	$500
General Site Repair (Wages, Salary & Overhead for an employee paid $20/hr)	hrs	$60	96	$5,760
Weed Control	ls	$2,500	1	$2,500
Vector & Nuisance Animal Control (This typically covers problems with pack rats, bees, etc.)	ls	$300	1	$300
Water for Irrigation (2 acft/ac/yr for a semi-dry Mesquite Bosque at Pima County Wheeled Rate)	acft	$150	34	$5,100
Irrigation Schedule Inspection & Adjustment (Wages, Salary & Overhead for an employee paid $20/hr)	hrs	$60	48	$2,880
Irrigation & Water Harvesting Feature Repairs (Wages, Salary & Overhead for an employee paid $20/hr)	hrs	$60	96	$5,760
Plant Replacement Due to Die Off	ls	$500	1	$500
Reporting (Wages, Salary & Overhead for an employee paid $30/hr)	hrs	$90	96	$8,640
Sub Total				$36,260
Contingency	%		15	$5,439
Total Cost				**$41,699**

Long Term Operation & Maintenance Costs (Year 10 to Year 50) Without Inflation

Activity	Unit	Cost / Unit	#	Cost
Site Inspection (Wages, Salary & Overhead for an employee paid $30/hr)	hrs	$90	48	$4,320
Trash Removal	ls	$250	1	$250
General Site Repair (Wages, Salary & Overhead for an employee paid $20/hr)	hrs	$60	96	$5,760
Weed Control	ls	$1,000	1	$1,000
Vector & Nuisance Animal Control (This typically covers problems with pack rats, bees, etc.)	ls	$300	1	$300
Reporting (Wages, Salary & Overhead for an employee paid $30/hr)	hrs	$90	96	$8,640
Sub Total				$20,270
Contingency	%		15	$3,041
Total Cost				**$23,311**

2.) Estimate of Annual Irrigation Maintenance Costs (SACAC)

Replacement interval			**Most Frequent**	**Moderate Freqency**	**Least Frequent**	**High Annual Irrigation Cost**	**Average Annual Irrigation Cost**	**Low Annual Irrigation Cost**
	Cost per item	Number						
Emitters	$ 0.23	414	2.00	0.67	0.33	$190.44	$ 63.48	$ 31.74
Bubblers - Iratrol ($/item)	$ 1.20	0	0.67	0.20	0.10	$ -	$ -	$ -
Bubblers - Toro ($/item)	$ 1.29	0	0.67	0.20	0.10	$ -	$ -	$ -
Bubblers - Rainbird ($/item)	$ 0.67	0	0.67	0.20	0.10	$ -	$ -	$ -
Pre-set bubbler - Rainbird ($/item)	$ 2.96	0	0.67	0.20	0.10	$ -	$ -	$ -
Poly Lines ($/foot)	$ 0.05	940	1.33	0.40	0.20	$ 67.33	$ 20.20	$ 10.10
Materials subtotal						$257.77	$ 83.68	$ 41.84
Labor, ($/hour)	$ 32.55	52	15%	10%	5%	$253.89	$169.26	$ 84.63
Total						$511.66	$252.94	$126.47

Emitters will last according to the hardness of the water and can last to 6 months,
1.5 years and 3 years (plug easily, plug moderately, plug slowly)
Bubblers will last according to the hardness of the water and last to 1.5 years,
1.5 years, 5 years and 10 years (plug easily, plug moderately, plug slowly)
Polylines will last 9 months where critters chomp the lines frequently,
average lines breaks every 2.5 years and life of existing poly line is five years.

3.) Estimate of Annual Stormwater Available for Harvesting

The annual volumes of stormwater were estimated using a simplification of the lot model (City-County Water Study, 2009), which uses a simple mass balance of rainfall and runoff derived from the Curve Number using daily precipitation input for the period 1895 to present. Based on that approach, the percent harvestable for each hydrologic soil group and for impervious surfaces can be estimated.

These are:

Hydrologic Soils Group	CN	Harvestable Fraction of Rainfall
A & B	83	17%
C	88	22%
D	91	25%
Impervious	99	72%

Using the observed hydrologic soils groups maps and impervious cover maps (attachment__), it is possible to

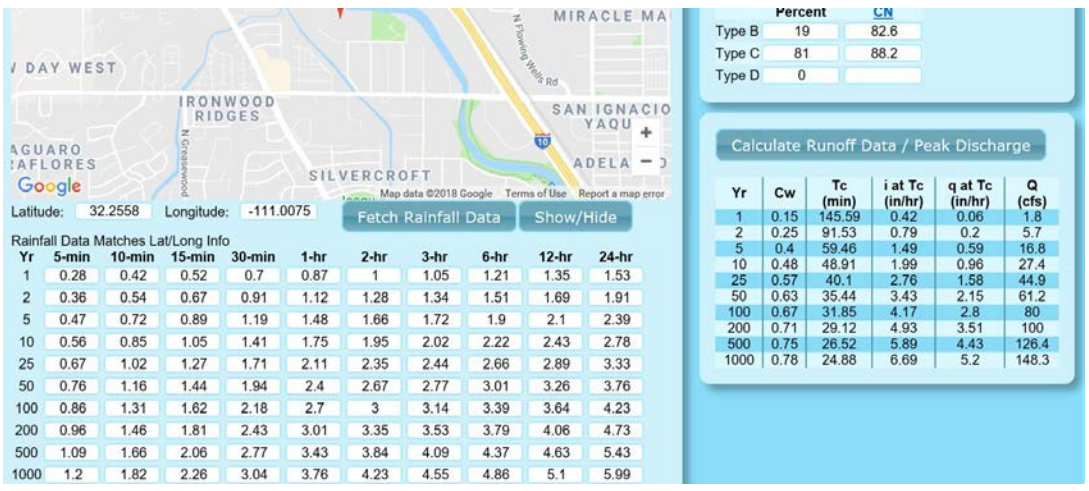
		Area (acres)	Rainfall Inches (avg)	Fraction	Runoff inch (avg)	Acre-ft Runoff (avg)
Offsite		28.0				
West		22.0				
	Impervious	2.4	11.16	0.72	8.0352	1.6
	Pervious 'C'	19.6	11.16	0.22	2.4552	4.0
	Sub-total					***5.6***
South		6.0	11.16			
	Pervious 'C'	6.0	11.16	0.22	2.4552	1.2
	Sub-total					***1.2***
Total Offsite						**6.9**
Onsite						
	Pervious 'B'	**11.4**	**11.16**	**0.17**	**1.8972**	**1.8**

Ajo Summary

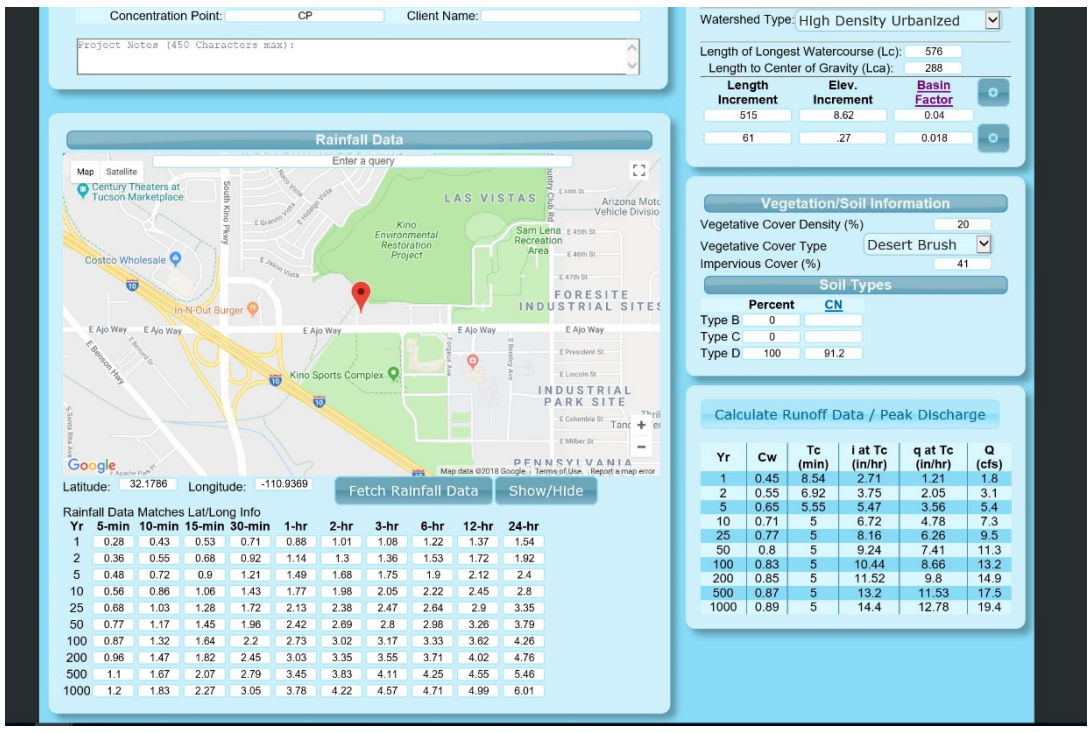
		Area (acres)	Rainfall Inches (avg)	Fraction	Runoff inch (avg)	Acre-ft Runoff (avg)
Offsite						
	Impervious	0.6	11.16	0.72	8.0352	0.4
	Pervious 'D'	0.9	11.16	0.25	2.79	0.2
	Total Offsite					***0.6***
Onsite						
	Impervious	0.3	11.16	0.72	8.0352	0.2
	Pervious 'D'	0.9	11.16	0.25	2.79	0.2
	Total Onsite					***0.4***

4.) Estimate of Peak Flows: Peak flows were estimated using PC Hydro Version 6.1

a. Meander Park (offsite only):

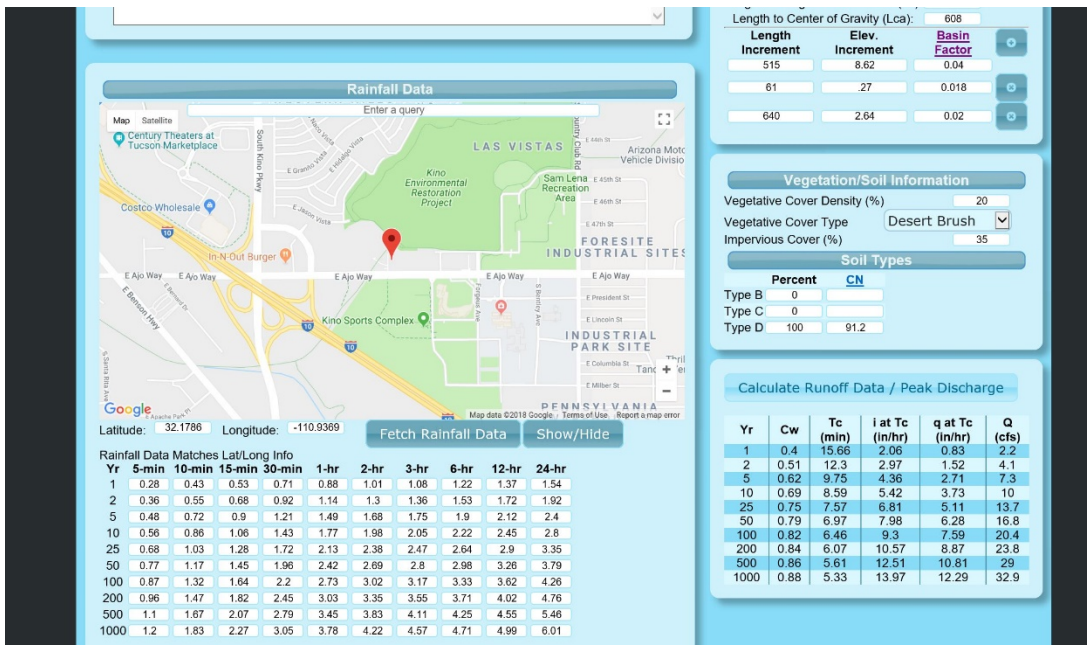


b. SACAC



i. Offsite only

ii. Onsite + Offsite

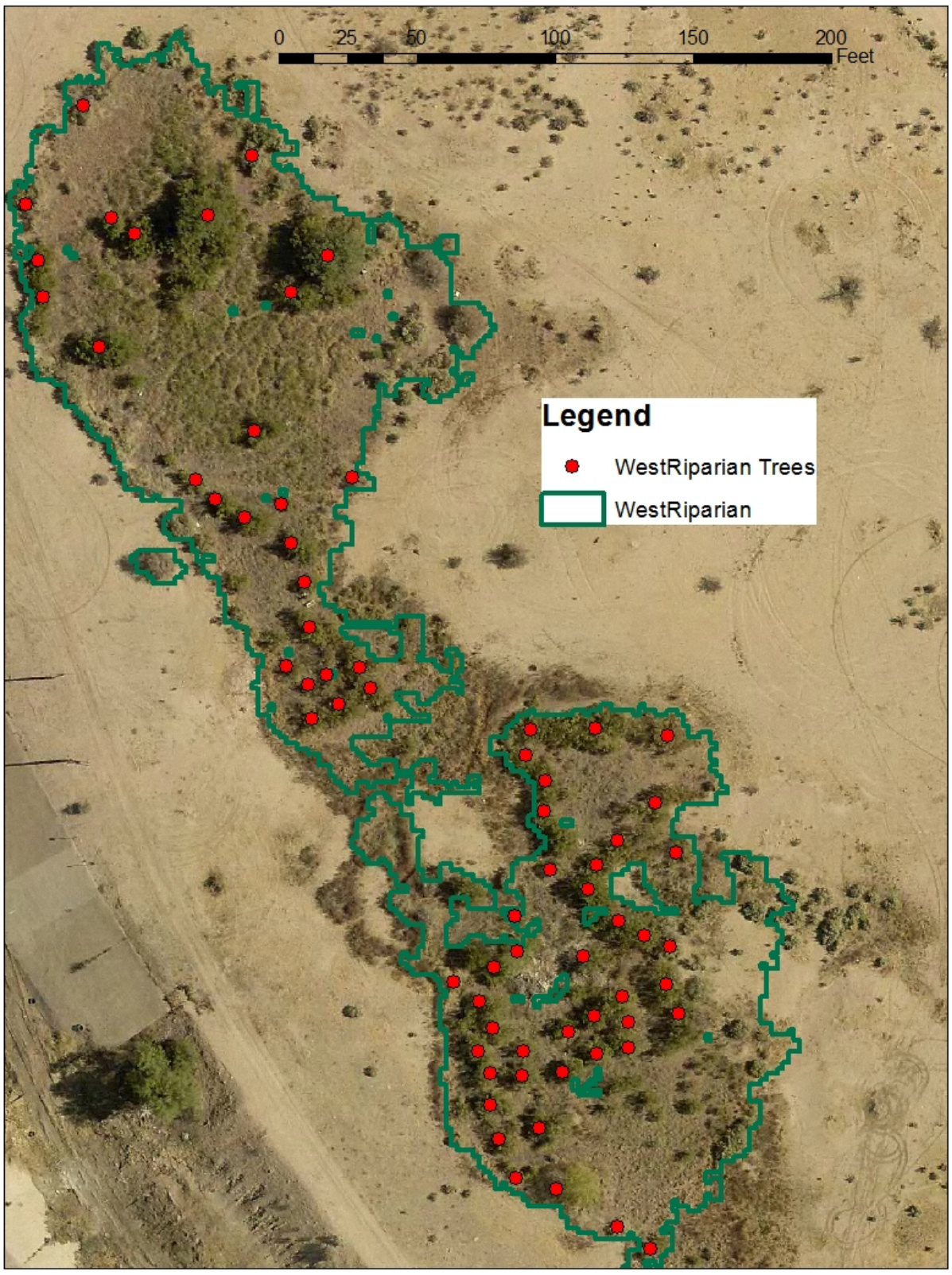


5.) **Estimate of Vegetation that Can Grow from Seed at Meander Bend Park:** Two separate lines of evidence were considered to estimate the potential for vegetation derived from seeding of the Meander Bend Park.

a. **Counting the Number of Trees in the Adjacent One Acre Riparian Area:** By counting the number of trees in a 0.95 acre area to the immediate west of Meander Park below and scaling up to the 6 acres of basin in the Meander Restoration Site.

Tree and Prickly Pear Estimate

	# acre	Acres	Total at Maturity	# Landscaped	Total From Seed	Source
Prickly Pear	100	6	600	112	488	Reasonable number based on Texas Removal Website
Trees	70	6	420	82	338	Count from 1 Acre West Riparian Site



b. **By Estimating the Number of Trees that Can Grow on Stormwater Available:** Using the available stormwater, plant water demand and irrigation efficiency.

Alternate (by Water Availability for Mesquite)

		Area (acres)	Rainfall Inches (avg)	Fraction	Runoff inch (avg)	Acre-ft Runoff (avg)
Offsite		28.0				
West		22.0				
	Impervious	2.4	11.16	0.72	8.0352	1.6
	Pervious 'C'	19.6	11.16	0.22	2.4552	4.0
	Sub-total					***5.6***
South		6.0	11.16			
	Pervious 'C'	6.0	11.16	0.22	2.4552	1.2
	Sub-total					***1.2***
Total Offsite						**6.9**
Onsite						
	Pervious 'B'	**11.4**	**11.16**	**0.17**	**1.8972**	**1.8**

Total Runoff (acre-ft)	14.3
Total Precip (acre-ft)	16.8
Total Water Available	**31.1**
Mesquite Tree Demand (feet of Water)	1.56
	Low Water Use Plant * Reference ET (Eto)

Efficiency Adjustment at 50%	3.12
	Accounts for Rainfall Availabilty and Drought
Acres of Mesquite	9.96
Single Canopy Area (sq-ft)	314.16
Acre-feet of Water/tree	0.022501818
# of Trees	**443**

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