Prioritizing Candidate Green Infrastructure Sites within the City of Ukiah: A Demonstration of the Site Locator Tool of GreenPlan-IT

Report prepared for the City of Ukiah
Department of Public Works, WWTP

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1. EXECUTIVE SUMMARY

Green infrastructure (GI), also known as Low Impact Development (LID), has emerged as an integral aspect of multi-benefit, watershed approaches to address concerns about stormwater quality and quantity in an urban environment. When carefully applied, GI installations, such as rain gardens, tree-well planters, and permeable pavement, can be cost-effective, resilient ways to manage storm water at its source with measurable, cumulative environmental and community benefits.

GreenPlan-IT is a set of four planning level tools that was developed by the San Francisco Estuary Institute (SFEI) with strong stakeholder consultation for use in urban settings (Figure 1). The tools were designed to support cost-effective selection and placement of GI in urban watersheds through a combination of GIS analysis, watershed modeling, and optimization techniques. The four GreenPlan-IT tools are: (1) a GIS-based Site Locator Tool (SLT) that combines the physical properties of different GI installation types with local and regional GIS information to identify and rank potential GI locations; (2) a Hydrologic Modeling Tool that is built on the US Environmental Protection Agency's SWMM5 (Rossman, 2010[1]) to establish baseline conditions and quantify anticipated runoff and pollutant load reductions from GI installation sites; (3) an Optimization Tool that uses a cost-benefit analysis to identify the best combinations of GI types and numbers of sites within a study area for achieving flow and load reduction goals; and (4) a Tracker Tool that is designed to track GI installations, their individual and cumulative effects on flow attenuation, treated pollutant mass, maintenance needs, and report spatial and cumulative outcomes of GI implementation for annual reports over time. The GreenPlan-IT toolkit includes software for the four tools plus their user manuals. The toolkit and a demonstration report are available on the GreenPlan-IT web site hosted by SFEI (http://greenplanit.sfei.org/).

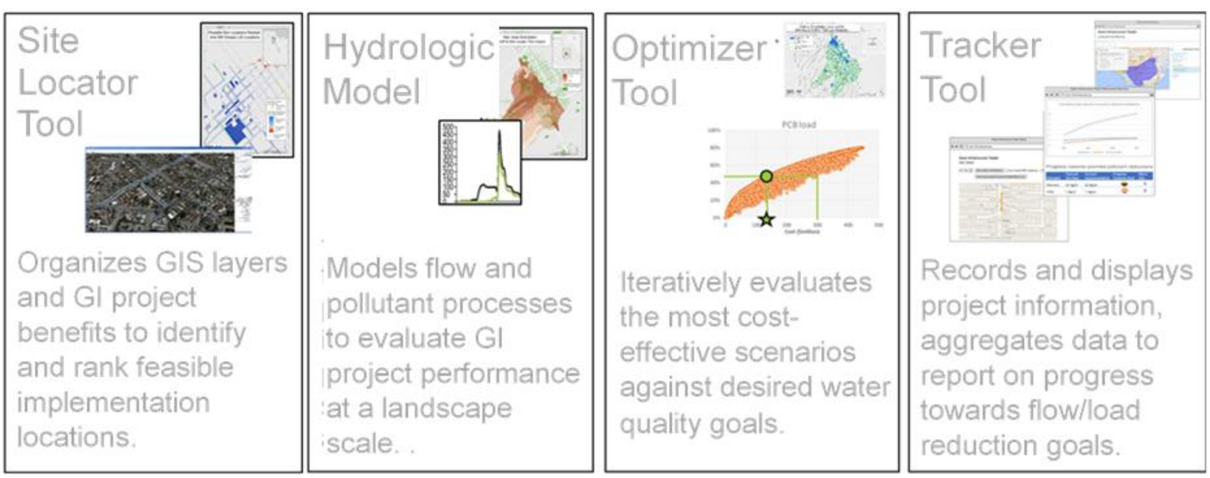

Figure 1. *Four component tools of GreenPlan-IT.*

[1] Rossman, L. A (2010). Storm Water Management Model User's Manual, Version 5.0, U.S. Environmental Protection Agency. Office of Research and Development. EPA/600/R-05/040.

When combined together, GreenPlan-IT tools help address the following stormwater management questions:

- Where are the best locations for GI implementation based on local planning priorities;
- What areas have the greatest potential to reduce stormwater runoff and pollutant loads;
- How much water quality and/or hydrologic improvements can be achieved with different kinds of GI installations per unit cost of implementation?

This Supplemental Environmental Project (SEP) demonstrated the GreenPlan-IT SLT, which addresses the first management question. The GIS-based SLT tool implements a systematic, unbiased methodology for ranking GI locations among competing planning priorities. SFEI coordinated with the City of Ukiah Department of Public Works, Waste Water Treatment Plant Director (Sean White) and the project workgroup to identify and rank local planning priorities for the placement of GI installations on publicly owned property within the City.

The outputs of the SLT demonstration were GIS shapefiles and tables of ranked GI installation sites, based on local planning priorities for five different kinds GI installation types, and this memorandum. These outputs can be used to: (a) identify specific high priority GI installation sites; (b) support the City's current and future infrastructure and stormwater planning efforts, and (c) be used in implementing the other GreenPlan-IT tools.

Future phases to support a watershed based approach to stormwater management and planning in the City of Ukiah could include implementing the other three GreenPlan-IT tools. This would include: (a) setting-up and calibrating the hydrologic Model, (b) running the Optimization tool (based on the Site Locator and Model outputs), and (c) implementing the project tracker tool. Modeled base-line hydrologic and pollutant loads in the watershed would be required input for the Optimization Tool, which uses iterative calculations to estimate the effectiveness of different combinations of proposed GI projects vs. cost in reducing storm water runoff and pollutant loads. Eventually, the Tracker tool could be used to track GI installations and evaluate their cumulative benefits in reducing runoff and pollutant loads.

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2. INTRODUCTION

The GreenPlan-IT toolkit is a free, publically available, geospatial planning tool that supports municipal stormwater management and GI planning by identifying, and ranking potential GI installation locations based on their potential for achieving multiple ecological and/or community benefits (or other priorities defined by the user), and evaluating the effectiveness of GI installations in reducing stormwater runoff and pollutant loads at a watershed scale. The toolkit is comprised of four tools: (1) a GIS-based Site Locator Tool (SLT); (2) a Hydrologic Modeling Tool; (3) an Optimization Tool; and (4) a Tracker Tool.

The objective of this SEP task was to demonstrate GreenPlan-IT's SLT to identify and rank candidate GI installation sites within the City of Ukiah. The SLT is the first (foundational) tool of the GreenPlan-IT toolkit, meaning that the outputs of the SLT are required inputs for both the Hydrologic Modeling and Optimization tools. The SLT addresses the question: where are the best locations for GI implementation based on local planning priorities?

The SLT tool implements a systematic, unbiased methodology for ranking GI locations among competing planning priorities. SFEI coordinated with the City of Ukiah Department of Public Works, Waste Water Treatment Plant Director (Sean White) and the project workgroup to identify and rank local planning priorities for the placement of candidate GI installation sites on publicly owned property within the City.

The outputs of this SLT demonstration were GIS shapefiles and tables of ranked GI installation sites, based on local planning priorities for five different GI installation types, and this memorandum. These outputs could be used by City managers and planners to: a) identify specific high ranking candidate GI installation sites; b) support the City's current and future planning efforts, including GI Master Plans and Stormwater Resources Plans; and c) help comply with future Stormwater Permit requirements. For example, the ranked candidate GI installation sites could be used as a planning tool to identify prioritized off-site stormwater mitigation opportunities.

This memorandum describes the SLT demonstration for the City of Ukiah performed by SFEI. The memo describes the project's methods including: the workgroup that was convened to identify GI planning priorities for the City, the SLT input GIS data layers, the nested weighted overlay table developed for ranking opportunity areas and constraints, and presents an example map of the SLT GIS output, which consist of GIS-shapefiles of candidate GI installation sites within the City, ranked according to the planning priorities set by the project workgroup.

3. PROJECT SETTING

The City of Ukiah is the County Seat and the largest city in Mendocino County, California. It is situated in the northern part of the Ukiah Valley within the Russian River Watershed, a major watershed of the Coast Range. The City generates stormwater runoff from 10-12 mi^2 of low- to high-density development (Figure 2). Most of the stormwater from the City flows to the Russian River (east of the City) through five tributaries, namely Hensley, Ackerman, Orr, Gibson, and Doolin Creeks. Stormwater runoff from Ukiah is regulated by a Municipal Regional Stormwater NPDES Permit (MRP). Stormwater management is a major consideration for the City.

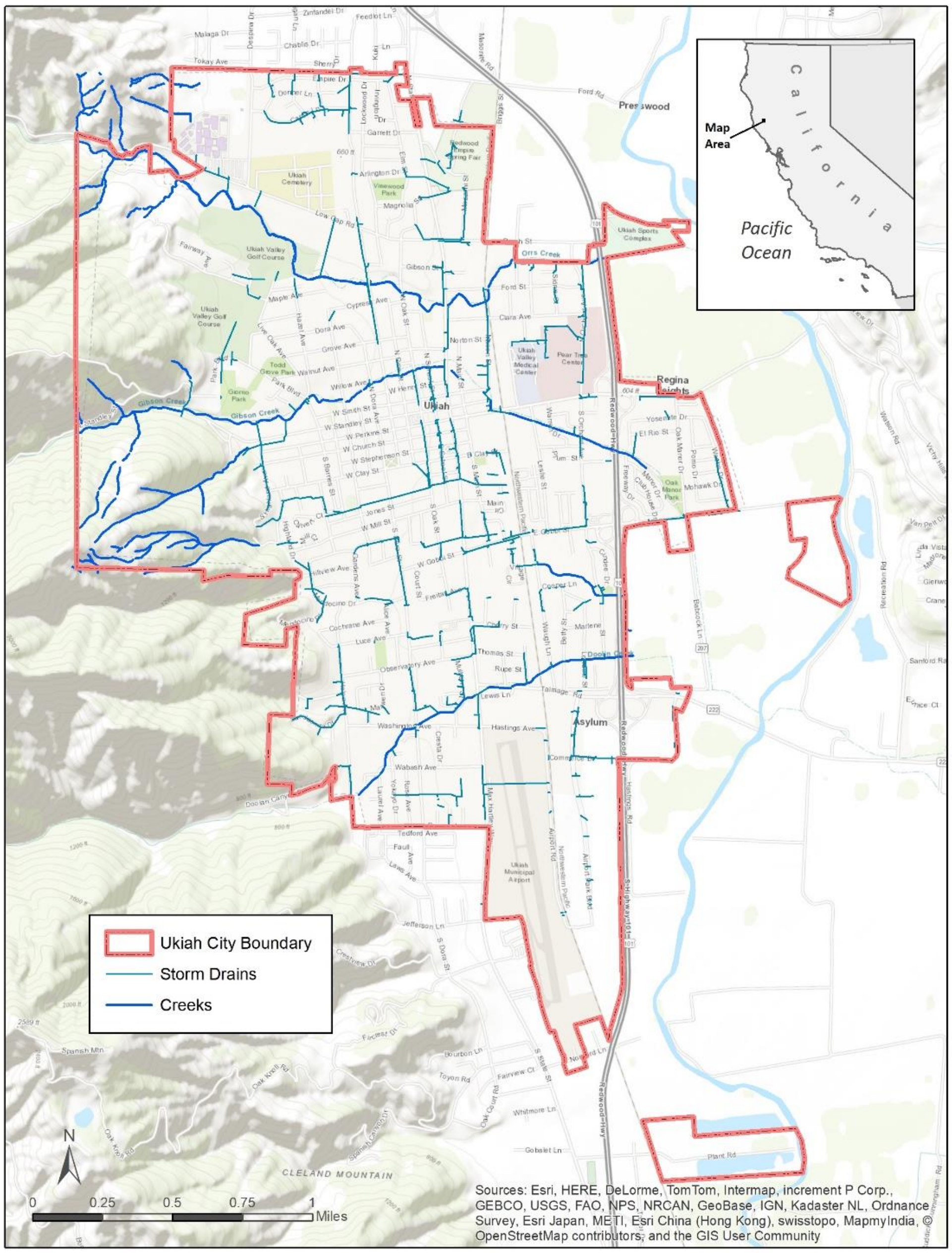

Figure 2. *Ukiah city boundary and Study Area for this demonstration of the GreenPlan-IT Site Locator Tool (SLT). Stormdains and creeks are shown in blue.*

4. SITE LOCATOR TOOL APPLICATION

Application of the GreenPlan-IT toolkit begins with the GIS-based SLT. The SLT is used to identify and rank potential GI locations based on the GI installation types (the different kinds of GI structures) and physical aspects of the landscape. This section describes the application of the SLT in the City of Ukiah.

4.1 PROJECT WORKGROUP

A workgroup was convened to coordinate the compilation of local GIS datasets and relevant planning reports, and to identify a list of local planning priorities for placement of different GI installation types. The workgroup met several times over the course of the project to identify GIS datasets that might serve as input data for the SLT, develop local GI planning priorities, and review and comment on the draft outputs of the SLT.

The workgroup was comprised of staff from the City of Ukiah and SFEI's project leads:

Sean White (Director of Sewer and Water)
Rick Seanor (Deputy Director of Public Works)
Andrew Strickin (GIS Department)
Pete Kauhanen (SFEI GIS Manager and technical lead on the Site Locator Tool)
Sarah Lowe (SFEI Senior Environmental Scientist and Project Manager)

The workgroup selected five of the nine GI installation types currently available in the SLT. A standard (default) size for each GI installation type was used in this SLT demonstration (Table 1). The default GI installation sizes and type descriptions are included with the GreenPlan-IT toolkit at http://greenplanit.sfei.org/content/greenplan-it-site-locator-tool. Permeable pavement, stormwater wetland, wet pond, and bioretention without an underdrain were not selected.

Table 1. GI installation types selected for the Site Locator Tool (SLT) demonstration for the City of Ukiah.

GI Installation Type	Installation Size
Bioretention with an underdrain	1000 ft^2
Flow through planter boxes	200 ft^2
Infiltration trench	500 ft^2
Vegetated swale	500 ft^2
Tree wells	30 ft^2

All five GI installation types were run through the SLT for this demonstration and the outputs were submitted to the project manager and North Coast Regional Water Quality Control Board in a separate SLT GIS data layers and output deliverable. Only the Bioretention with an underdrain GIS output presented in this memo as an example of the SLT output. The reason only one map is presented is because the scale of the maps on the page will not show significant differences in the ranked scores between installation types - one needs to review the outputs in a GIS or KML format to further explore variations in site ranking scores.

4.2 GIS DATA LAYERS USED IN THE CITY OF UKIAH SLT DEMONSTRATION

The GIS SLT integrates regional and local GIS data to locate and prioritize potential GI installations. The SLT can accommodate a wide range of data and information. Data selection was primarily driven by the available datasets and the planning priorities set by the project workgroup. The workgroup helped identify City plans and GIS data for use in the SLT demonstration. The main sources of the input GIS data layers included:

- Ukiah Bicycle and Pedestrian Master Plan. August 2015. Prepared for the City of Ukiah by Alta Planning + Design, W-Trans, and Walk Bike Mendocino.
- 2017 Pavement Management Program Update. August 2017. Final Report prepared for the City of Ukiah Public Works Department by NCE in Richmond, CA. Project No. 270.08.55.
- City of Ukiah IT/GIS Department
- County of Mendocino Information Services Department
- Open Street Maps

Table 2 lists the regional and local GIS data layers included in the SLT demonstration for the City of Ukiah. Some data layers were only used to identify public- and privately-owned parcels, and the City boundary (Analysis Type = *Locations & Ownership* and *Study Area*). For more information on the different analyses that are built into the GreenPlan-IT SLT, see the GreenPlan-IT online documentation (http://greenplanit.sfei.org/books/green-plan-it-siting-tool-technical-documentation).

Table 2. GIS Data Layers used in the Site Locator Tool (SLT) for the City of Ukiah Demonstration.

GIS Data Layers	Analysis Type
City of Ukiah Owned Parcels	Locations & Ownership
County of Mendocino Owned Parcels	Locations & Ownership
On Street Parking Estimate	Locations & Ownership
Public Parking Lots	Locations & Ownership
Ukiah Civic Center	Locations & Ownership
Ukiah City Limits	Study Area
Collision Locations	Local Opportunities & Constraints Analysis
Crossing Gateway Improvements	Local Opportunities & Constraints Analysis
Industrial Areas	Local Opportunities & Constraints Analysis

GIS Data Layers	Analysis Type
Lane Reconfiguration Streets	Local Opportunities & Constraints Analysis
Pedestrian Corridors	Local Opportunities & Constraints Analysis
Problematic Intersections	Local Opportunities & Constraints Analysis
School Zone Reduced Speed Limits	Local Opportunities & Constraints Analysis
Sidewalk Gaps	Local Opportunities & Constraints Analysis
Sidewalk Gap Closures	Local Opportunities & Constraints Analysis
Sidewalk Widening Areas	Local Opportunities & Constraints Analysis
Streams and Storm Drains	Local Opportunities & Constraints Analysis
Street Furnishings (Trees)	Local Opportunities & Constraints Analysis
Ukiah Planned Bike Lanes	Local Opportunities & Constraints Analysis
Downtown Area	Local Opportunities & Constraints Analysis
Fire Hydrants	Local Opportunities & Constraints Analysis
Geotracker Sites	Local Opportunities & Constraints Analysis
City of Ukiah Owned Parcels	Local Opportunities & Constraints Analysis
Parks	Local Opportunities & Constraints Analysis
Problematic Street Segments	Local Opportunities & Constraints Analysis
Pavement Condition Index	Local Opportunities & Constraints Analysis
Schools	Local Opportunities & Constraints Analysis
Ukiah Safe Routes To Schools	Local Opportunities & Constraints Analysis
Ukiah Trails	Local Opportunities & Constraints Analysis

4.3 NESTED WEIGHTED OVERLAY TABLE FOR RANKING OPPORTUNITY AREAS & CONSTRAINTS

The SLT uses GIS data layers to evaluate and assign relative ranking scores for candidate GI installation sites based on local planning priorities (known as ‘factors’ within the SLT documentation), and their opportunity areas and constraints. The project workgroup identified five planning priorities for placing candidate GI installations on publicly owned property[2] within the City of Ukiah. The five GI installation planning priorities were:

- Consistency with existing City planning documents;
- Street characteristics (e.g. street pavement condition, narrow and wide streets);
- Safety (e.g. collisions and problematic streets);

[2] Within Table 2, data layers listed as ‘Locations & Ownership’ were used to identify candidate GI installation sites. Some publicly owned areas were excluded – for example, on-street parking spaces were considered candidate GI installation sites while on-street driving lanes were excluded.

- Pollutants (e.g. old industrial areas); and
- Community engagement (e.g. schools and parks).

The workgroup also identified GIS data layers (see section 4.2) and helped develop a nested weighted overlay table (Table 3) used by the SLT to rank GI opportunity areas and constraints according to the planning priorities. The nested weighted overlay table was developed as follows:

First, each planning priority was assigned a proportional weight based on discussions with the workgroup. The numerical value of the weights increases with the relative importance of each priority. The most important GI installation planning priority for the City of Ukiah was "consistency with existing planning documents", which was assigned the highest-value (0.375). The five planning priority weights sum to a value of 1.0.

Next, three or more GIS data layers were identified as opportunity areas or constraints for GI installation. Each layer either positively or negatively influenced the overall ranked score of a particular candidate GI installation area (Table 3). For example, narrow streets and fire hydrants were considered constraints for placing GI installations, so those areas were assigned a '-1' (indicating a negative influence to placement of GI installations in those areas). Layers considered as opportunity areas for placing GI installations were assigned a '1' (a positive influence). Those opportunity layers included existing plans for pedestrian friendly corridors and bike routes, school zones and parks, locations of problematic traffic, and areas planned for traffic calming and street repair. Similar to the five planning priorities described above, the weights of the GIS data layers that comprised opportunities and constraints within each planning priority summed to a value of 1.0.

Lastly, the spatial extent of a data layer could be expanded beyond the footprint of their original area by enlarging the footprints through a process in GIS called "buffering." For example, if you wanted to expand the areas within 150 ft. of a crosswalk (listed as 'Crossing Improvements' in the *GIS Data Layer* column within the 'Existing Plans' section of the *Planning Priority* column in Table 3) as potential area for GI installations, you would assign a *Buffer Type* of "FULL" and put "150" in the *Buffer Amount* column.

The final custom inputs for the SLT were the compiled GIS data layers (listed in Table 2), and the nested weighted overlay table (Table 3). The actual numerical method the SLT uses for the ranking of a publically owned candidate site is:

Sum of ([GIS Data Layer weight][Rank Influence (1 or -1)])* [Planning Priority weight]*

In Summary:

- Each GIS data layer is weighted for its relative importance within each planning priority;

- A GIS data layer comes into play if it overlaps a site;
- The planning priorities have their own weights based on their relative importance;
- A planning priority come into play if one or more of its GIS data layers overlaps a site.
- For each potential green infrastructure site, a relative ranking score is calculated as the sum of the proportional contribution of all overlapping GIS data layer weights, which is calculated for each overlapping layer using the above equation and the proportional weight contributions listed in the nested weighted overlay table.

Table 3. Nested Weighted Overlay Table showing the GIS Data Layers used to represent the Planning Priorities used to rank potential locations the Site Locator Tool (SLT).

Planning Priority	Priority Weight	GIS Data Layer Name	Rank Influence (pos.=1, neg.=-1)	Layer Weight	Buffer Type	Buffer Amount (Feet)
Existing Plans	0.375	Ukiah Trails: Street Scape	1	0.18	FULL	100
		Safe Routes to Schools	1	0.18	FULL	100
		Street Furnishing Trees (Funded)	1	0.18	FULL	100
		Planned Bike C II buffed & C III Sharrows	1	0.12	FULL	100
		Planned Bike C II & C III	1	0.03	FULL	100
		Pedestrian Corridors	1	0.06	None	0
		Crossing Improvements	1	0.06	FULL	150
		Sidewalk Gap Closure	1	0.06	FULL	60
		Sidewalk Widening	1	0.06	FULL	60
		Lane Reconfiguration	1	0.06	FULL	100
Street Characteristics	0.25	Pavement Condition Index (PCI bad = ≤25)	1	0.17	FULL	100
		Pavement Condition Index (PCI med = <60)	1	0.17	FULL	100
		Wide Streets	1	0.17	FULL	100
		Narrow Streets	-1	0.17	FULL	100
		Ukiah Fire hydrants	-1	0.11	FULL	60
		Storm drains and creeks (merged)	1	0.13	FULL	100
		Sidewalk gaps	1	0.08	FULL	100
Safety	0.1875	Reduce School Zone Speed Limits	1	0.73	FULL	100
		Collisions	1	0.09	FULL	100
		Problematic Intersections	1	0.09	FULL	100
		Ukiah Problematic Street Segments	1	0.09	FULL	100
Pollutants	0.125	Old Industrial Areas	1	0.5	None	0
		Ukiah Geo Tracker Sites	1	0.25	FULL	200
		Current Commercial and Industrial Parcels	1	0.25	None	0

Planning Priority	Priority Weight	GIS Data Layer Name	Rank Influence (pos.=1, neg.=-1)	Layer Weight	Buffer Type	Buffer Amount (Feet)
Community Engagement	0.0625	Ukiah Schools	1	0.33	FULL	60
		Ukiah Parks	1	0.33	FULL	60
		Ukiah Downtown	1	0.33	FULL	60

The full potential range of the SLT ranked scores is theoretically between 1 and -1, assuming full coverage of all GIS data layers. Actual ranking scores are driven by availability, coverage, resolution, and accuracy of the underlying GIS data. The actual range of ranking scores from a custom SLT run is nearly always less than the theoretical range and is a function of the number of input GIS layers, the number of planning priorities, and the actual coverage of each of the input GIS data layers.

Each custom SLT run is unique to the city for which the tool is customized and run. Therefore, ranked scores cannot be directly compared between cities, unless the same layers are available, at full coverage, for both cities and use the same ranking. In addition, city managers may select different ranges of ranked scores as candidate GI installation sites considered for implementation.

4.4 SITE LOCATOR TOOL OUTPUTS

The outputs of the SLT are GIS layers and comma separated tables (.csv files) that indicate the amount of overlap of the data layers and relative ranking scores of the various input GIS-layers for each GI installation type. The SLT was run for each of the five GI installation types for the City of Ukiah's SLT demonstration and the outputs were included with the GIS data package as a project deliverable. The differences between the outputs for each GI installation type is driven by the estimated (default) size of each installation type (see Table 1, above).

Figure 3 is a map of the SLT GIS output of the ranked scores for candidate sites for bioretention with an underdrain GI installations within the downtown area of City of Ukiah. A standard purple-to-red color symbology was used to represent the full range of possible rankings from +1 (highly ranked GI placement site) to -1 (very low ranked GI placement site). For this demonstration, the ranked scores ranged from +0.6 to -0.1, and there were very few negatively ranked locations. It is common that there are relatively few negatively ranked GI installation sites because most of most of the input GIS data layers have positive impact on site rankings (refer to Table 3, above).

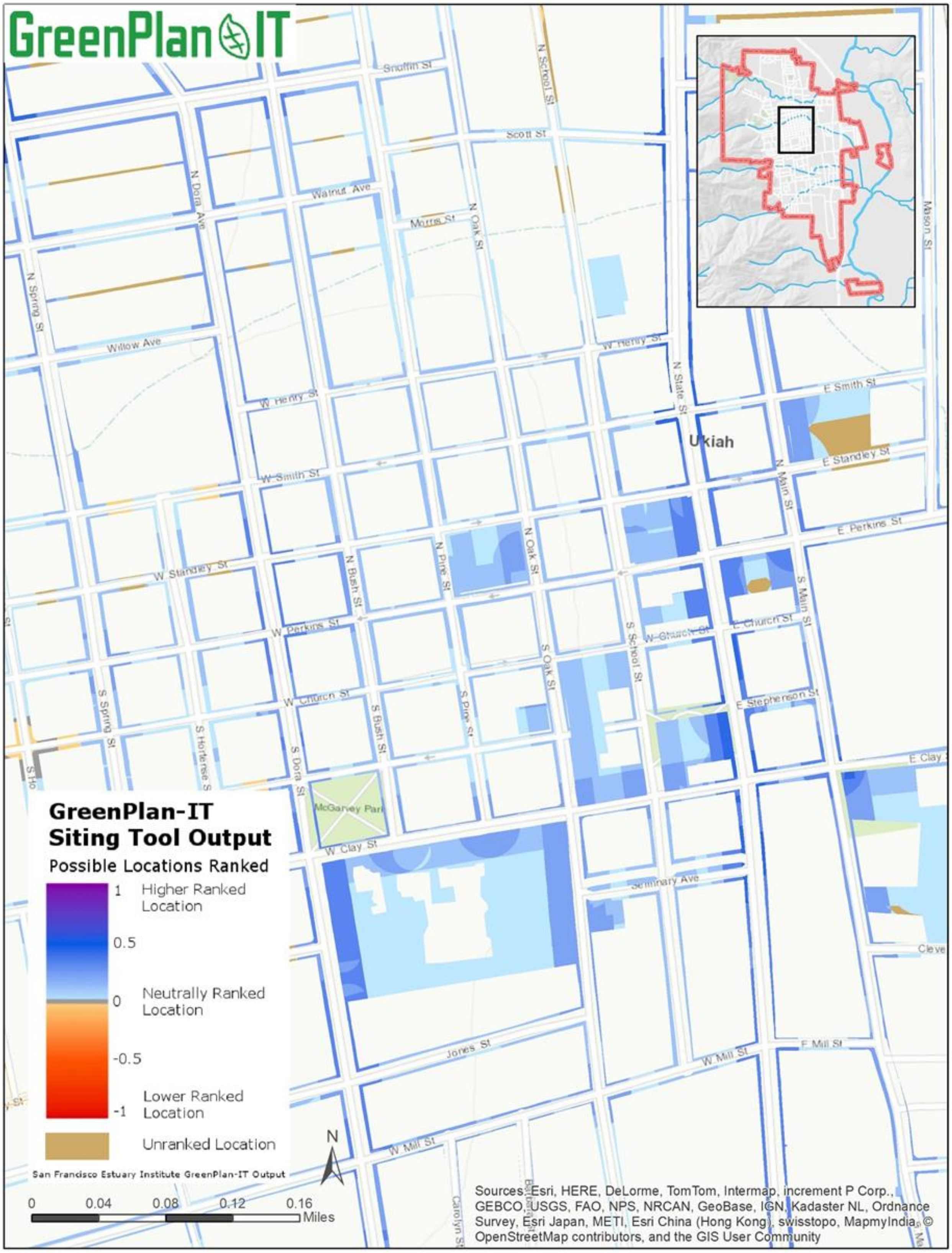

Figure 3. *Map of ranked potential bioretention locations within downtown Ukiah based on the local ranked planning priorities list developed by the project workgroup (Table 3).*

The SLT identified and ranked 242 acres of candidate GI installation sites on publically owned property within the City of Ukiah. Those areas included only acreage that overlapped with at least one of the input opportunity area or constraint GIS data layers associated with at least one planning priority. The remaining 127 acres of candidate sites on publically owned property did not overlap with any of the opportunity areas and constraints GIS data layers and those areas were indicated as 'unranked location' in Figure 3.

For the bioretention with an underdrain GI installation type, 12 acres of publicly own property had ranking scores +0.4 or greater. These areas are the top ranked candidate sites and thus could be investigated for potential GI installations first. An additional 19 acres had GI installation sites ranked between +0.2 and +0.3. These additional 19 acres of candidate sites could be used as a second tier of potential locations for GI installations. It is important to note, however that the ranking is continuous and thus it is possible to create custom bins of ranked candidate sites, resulting, for example, in smaller acreages of highest ranked sites.

The threshold for deciding what ranking scores constitute 'highly ranked' locations should be decided by local planners. It is recommended that the highest ranked sites should be considered first for implementation because they represent areas with the most overlap with GI planning priorities. The most highly ranked GI installation sites for each of the five GI installation types submitted in the project's GIS data package provide a starting point for the City's future GI planning and prioritization discussions.

It is recommended that planners utilize the digital GIS outputs of this SLT demonstration to quickly query the areas that are relevant to specific planning needs. The GIS allows one to select candidate GI installation sites that overlap with specific GIS layers, such that only top ranked candidate sites, or even only top ranked candidate sites that overlap with the *safe routes to schools* data layer would be displayed. To review the data that went into the final ranked scores, one can use the GIS "*identify*" function to view the attribute tables of one or more ranked candidate sites. The site attribute table lists the calculated ranked score of each site as well as the specific GIS data layers and planning priorities that overlap that site. The "*identify*" function is useful for comparing one GI installation type to another at a particular location.

Further analyses could be done to optimize the tradeoffs between the stormwater runoff reduction effects and costs of GI installations. As described in the introduction of this report, the GreenPlan-IT's Hydrologic Modeling and Optimization tools are designed for these kinds of analyses. They use output from the SLT and hydrologic modeling to evaluate flow and/or pollutant loading based on different GI implementation scenarios. The output of the Optimization Tool is a planning map that recommends the best placement of different kinds GI installation types, considering both their efficacy and cost.

5. SUMMARY

GreenPlan-IT is a set of four tools that are used sequentially to evaluate potential locations for GI installations, optimize the placement of GI based on their likely effectiveness and cost, and track and report on the cumulative benefits of implemented GI installations for managing stormwater within urban watersheds. Using the complete toolkit together will provide the most benefit, however intermediate outputs from singular tools, such as the Site Locator Tool, will produce useful outputs that can assist with GI planning documents. Outputs from GreenPlan-IT become more useful with the careful consideration from users to decide the relative importance of different factors affecting GI effectiveness, and the quality of input data.

This Supplemental Environmental Project (SEP) initiated a phased approach to support stormwater resource management in the City of Ukiah by demonstrating the Site Locator Tool of GreenPlan-IT. SLT was used to identify and rank candidate GI installation sites within the City limits, based on the guidance of City staff and an adequate array of input GIS data. The results of this SLT demonstration were GIS shapefiles and tables of ranked GI installation sites, based on local planning priorities for five different kinds GI installation types. These data can be used to: (a) identify specific highly ranked candidate GI installation sites and potentially support the City's current and future infrastructure and stormwater planning efforts.

Future phases to support a watershed-based approach to storm water management and planning in Ukiah could include implementing the other three GreenPlan-IT tools to determine the optimal number and locations of different kinds of GI installations to maximize the cumulative cost-benefit ratio. This would involve: (a) setting-up and calibrating the Hydrologic Model Tool, (b) running the Optimization Tool (based on the Site Locator and Hydrologic Model outputs), and (c) implementing the Project Tracker Tool. The model of flow within the watershed would be required as input for the Optimization Tool, which uses iterative calculations to compare the cost-effectiveness of different combinations of proposed GI installations. The Tracker tool could be used to track implemented GI installations and evaluate their cumulative benefits to storm water resource management.