FINAL REPORT

# Integrating Water and Land Management: A Suburban Case Study and Locally Adaptable Tool

CALIFORNIA DEPARTMENT OF WATER RESOURCES
AND SONOMA STATE UNIVERSITY

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**Please go to the website for the California Water Plan Update 2013. < http://www.waterplan.water.ca.gov/cwpu2013/index.cfm > Then navigate to Volume 4.**


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# EXECUTIVE SUMMARY

## BACKGROUND

Managing the impacts of development on water resources is an urgent challenge in California. To support more efficient growth with fewer environmental impacts, the California Legislature and governor have adopted policies to better integrate land use and resource management. The Land Use Planning and Management Resource Management Strategy (RMS) located within California's 2009 Water Plan Update calls for Low Impact Development (LID) and Leadership in Energy and Environmental Design (LEED) development approaches to reduce land use impacts on water resources. These strategies are suggested to decrease indoor/outdoor or residential water consumption, improve the quality of stormwater runoff, decrease the quantity and flow rates of stormwater runoff, and protect downstream riparian habitat.

The 2009 RMS set in motion a study to quantify costs and benefits associated with water-smart land use practices. Following this 2009 initiative, the charter for the RMS in the 2013 California Water Plan Update proposed a land use decision tool and demonstration of its application through pilot projects. For the first time since 1957, the Water Plan will also include a land use objective linked to corresponding actions. Consistent with this approach, the California Department of Water Resources partnered with Sonoma State University's (SSU) Center for Sustainable Communities and conducted four case studies of suburban development in Sonoma County. An "Integrated Water and Land Management Tool" was also designed and built as part of this project. **This tool may be downloaded free of charge at the website for the California Water Plan Update 2013. < http://www.waterplan.water.ca.gov/cwpu2013/index.cfm > Then navigate to Volume 4.**

Although existing tools are available to guide practitioners, those that are easy to use generally could not be modified to reflect local conditions. And calculators that could be modified possessed challenging user interfaces that required extensive background knowledge. Thus, the project team determined that a user-friendly calculator with the ability to customize and save local data would be a valuable asset. The case studies were then compared and contrasted using the new tool. This allowed users to specify different residential land cover and infrastructure choices and compare development outcomes, especially at the lot and neighborhood levels.

Guiding principles for the study and creation of the tool were to:

- Create an open, locally modifiable, and user-friendly tool to help guide land use and land cover decisions
- Quantify relationships between land use alternatives and key water management benefits relating to water supply reliability, flood management, water quality, habitat value, and greenhouse gas emissions
- Quantify the monetary costs of implementing LID and traditional development strategies, including long-term costs
- Compare and contrast outputs from different development approaches, as exemplified in four case study sites

This report, "Integrating Water and Land Management: A Suburban Case Study and Locally Adaptable Tool", proceeds in two major parts: developing the tool, and then applying the tool to four residential developments in Sonoma County, California, as a proof of concept. While preliminary conclusions are made from the analysis of the case studies, the primary contribution of this research effort is a new, open-source Integrated Water and Land Management Tool, which will further grow and develop over time as additional case studies and applications are completed.

## INTENDED USERS

Because of the range of spatial scales the tool addresses, the results will apply to a wide user base. These users may include:

- **Homeowners** interested in testing possible retrofits to their properties, examining costs versus benefits.
- **Residential developers** seeking to evaluate different design strategies.
- **Local agency officials**, including planning and public works staff, and elected and appointed decision-makers, such as council members and planning commissioners. The tool is intended to be useful for evaluating the effectiveness of water conservation measures being considered in a project or by suggested redesign or conditioning. Local agencies may also use the model to help generate standards that would apply to new developments through general plan, zoning, and subdivision regulations; design guidelines; or other planning documents designed to give guidance to private project proponents.
- **Regional agencies and researchers**, seeking to envision cumulative impacts of development or evaluate alternative futures.

## TOOL INPUTS AND OUTPUTS

The tool requires two major types of inputs and calculates nine outputs.

### TOOL INPUTS

1. Land cover
2. Water infrastructure

Within the Excel workbook, the user selects the tab for the spatial scale of interest. For example, a homeowner might select the "Lot" tab. On the Lot tab, the homeowner specifies the areas of all the land cover types on their lot (in square feet) and answers questions like, "Is there an irrigation controller?" At the neighborhood level, it is also necessary to specify data on public infrastructure. The user will input the square footage of asphalt and maintained parks, for example. See the "User Guide" for more information.

### TOOL OUTPUTS

From the inputs, the tool calculates nine metrics, four of which relate to water and five to costs:

#### Water Metrics

1. Percent impervious surfaces
2. Stormwater runoff (from impervious surfaces)
3. Outdoor water requirements
4. Greenhouse gas emissions (from applied outdoor water)

#### Monetary Metrics

1. Cost of implementation
2. Cost over 10 years
3. Cost over 20 years
4. Cost over 50 years
5. Cost over 100 years

## MAJOR CONCLUSIONS

The Integrated Water and Land Management Tool provides a methodology to link land cover and water infrastructure choices with water and monetary metrics. Other major conclusions of the study include:

1. The tool effectively demonstrates real differences in consumption at the lot and neighborhood levels when applied to case study sites. The tool is easy to use and locally adaptable. It is most useful for preliminary planning and conceptual design. This tool should not be used in place of a more specific hydrological analysis to calculate volumes of stormwater runoff.
2. Reducing hardscape is a critical component to minimizing water resource impacts. In the context of the suburban case studies, it was possible to minimize costs and impacts while using standard building materials, like concrete. In a more urban context, or when reduced hardscape is not a development option, more expensive porous materials may be a viable alternative. Matching design strategies with development context is a useful future trajectory of the tool.
3. Common building materials can be intelligently sited to further decrease impacts on water resources. For example, if a small concrete driveway is graded to drain into a permeable surface, the impacts will be even less than if it's graded to drain into the street. By minimizing new hardscape and creatively draining and diverting water, it is possible to create a low-cost development that is also low-impact.
4. The tool's output is strongest when evaluating conventional materials. For example, assessing changes in water and cost metrics if turf grass is substituted for a brick patio is reliable because costs and lifespans are well known for these materials. In contrast, comparing the costs and benefits of bioswales is less well documented.
5. In all of the case studies, the environmental and monetary impacts of public infrastructure were sufficiently large that they overwhelmed many of the lot-by-lot choices. Public infrastructure may be the most critical component of a development. With further development of lifecycle costs calculations, it is likely that there will be an increasingly strong case for green infrastructure.
6. Due to small sample size and site-specific conditions, it is premature to extrapolate major conclusions on stormwater policies. Expansion of the study is needed to evaluate a larger sample of developments and more comprehensively document the relationships between policies and outcomes.

## NEXT STEPS

The following next steps are recommended to further expand and refine the tool:

1. Distribute and test the tool at planning, building, water and public works agencies.
2. Validate results of recorded outdoor water use and cost data in different climates.
3. Conduct case studies of high-density residential and mixed use projects.
4. Conduct case studies at broader spatial levels, including the city, county, and watershed.
5. Improve cost calculations by revising lifecycle costs and folding externalities into per unit valuations.

# 1 INTRODUCTION

## 1.1 BACKGROUND

Managing the impacts of development on water resources is an urgent challenge in California. To support more efficient growth with fewer environmental impacts, the California Legislature and governor have, over decades, adopted policies and programs to better integrate land use and resource management.[1] Although there are still few standards, land use strategies continue to shift to reflect better understanding of and management for water resources.

The Land Use Planning and Management Resource Management Strategy (RMS) within the State of California's 2009 Water Plan Update called for Low Impact Development (LID) and Leadership in Energy and Environmental Design (LEED) development approaches to reduce land use impacts on water resources. LID and LEED strategies are suggested in order to decrease household water consumption, improve the quality of stormwater runoff, decrease the quantity and flow rates of stormwater runoff, and protect downstream riparian habitat.

The 2009 RMS set in motion a study to quantify costs and benefits associated with water-smart land use practices. Following this 2009 initiative, the charter for the RMS in the 2013 California Water Plan Update proposed a land use decision tool and demonstration of its application through pilot projects. For the first time since 1957, the Water Plan will also include a land use objective linked to corresponding actions. Consistent with this approach, the California Department of Water Resources partnered with Sonoma State University's (SSU) Center for Sustainable Communities and conducted four case studies of suburban development in Sonoma County. An "Integrated Water and Land Management Tool" was also designed and built as part of this project.

## 1.2 STUDY OBJECTIVES

Following the intent of recent legislation such as AB 857 and ongoing trends to integrate water and land use planning, it is increasingly necessary to quantify the benefits and costs of land use and land cover choices. Many commonly used methods of assessing benefits and costs do not adequately address lifecycle costs, positive and negative externalities, and non-monetary impacts. This study seeks to relate local land use and land cover choices to a comprehensive set of benefits and costs over time, identifying both immediate and cumulative impacts.

To do so, the SSU and DWR team built the Integrated Water and Land Management Tool, which allows users to specify different residential land cover and infrastructure choices at the lot and neighborhood level, and compare development outcomes. Principles guiding the study and creation of the tool are as follows:

- Create an open, locally modifiable and user-friendly tool to help guide land use and land cover decisions
- Quantify relationships between land use alternatives and key water management benefits relating to water supply reliability, flood management, water quality, habitat value, and greenhouse gas emissions
- Quantify the monetary costs of implementing LID and traditional development strategies, including long-term costs
- Compare and contrast outputs from different development approaches, as exemplified in four case study sites

This report proceeds in two major parts: developing the tool, and then applying the tool to four residential developments in Sonoma County, California, as a proof of concept. We draw preliminary conclusions from the analysis of the case studies. The primary contribution of this research effort, however, is a new, open-source Integrated Water and Land Management Tool, which will grow and develop beyond this study.

[1]Such as, "State goals for more compact sustainable development (State Assembly and Senate bills AB 857, SB 732 and SB 375); regional blueprint planning being funded by California Department of Transportation (Caltrans); strategies being developed by the California Air Resources Board (ARB) to achieve AB 32 greenhouse gas (GHG) reduction target; and SB 375 linking land use and transportation" (California State Water Plan 2009, Chapter 24).

## 1.3 THE INTEGRATED WATER AND LAND MANAGEMENT TOOL

After reviewing existing water-land tools, we determined that there are not currently any open, accessible tools calibrated to California that help users to simply evaluate development alternatives at the lot and neighborhood scale. Drawing inspiration from the Green Infrastructure Valuation Toolkit and the National Stormwater Management Calculator, we sought to fill this gap with the Integrated Water and Land Management Tool. (See Section 2.1 for further discussion of existing tools; see Appendix 5.3 for a table summarizing the tools.)

### ➤ WORKING WITH THE TOOL

To maintain the highest level of transparency and accessibility, we chose to build the tool in Microsoft Excel. The tool is available for download and can be used by anyone running Excel.

Within the Excel workbook, all the calculations and data are visible and editable. Users are invited to view, scrutinize, and change the tool to reflect local policies, practices, services, and emerging information. Further information on working with the tool is available in the "User Guide," Appendix 5.1. More information on how the tool was developed is available in Section 2.

In the Excel workbook, calculations are divided into three spatial scales: Lot, Neighborhood (e.g., Planned Unit Development), and Town/City/Region/Watershed. Calculations at the Lot and Neighborhood levels were carefully developed in concert with the case studies. Town/City/Region/Watershed calculations are extrapolations from Neighborhood outputs. As a result, the tool is most accurate when examining water and land at the lot and neighborhood scales. Results from broader spatial scales should be used only for broad visioning exercises.

### ➤ INTENDED USERS

Because of the range of spatial scales the tool addresses, the results will apply to a wide user base. These users may include:

- **Homeowners** interested in testing possible retrofits to their properties, examining costs versus benefits.
- **Residential developers** seeking to evaluate different design strategies.
- **Local agency officials**, including planning and public works staff, and elected and appointed decision-makers, such as council members and planning commissioners. The tool is intended to be useful for evaluating the effectiveness of water conservation measures being considered in a project or by suggested redesign or conditioning. Local agencies may also use the model to help generate standards that would apply to new developments through general plan policies, zoning and subdivision regulations, design guidelines, or other planning documents designed to give guidance to private project proponents.
- **Regional agencies and researchers**, seeking to envision cumulative impacts of development or evaluate alternative futures.

### ➤ TOOL INPUTS

The tool requires two major types of inputs: land cover and water infrastructure. Within the Excel workbook, the user selects the tab for the spatial scale of interest. For example, a homeowner might select the "Lot" tab. On the "Lot" tab, the homeowner specifies the areas of all the land cover types on their lot (in square feet) and answers questions like, "Is there an irrigation controller?" At the neighborhood level, it is also necessary to specify data on public infrastructure. The user inputs the square footage of asphalt and maintained parks, for example. See the "User Guide" for more information.

### ➤ TOOL OUTPUTS

From the inputs, the tool calculates nine metrics: four metrics that relate to water and five that relate to costs:

#### Water Metrics

1. Percent impervious surfaces
2. Stormwater runoff (from impervious surfaces)
3. Outdoor water requirements
4. Greenhouse gas emissions (from applied outdoor water)

#### Monetary Metrics

5. Cost of implementation
6. Cost over 10 years
7. Cost over 20 years
8. Cost over 50 years
9. Cost over 100 years

*Detailed information on these metrics is available in Section 2.3.*

## 1.4 APPLYING THE TOOL

All case study sites are located in Sonoma County. Sonoma County is an excellent area to study suburban residential development because it has a wide range of development approaches, from traditional pre-water code developments to innovative, conservation-oriented developments.

### ➤ ACCESSING THE TOOL

**This tool may be downloaded free of charge at…**

### ➤ APPLYING THE TOOL TO CASE STUDIES

To test the model, we selected four residential developments that capture the spectrum of stormwater practices:

1. **Traditional.** A single-family detached subdivision predating stormwater policies and not explicitly incorporating LID or LEED strategies
2. **Local Standard.** A subdivision meeting an earlier local requirement known as a Standard Urban Stormwater Mitigation Plan (SUSMP) and implementing some LID strategies
3. **GreenPoint.** A subdivision with many LID and LEED strategies that exceeds SUSMP and earned a GreenPoint certification
4. **One Planet.** A projected development designed with water conservation and quality as major components meeting One Planet objectives.

*More information on selecting the case study sites is available in Section 3.1. The specific outdoor water practices at each site are summarized in a table in Appendix 5.5.*

## 1.5 CAUTIONS AND LIMITATIONS

The Integrated Water and Land Management Tool provides a systematic, rational, and quantitative method of evaluating the costs, benefits, and effectiveness of various water conservation measures. Yet, due to gaps in data and necessary simplifying assumptions within the tool, it is best suited for preliminary planning at the lot and neighborhood levels. This tool should not be used in place of a more specific hydrological analysis to calculate volumes of stormwater runoff. In addition, applications of the tool beyond the neighborhood should be for visioning purposes only. The Urban Footprint model, discussed in Section 2.1, may be most appropriate for large regional and statewide modeling.

The output data from the Integrated Water and Land Management Tool are most reliable when evaluating alternatives at the same lot or neighborhood site. Differences in topography, microclimate, and soil will lead to slight differences in water consumption, runoff, and cost output between different sites. For example, when comparing two lots with equally sized lawns, the theoretical water consumption will be the same. In actuality, one lot may be warmer and drier than the other, necessitating more water. See "Sensitivity Testing" in Section 3.4 for more information.

Furthermore, until there is more data on many LID building materials and methods, the tool's output will be strongest when evaluating traditional materials. For example, assessing changes in the water and cost metrics if turf grass is substituted for a brick patio will be reliable because the material costs, installation costs, maintenance costs, and lifespans are fairly well documented for these materials. In contrast, comparing the costs and benefits of bioswales will be less accurate because data are less developed for relatively new LID and LEED strategies.

Finally, because the case studies are located within Sonoma County, the tool was developed with data from Sonoma County. Differences in microclimates, labor, prices, and local behavior will impact the accuracy of the tool in other areas. Though some data may be transferable, we suggest that numbers and formulas be reviewed and updated with information that is as locally specific as possible. See the "User Guide" for more information.

In general, accuracy will vary depending on location, land covers being analyzed, the scale of analysis, and the metric under evaluation. It is up to the individual user to review the calculations and assumptions, update the tool with local data, and apply the tool with caution.

# 2 TOOL DEVELOPMENT

## 2.1 REVIEW OF EXISTING TOOLS

Prior to developing the Integrated Water and Land Management Tool, we surveyed existing LID and stormwater planning tools. Many cities and organizations are already committed to installing Low Impact Development (LID) and Green Infrastructure and have developed their own tools (including guides, reports, and calculators) to guide practitioners. In this review we sought to: inventory the key factors and criteria they used to develop their tools and understand their relevance to our work; understand the context of each project and what contributed to their successes and failures; identify gaps in knowledge.

A comprehensive table of available tools with detailed descriptions can be found in Appendix 5.3. This table provides the following tool attributes:

| ATTRIBUTE | DESCRIPTION |
|---|---|
| Toolkit name | Toolkit name. |
| Tool type | Calculator, guide, or report.<br>Calculators were further classified as being a Web-based tool or a downloadable Microsoft Excel–based tool. |
| Year | Year produced or published. |
| Creator | Lead organization responsible for tool development. |
| Description | Additional relevant information about the tool, its development, or its application. |
| Location | Region for which the tool was developed. |
| Inputs | If a calculator, the factors included in the calculations. |
| Outputs | If a calculator, the type of numbers produced (e.g., dollars, water volumes). |

### ➤ SUMMARY OF KEY TOOLS

Most Low Impact Development (LID) tools are guides and reports. These various reports and guides list development techniques, potential costs, and benefits of LID, and often highlight case studies of successful LID projects. The second type of tools consists of LID and stormwater calculators, which come in two formats: Web-based and Excel-based. These calculators are often created by city and county governments. Most are localized to a specific city region, though one is national. A summary of the tools most aligned with our objectives is provided below:

#### National Stormwater Management Calculator

One of the most comprehensive and intuitive calculators is the National Stormwater Management Calculator, created by the Center for Neighborhood Technology. The National Green Values™ Calculator (GVC) is a Web-based calculator designed to quickly compare the performance, costs, and benefits of Green Infrastructure, or Low Impact Development (LID), to conventional stormwater management practices.

According to the GVC User Manual, the GVC attempts to do a holistic cost-benefit analysis for the full lifecycle of the site, including the first-time construction costs for the developer, as well as the lifecycle operation and maintenance costs and benefits to the public and to the private property owner. Included in the benefits analysis are the dollar values for the carbon sequestration capacity and groundwater recharge, as well as an estimate of the increased property value from enhanced tree cover.

The GVC is centered on runoff volume reduction. It is designed to take the user step-by-step through the process from determining the average precipitation at a site to choosing a stormwater runoff volume reduction goal. From there, it guides the user to characterize the impervious areas of the user's site under a conventional development scheme, and then choose from a range of Green Infrastructure Best Management Practices (BMPs) to find the combination that meets the necessary runoff volume reduction goal in a cost-effective way.

The GVC is focused on runoff volume reduction (infiltration, evapotranspiration, and reuse). In addition, it includes a large portfolio of green infrastructure strategies in its cost calculation, as well as a number of quantified benefits of green infrastructure, such as reduced air pollutants, carbon dioxide sequestration, compensatory value of trees, groundwater replenishment, reduced energy use, and reduced treatment benefits.

One limitation of the tool's interface is that it is difficult to save calculations and adjust scenarios. The numbers and formulas are hard-coded and hidden behind the user interface. Therefore, we cannot learn about how the tool was developed or the assumptions embedded in the calculations, and we cannot customize the tool for local conditions. An additional limitation is that the tool uses a vast array of data from all over the nation for its calculations, which limits the accuracy of its output metrics. Finally, the GVC was designed to be applied to a single site or a campus of buildings contained on a single site and cannot be scaled to the neighborhood.

## Green Infrastructure Valuation Toolkit

The tool that aligned the most with our objectives is from England. Called the Green Infrastructure Valuation Toolkit, it is a Microsoft Excel–based calculator that "assess[es] the value of green assets or projects across a wide range of potential areas of benefit—such as climate change, health, or property values" (Building Natural Value for Sustainable Economic Development, 2012). The tool seeks to describe costs and benefits in both quantitative and qualitative terms.

Many of the tool's most ambitious metrics are still under development. These limitations are acknowledged in the "User Guide." The tool is based on 11 groups of green infrastructure benefits, though overlap exists between some groups, and it is possible for benefits to be double-counted. In addition, as is the case with many tools, the toolkit uses assumption-based factors based on a limited body of evidence. While developers built in the option to tailor the toolkit to local conditions when good local data are available, they feel that it would lack sufficient rigor to permit anything more than indicative valuation results. Therefore, the developers themselves feel that the toolkit outputs will remain broad scale and contextual.

This tool offers many of the qualities we are aiming for in the creation of our tool, including being in an Excel-based format and all-encompassing of the costs and benefits, but it was developed for a U.K. economy and environment, and lacks some detail in the input values, including land cover options and green infrastructure components.

## LID Calculator (Los Angeles County)

One of the few tools we were able to find within California was created by the County of Los Angeles Public Works Department. This tool, called a "LID Calculator" has the goal of mimicking "the undeveloped runoff conditions of the development site with the post-development conditions" (Landscape Institute, 2012). The tool is designed to help developers comply with local regulations for managing stormwater onsite. There are two tools, one for running scenarios to reduce runoff volume, and one for reducing the rate of runoff. Inputs include area, percent impervious surfaces, and soil type for calculating runoff rates; and area, percent impervious surfaces, soil type, rainfall amount, flow path (ft) and slope for calculating runoff volume. The user can use the prebuilt calculator interface, which does not show the calculations, but the Excel interface is still accessible for viewing the underlying assumptions.

The calculator is useful for understanding how to properly size BMPs to meet runoff volume goals. As the tool was developed for regulatory compliance purposes, it is prescriptive (calculating runoff reductions), not a cost-benefit analysis of green infrastructure as a whole. It is also not concerned with secondary benefits of green infrastructure, such as greenhouse gas reduction or cost savings when compared with traditional hard infrastructure solutions.

### BMP Sizing Calculator (San Francisco Public Utilities Commission)

The BMP Sizing Calculator developed by the San Francisco Public Utilities Commission targets the same goals of the Los Angeles County LID Calculator—it calculates water runoff volumes to help users meet regulatory compliance requirements for managing stormwater in San Francisco. The decision is not between green and gray infrastructure, but between the different green infrastructure strategies.

Similar to the Los Angeles tool, the BMP Sizing Calculator helps developers to determine the combination of green infrastructure strategies to implement to reduce runoff rates and volumes using an Excel-based platform. The calculator asks the user to classify the project area as impervious or pervious and allows the user to select from surface types with different runoff coefficients. Unlike the Los Angeles tool, the BMP Sizing Calculator takes into consideration the specific detention and retention characteristics of a suite of green infrastructure strategies, such as: detention ponds, wet ponds, infiltration basins and trenches, vegetated swales, constructed wetlands, rainwater harvesting systems, vegetated roofs, and permeable pavement.

The tool does not allow for cost comparisons between traditional and green infrastructure, and it does not include secondary benefits of green infrastructure. Additionally, with very detailed inputs and outputs, the interface can be challenging for nontechnical users who lack previous training in hydrology.

### Urban Footprint

One of the most recent tools developed for assessing development impacts in California is Urban Footprint, created by Calthorpe Associates and funded by the California High Speed Rail Authority and the California Strategic Growth Council. Urban Footprint assesses a variety of urban development impacts, including water-related metrics.

Unlike the other tools we reviewed, Urban Footprint was not available for us to directly interact with. The model is not yet available to the public. When it is released, it will initially be distributed as a series of python scripts with a base dataset (Mike McCoy, pers. comm.). Urban Footprint's Technical Summary notes that the model is raster-based with 250 ft. grid cells (Urban Footprint Technical Summary: Model Version 1.0, 2012), which is efficient for a large area but too coarse for lot or neighborhood analyses.

Urban Footprint is best suited for expert users comparing impacts of city, county, regional, and state growth decisions.

## ➤ GAP ANALYSIS

The existing water-land tools form an excellent point of departure for the Integrated Water and Land Management Tool. There is no single tool, however, that incorporates all the calculations and features we would like to include. In summary:

- **Web-based tools are hard coded.** While Web-based tools, like the National Stormwater Management Calculator, were visually appealing and the most intuitive, the source information was often hidden so that we could not see the numbers or formulae they used for their calculation methods and could not change the variables if we wanted to customize the calculations using locally derived data from our area. These tools were useful for understanding the inputs and outputs often considered in tool development, however, and the importance of creating a user-friendly interface.
- Excel-based tools offer more transparency and flexibility. Though the user interfaces of Excel spreadsheets felt more technical than Web-based tools, they allowed for more customization. In particular, an unlocked Excel-based tool provides the desired flexibility, allowing users to calibrate the tool to local information or conditions, refine background numbers based on new research, and add new technologies as they become available.

- Locally calibrated models are scarce. There is a lack of tools that reflect community-specific costs and benefits. Though Los Angeles and San Francisco stormwater calculators exist, the tools are not coded in such a way that another location could alter the numbers to best fit their local conditions.
- Lot and neighborhood scale is rare. Each tool tends to work best at one spatial scale. In California, Urban Footprint allows for broad regional analysis of water management and land use. The available stormwater calculators can be applied to lots or neighborhoods but are very specific to reducing runoff volumes. There are no planning tools with comprehensive metrics at the lot and neighborhood levels.
- Scalability is rare. There are currently no tools that allow the user to scale a project up from the parcel, to the block or neighborhood, and on to larger spatial regions. There are few tools that assess impacts over time. Without spatial or temporal scalability, it is difficult to assess cumulative impacts of local actions.

## 2.2 TOOL OBJECTIVES

After reviewing existing tools and identifying gaps, we sought to develop a tool that is comprehensive, accessible, modifiable, and scalable.

### ➤ COMPREHENSIVE

Because the objective of this tool is to broadly consider costs and benefits of land use planning for integrated water management, we sought a comprehensive set of metrics that address water quantity, water quality, flood risk, habitat, and climate change adaptation and mitigation.

Refined over multiple tool iterations, we ultimately chose to focus on impervious surfaces, stormwater runoff, outdoor irrigation requirements, greenhouse gas emissions associated with outdoor water use, and the monetary costs of implementing a land use / land cover plan. We selected these metrics because they are useful, relevant indicators of key water management concerns, while they are also possible to derive from streamlined inputs and transparent calculations.

### ➤ ACCESSIBLE

One of our primary objectives was to create a tool interface that is accessible to non-technical users who may have little experience in hydrology or water resource management. Homeowners, developers, and planners should feel comfortable with the tool interface, the data inputs, and the tool outputs. These values are reflected in the tool through the following choices:

- **Excel-based**. Microsoft Excel is commonly available and widely familiar. All data and calculations are transparent.
- **Simple inputs**. We sought to identify the smallest number of data inputs that could be easily measured and reasonably address our multiple water metrics. After discussions with landscape architects, hydrologists, and a climate action planner, and several rounds of testing with the case studies, we identified a streamlined set of inputs.
- **Clear outputs**. Beyond being comprehensive, the metrics used in this analysis were selected for their clarity. Outputs can be visualized and compared relative to one another. People without a background in hydrology can assess and understand the relative impacts of different development choices.

### ➤ MODIFIABLE

This tool is open and transparent. Any users may alter the tool as they see fit.

- **Update with local data**. Given the varying environmental conditions and construction costs through California, locally specific data are essential to reliable calculations. The tool we developed is calibrated to Sonoma County, the site of our test studies. Cost information and weather data are focused on Sonoma County. Some of the data from Sonoma County will hold true elsewhere, while other information may not. Users with knowledge of their local environment and construction costs may easily update the tool.

- **Alter calculations**. Similarly, if a user is interested in a calculation, all cells are unlocked and modifiable. Any calculation can be updated to better reflect new policies, emerging knowledge, or locally specific needs.
- **Build your own scenarios**. Water-smart development is not all or nothing. There is a range of solutions that are appropriate in different locations and meet different project goals. As a result, the tool acts like a menu. Users can choose the features most appropriate for their site or add new data inputs as necessary. Everything can be customized.

### ➤ SCALABLE

The tool allows the user to examine water supply benefits at many spatial scales. The most accurate results come from the lot and neighborhood levels, where users can fine-tune data for land areas, water consumption, and the costs of components to compare different development scenarios. The user can also save custom neighborhood profiles.

Beyond the neighborhood, the tool accepts inputs of acreage for predefined neighborhood types (including any custom neighborhoods). The tool scales output values by neighborhood area. For example, a user may decide that a town is composed of 70 acres of traditional development and 30 acres of local standard SUSMP development.

Extrapolating from the neighborhood is subject to many inaccuracies. One challenge is that it is necessary for the user to categorize the whole area into a smaller subset of neighborhood types. This may prove difficult, particularly in areas that have been slowly developing over a long period of time, since development styles change incrementally. An additional challenge is that the tool assumes that all the areas within a neighborhood category will have the same outputs. In actuality, differences in behavior and microclimates may cause two areas that are similarly developed to exhibit different resource use.

All inaccuracies in the neighborhood specifications will be compounded when scaled over larger areas (e.g., watersheds). Yet, despite the limitations of bottom-up projections—as is done within this tool—extrapolating regions from neighborhoods can be a valuable and practical method for envisioning the cumulative impacts of small choices.

## 2.3 TOOL METRICS AND DATA

Within the metrics output by the Integrated Water and Land Management Tool there are embedded assumptions, decisions, and data limitations. There are also important factors that were challenging to quantify and, thus, capture in the tool's output. Following is an overview of the tool's nine metrics, a discussion of the figures and sources used for each metric, a discussion of the limitations of the output data from the tool, and some notes on qualitative considerations.

### ➤ METRICS 1 AND 2: WATER RUNOFF

#### Overview

Water runoff is a critical target of water-smart development but is also difficult to quantify with simple inputs. At a minimum, calculating specific runoff volumes requires information on slope, soil, and surface roughness. There are several tools available that calculate volumes and, as a result, require more detailed, technical inputs (e.g., Los Angeles County's LID Calculator and the San Francisco Public Utilities Commission's Stormwater Calculator). To keep the tool as accessible as possible, we chose to examine runoff through two related metrics: percent impervious surfaces and peak runoff from impervious surfaces.

#### Metric 1: Percent Impervious Surfaces

Although a simple metric, percent imperviousness is a very useful indicator of overall watershed health. In general, impervious surfaces contribute to higher volumes of water runoff, higher velocity runoff flows, and increased pollutants in water runoff. This combination induces erosion and pollution downstream (Impervious surface coverage: the emergence of a key environmental indicator, 1996).

Because of the relationship between imperviousness and watershed health, many LID designs target reducing impervious surfaces. In addition, some municipalities and counties require that redevelopment projects have no net increase in impervious surfaces. As a result, tracking the percentage of impervious surfaces can be valuable.

### Metric 2: Peak Runoff from Impervious Surfaces

The tool calculates maximum runoff volumes from impervious surfaces. This metric is helpful when considering sizing for water infrastructure, whether it is onsite retention or traditional stormwater conveyance. While precise volumes must be calculated with calibrated hydrological tools, this metric aids in initial scoping and comparing scenarios.

## Figures and Sources

### Impervious Surfaces

To calculate percent impervious surfaces, all fully impervious surfaces are summed for the study area and divided by the total study area. Fully impervious surfaces include:

- Asphalt
- Concrete
- Pavers, brink or natural stone with concrete joints
- Traditional (non-green) roofs

The area of each surface is from user-specified data on land cover.

### Rainfall

The tool calculates peak monthly runoff. We focused on monthly data because it is a time frame that works reasonably well across all of the metrics. This is an advantage because a consistent time frame allows the user to compare and contrast monthly runoff against monthly applied outdoor water, for example, and assess volume differences.

Monthly rainfall data are available from the California Irrigation Management Information System (CIMIS). We relied on a 10-year rainfall averages from the Santa Rosa CIMIS station (Santa Rosa Area Reference, 2012).

Users may be interested in modifying the tool to calculate runoff over different periods. For example, it is possible to modify the tool to determine runoff volumes for a typical LID design storm (24-hour storm) or a typical pipe infrastructure design storm (100-year storm) while using local rainfall data (Stormwater Best Management Practice, 2005).

## Data Limitations

### Calculating Runoff

One of the significant limitations of our method is that we are evaluating runoff only from fully impervious surfaces. Any runoff from surfaces with partial permeability is not included. For example, we do not assess the runoff contribution from turf grass, which can be significant. Yet, calculating runoff from semipermeable surfaces would require more-complex data inputs (slope, soil, surface roughness). This major simplifying assumption was necessary in order to maintain streamlined, accessible user inputs.

### Mitigating Runoff

Within the tool, we assume that there are four factors that mitigate runoff: rain barrels, rain gardens, bioswales, and ponds. We do not assess pools, which may have some retention effects, due to large variability in retention value. Some sites will not have any of these runoff mitigation measures, while others will have more than one.

Calculating the precise impacts of runoff mitigation measures is difficult because it is necessary to know the timing of rainfall versus the rate at which the water is being emptied from the site of collection. In the tool, we approximated these values with the following assumptions:

**Rain barrels.** We assume that rain barrels store their full volume of water each month. In reality, there may be multiple months that a rain barrel is never emptied (and, thus, not refilled), or there may be a month when the rain barrel is emptied and refilled multiple times.

**Rain gardens, bioswales, and ponds.** All rain gardens, bioswales, and ponds are assumed to retain and infiltrate one foot of water on a monthly time frame. This is a coarse assumption. In actuality, rain gardens, bioswales, and ponds may be constructed to retain more or less water. Also, during periods when there are smaller, regular storms or rainfall on sandy soils, it may be possible to infiltrate a greater amount of water. When storms are heavy or occur in areas where there are clay soils, there may be less infiltration.

The tool does not presently account for neighborhood stormwater capture, such as shared stormwater retention basins. This may be a valuable addition to the tool.

## Qualitative Considerations

### Runoff Velocity

One of the objectives of stormwater runoff management is to ensure that an area retains its pre-development hydrology, in both the quantity of runoff and the rate at which the runoff flows. An increase in impervious surfaces reduces the surface area where water can infiltrate while increasing the speed at which it flows. This combination can have serious impacts downstream, including erosion of the waterway, habitat loss, and increased risk of flooding (Hydromodification Assessment and Management in California, 2012).

The speed of water runoff is an important factor that is not considered in this model. To calculate runoff velocities it is necessary to know slope, soil, and surface roughness values. In general, however, the percent increase in impervious surfaces is a good indicator of runoff velocity — more impervious surfaces indicate higher runoff velocities than fewer impervious surfaces (Impervious surface coverage: the emergence of a key environmental indicator, 1996).

### Stormwater Retention and Storage

Because rain gardens and bioswales reduce the volume and speed of water runoff, it may seem as though this tool universally promotes stormwater capture. It is worth noting, however, that experts do not agree on the efficacy of large stormwater retention basins (Hydromodification Assessment and Management in California, 2012). Critics claim that important sediments are trapped in retention basins, and that prevents deposition of new soils into downstream rivers and contributes to erosion. The ecological value of stormwater retention basins will vary depending on design, size, and location in the watershed.

In addition, rain barrels can be controversial. While popular, local water storage is often critiqued in California's monsoon climate. With heavy winter rains, it can be difficult to capture enough water onsite to significantly impact water runoff. With long, dry summers, it can also be difficult to store enough water onsite to significantly decrease supplemental irrigation requirements. Rain barrels may be more effective in climates that receive more steady volumes of rain throughout the year.

# ➤ METRIC 3: APPLIED OUTDOOR WATER

## Overview

In the Integrated Water and Land Management Tool, calculating the outdoor water required for different landscaping approaches is executed in three steps.

First we calculate the theoretical irrigation requirements based on vegetation categories. This is also known as the "crop coefficient method." This calculation requires the following pieces of information:

1. Evapotranspiration zone (ET)
2. Species-specific plant water use coefficient
3. Planting density
4. Environmental exposure
5. Irrigation efficiency

From this information the tool identifies the water required by the landscaping each month in gallons.

Second, we assume that households with weather-based irrigation controllers apply water more efficiently. If the study site has weather-based irrigation controllers, this reduces the total outdoor water requirements by an overall percentage. Then there is a new, lower volume of water required by the landscape each month.

Third, we assume that any rainwater stored onsite will be applied to landscaping. The tool subtracts the volume contained in all rain barrels, for example, from the total volume of water required. We assume that all remaining water needs are met by applying standard potable, municipal water.

## Figures and Sources

### Evapotranspiration Zone

Information on the inches of water evapotranspired per month from a reference surface (e.g., grass) is available from the California Irrigation Management Information System (CIMIS). We relied on average reference evapotranspriation (ET) by zone, as published by CIMIS (ETo Zones Map, 1999). In the tool, we use peak monthly reference ET. In Zone 5, where Santa Rosa is located, the peak monthly reference ET is 6.51 inches of water (July). In contrast, there is an average monthly reference ET of 0.93 inches in December and January. The user may specify any month when calculating outdoor water requirements.

### Species-Specific Plant Water Use Coefficient

In California, species-specific plant water use coefficients are available from the Water Use Classification of Landscape Species (WUCOLS) study, developed by the University of California Cooperative Extension (Water Use Classification of Landscape Species, 2012). For the purposes of this tool, however, species-specific calculations were overly detailed. Instead, we chose to follow coarser categories of water use coefficients offered by Sonoma Master Gardener, also available through the UC Cooperative Extension (Master Gardener, 2012).

### Irrigation Efficiency

The percentage of water that is successfully applied to the roots of a plant varies by irrigation method. Drip irrigation methods are found to be up to 90% efficient, while surface sprinklers are approximately 60% efficient. In a DWR water budget calculator made available through the Model Landscape Ordinance, default irrigation efficiency is given to be 71% (Model Landscape Ordinance, 2011). We chose to remain consistent with this value.

### Irrigation Controllers

There are two forms of irrigation controllers: the automatic clock-driven irrigation systems and the smart, or weather-based, controllers. While automatic controllers may inefficiently or excessively irrigate, weather-based controllers adapt watering schedules based on soil moisture calculations. The 2009 "Evaluation of California Weather-Based 'Smart' Irrigation Controller Programs" concluded that overall outdoor water use was reduced by an average of 6.1% when using a weather-based irrigation controller.

## Data Limitations

While WUCOLS provides useful guidelines on theoretical irrigation needs, actual water use may be higher or lower, depending on topography, solar exposure, wind exposure, soil types, mulching practices, and irrigation efficiency. It is likely possible to improve the accuracy of these calculations with more localized data.

### Planting Density

Areas that have a high density of plants tend to consume more water. As a result, the crop coefficient method typically includes a variable for planting density. In aerial imagery examined for the case studies, we found that separating areas into sparsely and densely planted vegetation was reasonably straightforward and useful.

### Environmental Exposure

The impact of microclimates on theoretical irrigation volumes is accounted for by an exposure multiplier. To maintain simplicity in this tool, we chose to assume a constant exposure. This assumption should be reasonable over larger areas and when comparing scenarios at the same site. This assumption would be problematic, however, if comparing a sheltered, north-facing site with a windy, south-facing site.

### Qualitative Considerations

Using recaptured stormwater and wastewater to meet irrigation demands is increasingly common.

**Municipal recycled ("purple pipe") water** is now available in many places in California. Because recycled water is often not treated to the same degree as potable water, in some regions this may be a less energy intensive method of meeting irrigation requirements (The Role of Recycled Water In Energy Efficiency and Greenhouse Gas Reduction, 2008). At present, recycled water is not built into the tool, but it would be a relatively straightforward addition.

**Home graywater systems** can be an inexpensive method to supplement irrigation of outdoor landscaping, particularly if the system is from a single fixture and qualifies for an exemption from local permit requirements. More complex graywater systems, also restricted to non-potable uses such as outdoor landscape irrigation or indoor toilet flushing, may be pursued. Water volumes contributed by graywater systems may be entered into the tool.

## ➤ METRIC 4: GREENHOUSE GAS EMISSIONS FROM OUTDOOR WATER

### Overview

Water-related energy use accounts for 19% of California's total electricity use and almost 30% of natural gas use (Integrated Energy Policy Report, 2005). Both the California Energy Commission and the California Public Utilities Commission concluded that reducing energy consumed through water is an opportunity for cost-effectively limiting greenhouse gas (GHG) emissions.

The energy embedded in a unit of water varies across the state. It depends on the location of the water source, the location of the end use, the location of the wastewater outlet, and the quality of the incoming and outgoing water. Moving large quantities of water long distances, distributing it within communities, and treating it can all be energy-intensive processes.

Just as embedded energy varies with location, so does the degree of carbon dioxide emissions per unit of energy. Depending on the type of energy used in the water conveyance and treatment process, the value of the multiplier that converts energy consumption to carbon dioxide emissions will be higher or lower.

In the Integrated Water and Land Management Tool, we calculate the energy expended per gallon of municipal water in Sonoma County and then derive the associated carbon dioxide emissions (all the background calculations are included within the Excel workbook). The tool multiplies this carbon dioxide intensity ratio by the output from Metric 3: Applied Outdoor Water and gives an approximation of the carbon dioxide emissions associated with outdoor water use.

### Figures and Sources

From observed energy intensity ratios from the Sonoma County Water Agency for the groundwater pumps and booster pumps, we calculated the total energy intensity in kilowatt-hours per every million gallons of water used in the Agency's territory (Embedded Energy in Water Studies, 2010). Then, from Pacific Gas & Electric's GHG emissions factor (specific to Sonoma County electricity sources), we are able to find the total GHG emitted per unit of water consumed.

After calculations, we concluded that Sonoma County water contains approximately 160 pounds of carbon dioxide in every million gallons of water delivered. This is approximately the emissions equivalent of combusting eight gallons of gasoline (U.S. Energy Information Administration, 2012).

Little energy is consumed by water provision in Sonoma County, compared with many other regions. This is because the county collects groundwater that is naturally filtered through the gravel of the Russian River. The water requires no additional treatment prior to household consumption. In other area of California, there may be large energy expenditures associated with water treatment.

Instead, energy is primarily embedded in Sonoma County through water pumping. Groundwater is pumped from approximately 60 feet below ground and then lifted, via booster pump stations, to storage tanks located at a higher elevation than the water customers. Once the water is in the storage tanks, it is delivered to customers by gravity (Sonoma County Water Agency: Water Supply and Transmission, 2013).

Additional energy is used in wastewater treatment. This energy expenditure is not applicable to this tool, however, because of the tool's focus on outdoor water use. Unlike household water, outdoor water runoff in Sonoma County enters storm drains that empty into nearby creeks and streams. Outdoor water runoff is not treated (Storm Drain Systems vs. Sanitary Sewer Systems, 2011).

Areas of California that do not rely on groundwater may have to consult the California Public Utility Commission's "Embedded Energy in Water Studies 1, 2, and 3" to determine the amount of energy used to pump water before the water arrives within the boundary of the water agency (Embedded Energy in Water Studies Study 2, 2010). If the study area has a combined sewer system that collects water in storm sewers for treatment along with wastewater from households, energy for sewer pumping and wastewater treatment will also need to be included in energy calculations.

### Data Limitations

Calculations of embedded energy and associated carbon dioxide emissions rely on reported figures from multiple agencies. In Sonoma County, calculations require Sonoma County Water Authority's kilowatt-hours used for pumping groundwater and Pacific Gas & Electric's carbon dioxide coefficient, as reported to the California Public Utilities Commission and Climate Registry. Any inaccuracies in energy or emissions data will be reflected in the final greenhouse gas calculations.

Carbon dioxide coefficients for most California utilities are published by the Climate Registry and California Air Resources Board. The amount of carbon dioxide will depend on the power supply portfolio for each utility. These coefficients are not third-party verified but are refined periodically. Generally, greenhouse gas emission calculations are estimates, as not all levels of lifecycle analysis can be included, but they are useful for prioritization and comparison.

### Qualitative Considerations

This tool exclusively calculates the carbon dioxide emissions associated with outdoor water use. In a land use / land cover plan, many additional factors contribute to emissions differences. For example, some land cover features (e.g., concrete) and some infrastructure choices (e.g., bioswales) will also positively or negatively contribute to a plan's total greenhouse gas profile. As data on the net greenhouse gas impacts of land cover and infrastructure components become more available, this will be an interesting expansion of the tool. With the available information, however, considering greenhouse gases in outdoor water is a reasonable start.

Beyond reducing the amount of municipal water applied to outdoor landscaping, there are other methods of limiting water-associated greenhouse gas emissions. In particular, recycled water may prove to have considerable greenhouse gas emission savings in some regions of California, depending on the relative energy expenditure of new water and recycled water. Water providers importing water from distant sources, in particular, may see more significant energy savings by using recycled water.

## ➤ METRICS 5 THROUGH 9: MONETARY COSTS

### Overview

The cost metrics assess the monetary costs of a land use / land cover and water infrastructure plan. The tool includes the following metrics:

- Metric 5: Cost of Installation
- Metric 6: Cost over 10 Years
- Metric 7: Cost over 20 Years
- Metric 8: Cost over 50 Years
- Metric 9: Cost over 100 Years

We selected these time frames to correspond with standard design and planning cycles as well as engage in long-term thinking. Metric 6 is useful for homeowners making property upgrades and may be used in focused technical updates of general plans. Metric 7 will aid in general plan updates. Metrics 8 and 9 reflect the duration of standard infrastructure lifecycle calculations performed by the state and the federal governments, respectively. Should a user wish to study other time periods, customizing this feature of the tool is straightforward.

All metrics include prices of materials and labor. In addition, the long-term metrics (Metrics 6–9) include the costs of replacement, which are contingent on the stated lifespan of a land cover or infrastructure component.

## Figures and Sources

All price, maintenance, and lifespan estimates were collected in Sonoma County from June through November 2012. Sources include private contractors, commercial contractors, landscape developers, plant nurseries, public agencies, building supply stores, and online materials reference guides. We sought multiple price quotes whenever possible. When a price was not available from a Sonoma County source, we looked for information that was as close to Sonoma County as possible. In some cases, however, it was necessary to rely on coarser figures—for example, stormwater pipe prices were sourced from RSMeans, which summarizes construction data for all of California.

*Detailed data and sources are available in Appendix 5.4.*

## Data Limitations

### Price

To be implemented in the tool, construction prices needed to be identified per unit, such as price per square foot, per linear foot, per count, or per gallon. This allows the user to input an area, size, or quantity and calculate the corresponding cost. For example, if concrete is $1 per square foot and a user inputs "4" square feet, the result will be $4.

Ensuring that per unit prices are as accurate as possible is challenging. For some components, reasonably consistent data were found from multiple sources, helping validate the figures. For other components, however, there was a wide range in the available data. This likely reflected the reality that construction companies and suppliers range from budget to luxury. When there were multiple quotes, we averaged across the available quotes to find a mean price. This average price estimate is used in the tool's calculations.

For other components, very little data was available. At times, sources were hesitant to have their estimates published in a report, and construction companies were often too busy to provide price estimates for academic purposes. There was especially little data available for green infrastructure. Few companies are installing LID components, and the field has a shorter history, so price quotes are not as well developed.

In cases where there was little data, a single quote often became the working price within the tool. Single quotes may not accurately represent the field, however. These quotes may oversimplify the variability in quality of materials and construction.

Even when data were available, an additional challenge in determining per unit prices is that there are typically large economies of scale in construction. For example, with rainwater harvesting tanks, the price per gallon decreases as the tank size increases. Future iterations of the tool may consider creating steps of price data dependent on the quantity of product or high and low price estimates.

### Maintenance and Lifespans

Data on maintenance costs and lifespans were even sparser than price data. This is in part because there is more uncertainty in the data — materials, construction methods, environmental conditions, and owner behavior all influence the lifespan and maintenance of a particular component.

Ultimately, we were usually able to find lifespan data (with some exceptions, as noted in Appendix 5.4 and within the tool) from reliable sources with significant experience in the Sonoma County area. Yet, finding maintenance data proved to be challenging.

Often maintenance is performed ad hoc, folded within homeowner association fees or part of larger jurisdictional maintenance budgets. Relating maintenance to specific components (e.g., sidewalk versus road) was often impossible. More information is available for traditional infrastructure than for green infrastructure, but it is still difficult to find.

Because ongoing maintenance costs are not included in long-term cost calculations, the tool implicitly assumes that all infrastructure choices require equal expenditures on operations and maintenance. Yet, some infrastructure choices require a large degree of ongoing maintenance, while others require very little. As more data become available (across both traditional and green infrastructure), adding in maintenance costs will be easy and valuable.

### Replacement

One major simplifying assumption within the lifecycle calculations relates to replacement costs. As is, the tool assumes that when a land cover or infrastructure component has reached its lifespan, it is installed again. The tool does not include information on major repairs or removal of old materials, due to lack of data. In some cases, installation costs may be reasonable approximations of replacement costs. In other cases, replacement may cost more or less. Further study of this assumption is necessary.

### Long-Term Reliability

The most accurate monetary costs are in Metric 5, Cost of Installation. As time goes on, there is increasingly more uncertainty in the output of the monetary metrics. As a result, it is best to consider the long-term, lifecycle cost calculations in relative terms. These metrics are useful for comparing one alternative with another but are not reliable for absolute costs. Further development of this metric may include price discounting.

## Qualitative Considerations

Calculating costs poses questions of externalities, both positive and negative. At present, we are not able to feed the impact of externalities into cost calculations; the full web of cost connections is complex, not well understood, and poorly documented. There are several places where issues of externalities are an issue, however.

For example, many studies indicate that increased vegetation and community open space have positive impacts on home values (e.g., Open space, residential property values, and spatial context, 2006). As a result, it may be possible to recuperate more of the costs of green infrastructure choices than gray infrastructure. If the tool were extended to include cost recovery, it might reveal a stronger case for green infrastructure.

# 3. IMPLEMENTING THE TOOL: CASE STUDIES

## 3.1 SELECTING CASE STUDIES

The objective of applying the tool to case studies was to test and develop the tool in the context of real-world examples and then examine the differences of real land use alternatives in Sonoma County with metrics from the tool.

After speaking with local planners and water experts, we selected four case study sites that were representative of a cross-section of water infrastructure possibilities. In this report, each case study is named after its stormwater policies or practices: Traditional (pre-regulation), Local Standard (SUSMP), GreenPoint, and One Planet.

All of the case studies are suburban developments. We chose to initially focus the tool on the suburban realm because it is the dominant form of development in California.

### ➤ STORMWATER POLICIES AND PRACTICES

The case study sites were selected to highlight evolving stormwater management techniques. Each case study adheres to different stormwater policies and practices, guided by federal, state, and local stormwater regulations active during project approval. For a detailed table of the specific features at each development, see Appendix 5.5.

The first case study, Traditional, was constructed prior to stormwater regulations. Stormwater runoff regulations were first enacted in California in 1987, when the Federal Water Pollution Control Act (Clean Water Act) was amended (Stormwater Permit, 2012).

The second case study, Local Standard or SUSMP, was built in 2005 after stormwater regulations were updated with the more restrictive Standard Urban Stormwater Management Plan (Guidelines for the Standard Urban Stormwater Mitigation Plan, 2005).

The GreenPoint and One Planet developments voluntarily chose to exceed the standards put forward in regulations that were in place during project approvals. The GreenPoint case study incorporates stormwater measures from CALGreen. The One Planet case study implements both LEED and One Planet community standards.

An additional regulation, the Water Efficient Landscape Policy (WELP), was enacted in 1993 by the City of Santa Rosa. WELP included regulations for irrigation equipment, landscaping on steep slopes, rain sensors, auto shutoff, and hydrozoning techniques (Water Efficient Landscape Policy, 1993). WELP was superseded by SUSMP. None of the case studies were built to WELP standards, and thus WELP is not addressed further.

#### Challenges

The existing statewide stormwater policy is CALGreen, implemented in 2011. Since CALGreen was approved, no new developments have been built in Sonoma County. As a result, it was not possible to include a case study approved under CALGreen in our analysis.

In general, there has been minimal building activity in Sonoma County following the onset of the 2007 recession. The GreenPoint development is only partially built, with 12 completed lots. The One Planet development is not built and can be evaluated only through design documents and environmental impact reports.

Nonetheless, even with limited data on new developments, it is possible to perform some initial studies. Further vetting against built land covers and recorded water data will soon become possible.

## LOCATION



The case study sites are located in central Sonoma County, in the cities of Santa Rosa and Rohnert Park. Rohnert Park is home to 43,062. The median household income in 2000 was $67,097 in 2007 (Demographic Profile, 2010). Santa Rosa has a population of 169,292 as of 2011 (Santa Rosa, California, Quick Facts, 2013). The median household income was $59,838 in 2009 (City Profile, 2010).

## CLIMATE

Santa Rosa and Rohnert Park have similar climates. Both are temperate and have moderate precipitation. Most of the annual precipitation is concentrated in six months during the rainy season. Typically Santa Rosa experiences approximately 32 inches of rain per annum (Now Data, 2012). Rain intensity can be as high as .5 inches to .8 inches an hour every two years, reaching levels of 1.1 inches to 2.0 inches an hour every 100 years. Six-hour rain intensity for every two years ranges from 2 to 3 inches, with a 100-year intensity of 3.8 to 6.3 inches in a six-hour period (Climate of Sonoma County, 1964).

# 3.2 CASE STUDY DESCRIPTIONS

## TRADITIONAL DEVELOPMENT

Residential Units: 224

Size of Development: 70 acres

Density: 4 units/acre

Initial Year of Development: 1976

Stormwater Codes: N/A

### History

There are 224 homes within the Traditional community. The development was approved in 1974 (Policy Statement, 1974), and homes were built in three phases from 1976 to 1986.

### Design

This traditional development exemplifies post–World War II suburban communities. All the homes in this community are single-family detached homes with one floor and attached garages. There are three types of home designs: quadraplot homes, semidetached townhouses, and zero side yard houses. The typical home within this community is a three-bedroom, two-bathroom house ranging from 1,100 square feet to 2,300 square feet. The median house size is 1,400 square feet. The homes are on lots ranging from 4,000 square feet to 7,000 square feet. The median lot is approximately 5,600 square feet. The average density of this community is approximately 4 units per acre.

In the north central portion of the development there are 56 homes that differ from the normal building type in the community. These homes are smaller; are generally two bedrooms, two bathrooms; and are approximately 1,096 square feet on a 3,400-square-foot lot. In the center of this development is a community park with a basketball court and a community pool. A typical home in this community costs $260,000, with home values ranging from $204,000 to $308,000 (Zillow, 2012).

### Demographics

Traditional is located within the city of Santa Rosa. Its block group has a population of 1,637. The average household size is 3.03 persons per occupied unit. The median household income of the block group ranges from $57,005 to $62,516 (American Community Survey, 2012).

### Stormwater Management

Although stormwater runoff regulations were not enacted until 1987, when the Federal Water Pollution Control Act (Clean Water Act) was amended (Stormwater permit, 2012), some measures were observed within this subdivision. For example, the green space in the center of the development was graded to act as stormwater retention, slowing runoff and increasing infiltration.

## ➤ LOCAL STANDARD URBAN STORMWATER MITIGATION PLAN (SUSMP) DEVELOPMENT

Residential Units: 150

Size of Development: 18 acres

Density: 9 units/acre

Initial Year of Development: 2005

Stormwater Codes: Standard Urban Stormwater Management Plan

### History

The SUSMP subdivision consists of 88 single-family homes and 31 duplexes on 29.4 acres of land. Thirteen acres of land are set aside as a wetland preserve. The project was approved in 2005 and built shortly thereafter.

When the project was approved, the City of Santa Rosa conditioned the project so that runoff volumes from this redeveloped site would not exceed the pre-development flows.

### Design

There are six different models of homes, ranging from 1,680 square feet to 1,716 square feet. The lot sizes and yard space vary with each model, ranging from lots of 2,657 to 4,936 square feet. Development density is roughly 9 units per acre. Recently sold units ranged from the low $200,000s to the low $400,000s (Zillow, 2012).

### Demographics

The SUSMP subdivision is located on the western outskirts of the urban center of Santa Rosa. Its block group has a population of 2,307. The average household size is 2.87 persons per occupied unit. In addition, this census tract has a median household income ranging between $58,952 and $74,443 (U.S. Census, 2010).

### Stormwater Management

Stormwater runoff regulations within this subdivision are based upon SUSMP. The duplexes that surround the perimeter of the entire development all have Hollywood driveways (driveways with center strips of turf or gravel). These strips allow pollutants released from parked vehicles to naturally filter through soils, rather than be rinsed into storm drains. The remaining residences are single-family homes laid out in a cluster development pattern, where four residences share common driveways. This design is intended to reduce the degree of impervious surfaces per household. Curb cuts allow runoff to flow from the street into bioswales, decreasing its speed and providing for a greater opportunity to infiltrate, while excess water flows through a series of medium-sized stones that act as a buffer surrounding the storm drain. The subdivision also includes a retention pond.

## ➤ GREENPOINT DEVELOPMENT

Residential Units: 162 units

Size of Development: 35.4 acres

Density: 5.5 units/acre

Initial Year of Development: 2003

Stormwater Codes: Standard Urban Stormwater Management Plan

### History

The GreenPoint development was first approved in 2003. Development stalled after the onset of the 2007 recession. In 2010, a new developer purchased the property (Council Meeting, 2011). The development is not yet complete. There are currently 12 occupied units on the property.

GreenPoint is being built to surpass the minimum California building and energy requirements. The subdivision was awarded the 2012 Gold Nugget Award and is GreenPoint rated. The GreenPoint rating requires that the subdivision satisfy requirements in energy efficiency, resource conservation, indoor air quality, water conservation, and community.

### Design

GreenPoint is located on 26 acres of land. The projected build-out will include 138 single-family units, 24 apartments in two buildings, and a 2.16-acre neighborhood park. GreenPoint single-family home prices will range from $302,990 to $443,990 (GreenPoint, 2012).

### Demographics

GreenPoint is located in southeast Santa Rosa. As of 2010 (prior to the completion of the GreenPoint development), its block group had a population of 3,569. The average household size is 3.05 persons per occupied unit. The census tract has a median household income ranging between $48,446 and $54,485 (U.S. Census, 2010). The population and median income are likely to increase after GreenPoint is built.

### Stormwater Management

Beyond meeting SUSMP regulations, the development voluntarily implemented CALGreen measures. During a site visit, we observed a variety of stormwater management techniques: vegetated strips lined the streets; the community park doubled as a stormwater retention basin; swales lined the park. Additionally, a major component of the site is an extended bioretention basin and a constructed wetland, which further improve infiltration and natural filtration of stormwater runoff.

## ➤ ONE PLANET DEVELOPMENT

Residential Units: 1,892

Size of Development: 200 acres

Density: 8.5 units/acre

Initial Year of Development: Not yet built

Stormwater Codes: Standard Urban Stormwater Management Plan

### History

One Planet will be a 200-acre mixed use, solar powered, zero waste community. In 2001, the plans for this community earned the LEED Platinum rating, the highest rating awarded by the U.S. Green Building Council. In 2008, it earned the Governor's Environmental and Economic Leadership Award for its land use planning. This is the highest environmental honor in California. One Planet is the first community in North America to be endorsed by the One Planet Communities program.

Residential development was scheduled to occur in three to six phases over the course of 12 to 20 years, depending on market conditions. The project was approved by Rohnert Park's City Council, and the residential phase was due to start in 2011–2012. Residential construction has not yet begun, however (Development Update, 2011).

### Design

The development will house 5,000 people in a total of 1,892 homes. There will also be office, commercial, and retail space in the community (Demographic Profile, 2010). Lot sizes will range from 60 to 120 feet wide (One Planet Planned Development, 2010).

Because this is a mixed use development, it is not a true analog to the other three case study sites. The whole neighborhood includes many more services than the other residential-only neighborhoods. As a result, it is more consistent to examine the data from the One Planet single-family lots contained within the development than it is to evaluate the full neighborhood.

### Demographics

Residences are not yet built, so demographic information is not available. The town of Rohnert Park's median household income was $67,097 in 2007 (Demographic Profile, 2010).

### Stormwater Management

As this is a One Planet community, developers of One Planet strive to have a zero percent increase of water allocated to the site compared with the previous property owners (Developing a One Planet Community, 2012). Subsequently, stormwater runoff regulations were devised in a manner that will take full advantage of natural water. Rain barrels, cisterns, and underground water storage areas will enable rainwater to be utilized for irrigation purposes in vegetated strips and public areas ([One Planet], 2009). Such measures also contribute to LEED certification. Within the sustainable stormwater section, in order to achieve the highest point rating possible, a site located within a semiarid watershed is required to infiltrate, reuse, or evapotranspire 2.25 inches of water per year (Pilot Version, 2007). Other measures, such as pervious pavers, vegetated strips, and bioretention areas, will also contribute to an increased infiltration rate and decreased flow rate of stormwater runoff, provide natural filtration of pollutants, and decrease the likelihood of flooding in surrounding areas.

This site has clay-rich soils that limit the amount of runoff infiltrating the soils. Techniques for stormwater management include impervious surface controls, biofiltration swales and rain gardens, use of street trees with structural soil, and cisterns. The use of pervious surfaces for roads will be explored when appropriate for vehicle use for places such as alleyways, due to less traffic. In places where biofiltration areas or rain gardens are not feasible due to space requirements, underground infiltration galleries and cisterns will be put in place ([One Planet] Water Plan, 2009).

## 3.3 TRANSLATING FROM SITE TO TOOL

In order to analyze our case study sites with the tool, it was necessary to identify unique land cover types, quantify the area of each land cover, and identify water infrastructure. For the built developments (Traditional, Local Standard [SUSMP], and GreenPoint), we used high-resolution aerial imagery in a geographic information system (GIS) to identify and measure land cover and confirmed GIS findings with site visits. For the One Planet development—approved but not yet built—we relied on project documentation.

### Interpreting Land Cover with GIS

Aerial interpretation relied on images acquired from the City of Santa Rosa. We used the northwest and southwest quadrants, flown in 2009. While more recent aerials are available from other sources, the 2009 imagery was the only with sub-meter resolution. High granularity was essential in order to digitize different land covers as accurately as possible.

Even so, it was often challenging to tease apart different land cover types. Defining land cover categories became an iterative process, balancing the inputs necessary to quantify water consumption, runoff, and monetary costs, while maintaining a simple set of land cover variables that could be interpreted in the GIS.

Additional challenges we encountered while interpreting the aerial photos were:

- **Skewed images.** Some aerials were shot at an angle, not directly overhead. This caused vertical fences and walls to obscure the underlying land cover. In these cases, we made assumptions about the land cover, based on precedents in adjacent lots or elsewhere within the same lot.
- **Shadows.** When shadows obscured land cover, we also made assumptions on the likely land cover based on precedents.
- **Temporary land cover.** When trash cans or other unidentifiable objects seemed to be in place temporarily, we assigned the area the underlying land cover. We assigned trees with no leaves a conservative estimated tree canopy cover that would be present throughout most of the year.

### Field Verification of GIS Analysis

We visited each case study site in fall 2012, when we observed front yards and non-fenced areas. During the site visits, we confirmed GIS interpretation and assessed water infrastructure choices that were often difficult to observe in aerial images.

## ➤ TRADITIONAL

The primary challenge when digitizing the Traditional subdivision is that the trees are mature and have large canopies that grow together. During the site visit, we adjusted the tree count as necessary. Additionally, we noted downspout disconnections but no other consistent neighborhood green infrastructure techniques.

Following are final digitized maps of a representative Traditional lot and the Traditional neighborhood.

**Lot**


**Neighborhood**

## ➤ LOCAL STANDARD (SUSMP)

The SUSMP development was easier to digitize than the Traditional development. This subdivision is newer and trees are not yet mature—the lack of shadows and tree canopies made land covers more distinguishable. Also, as it is a newer development, the land covers are more consistent from lot to lot, making it easier to find recurring patterns.

A major issue is that the subdivision was incomplete when the high-quality 2009 aerials were flown. To digitize the full neighborhood (including the unfinished lots), it was necessary to make assumptions on roof square footage, landscaping, and driveways from local precedent. In addition, we were able to verify assumptions with lower-quality aerials flown in 2011, after the SUSMP development was complete. During the site visit, we paid special attention to the more newly built areas to ensure that they were represented as accurately as possible.

During the site visit, we confirmed vegetation types that were unclear in the aerial photos, identified permeable pavers, and noted LID features. For example, we found curb cuts that allowed water to flow into bioswales and then hit a stone buffer surrounding a storm drain (we classified these stone buffer zones as permeable pavement). We also discovered that residences within this subdivision have connected downspouts.

Following are final digitized maps of a representative SUSMP lot and the SUSMP neighborhood. In the neighborhood, note the large, reconstructed wetland on the eastern portion of the property.

Lot



Neighborhood


## ➤ GREENPOINT

Because the GreenPoint case study is currently under construction, it was necessary to use the most recent imagery available for digitization. As a result, we relied on lower-resolution 2011 aerials. Very few finished residences are visible in the aerial, but all of the lots are platted. We created a digitization of the full, projected development based on site visits, subdivision documentation, and regulations.

From the constructed units we observed that all downspouts are connected, funneling water underground and then onto the street and eventually downhill into the subdivision's park, which also acts as a stormwater retention area. The lots are landscaped with sparse vegetation irrigated by high-efficiency spray irrigation. Newly planted trees were difficult to discern on the aerial, but we were able to conduct a count during the site visit: the typical lot has two trees in the front yard—three on corner lots—and one or two in the rear yard.

Following are final digitized maps of a representative GreenPoint lot and the GreenPoint neighborhood.

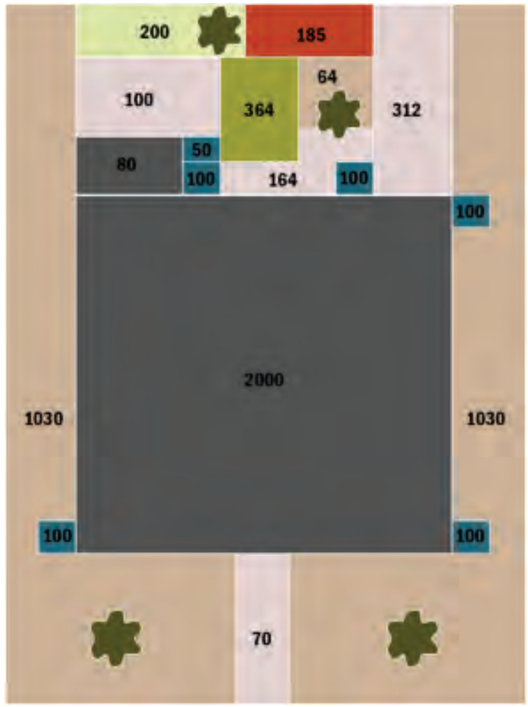
Lot


Neighborhood

## ➤ ONE PLANET

Unlike the other developments, the One Planet residential subdivision is not yet under construction. Following are the assumptions made when creating a representative single-family lot and digitizing the neighborhood plan.

Lot




Data for the lot were constructed based on zoning codes and neighborhood precedents. We determined the lot dimensions and setbacks from the Rohnert Park Code of Ordinances, based on guidelines for T3 Sub-Urban Zones (Title 17 Chapter 17.06 Article XV.A. Section 17.06.850). Section 17.06.850 states that lots can range from "sixty to one hundred twenty feet wide at the Principal Frontage" (Municipal Code of Rohnert Park, 2012). We assigned the lot a width of 70 feet, following local examples. Based on setback rules for T3 zones, we assigned the principal building a 20-foot setback from the front of the lot and a 6-foot setback from the sides.

The driveway is located behind the house and is accessed through a back alley, per the subdivision design. The driveway is 12 feet wide, which is the minimum residential driveway width for the City of Rohnert Park (Streets and Roadway Design Standards, 2011).

The roof area is calculated based on a two-story house, which is the minimum building height for the principal building in T3 zones.

The landscaping of the backyard was derived from zoning requirements and regional precedent. The turf dimensions were based on Section 17.06.850 6c, which states, "Turf area is limited to thirty percent of the landscaped area within the Principal and Secondary Frontages" (Municipal Code of Rohnert Park, 2012). The turf area in the lot scale is roughly 10% of the landscaped area, which is under the 30% limitation.

The size of the rain garden, 200 square feet, is based on an average size from the Groundwater Foundation (Rain Gardens). The estimated amount of rain barrels in gallons comes from a rain barrel sizing guide (Rain Barrels and Cisterns, 2007).

Remaining landscaping is mulch and sparse vegetation, consistent with drought-resistant planting styles. We assumed that the driveway is made of permeable pavers.

**Neighborhood**


Source: Final Development Plan, 2010

Similar to the lot size description, the numbers for the neighborhood scale are based on zoning codes, the Development Zoning and Regulating Plan from the City of Rohnert Park, and a Final Development Plan published by the developer.

From the Final Development Plan we found the areas of two civic parking lots and the neighborhood open spaces.

We assumed that there are sidewalks along all streets and all sidewalks are lined with bioswales, per the Development Zoning and Regulating Plan's specification that all sidewalks be lined with vegetated planter strips or tree wells.

Finally, stormwater pipe sizes are not yet available for the One Planet case study. We determined the total length of future stormwater pipes from the Municipal Services Plan. The plan also noted that the average pipe diameter would be 48 inches.

## 3.4 APPLYING THE TOOL

After quantifying the land cover and water infrastructure for the case studies, we evaluated the lots and neighborhoods using the Integrated Water and Land Management Tool.

In this exercise, we looked to see if the different policies and practices at each case study site led to different outputs of the tool as primarily a proof of concept of the tool. While we draw conclusions from the output of the tool, this is preliminary research. Further study of developments built pre-code, under SUSMP, or to GreenPoint or One Planet specifications is necessary before definitively assessing the relative performance of the development styles.

Furthermore, we do not generally support comparing tool metrics when applied to different sites. The tool is best for evaluating alternatives at the same site. Nonetheless, for the purposes of testing and demonstrating the tool, in this section we will compare across the case studies.

## ➤ LOTS

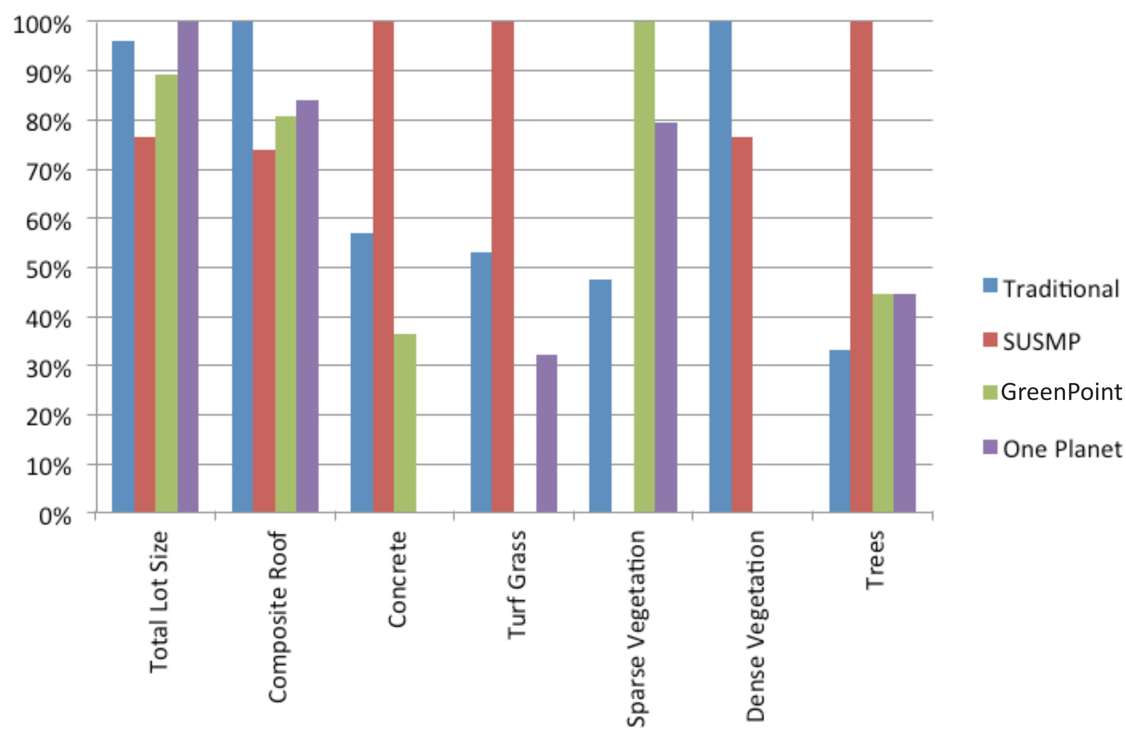
For each case study lot, we entered the land cover and site water infrastructure data into the tool and compared the output metrics.

### Inputs

While we built the tool to accommodate a wide array of different land cover types and water infrastructure options, we observed a more limited set of land covers in our typical lots. Following is a table summarizing the land covers recorded for each case study lot:

| | Traditional | SUSMP | GreenPoint | One Planet |
|---|---|---|---|---|
| **Total Lot Size** | 5,285 | 4,217 | 4,918 | 5,509 |
| **Composite Roof** | 2,480 | 1,831 | 2,001 | 2,080 |
| **Concrete** | 516 | 907 | 330 | |
| **Permeable Pavers** | | | | 828 |
| **Turf Grass** | 598 | 1,125 | | 364 |
| **Cultivated Garden** | | | | 185 |
| **Sparse Vegetation** | 1,228 | | 2,587 | 2,052 |
| **Dense Vegetation** | 463 | 354 | | |
| **Trees (count)** | 3 | 9 | 4 | 4 |

Following are the land covers present at more than one site, visualized on a normalized scale:




From the chart, it is easier to read that Local Standard (SUSMP) is the smallest lot with the smallest roof area but has the largest amount of concrete and turf grass. In comparison, GreenPoint and One Planet have little turf grass. In fact, the standard, representative GreenPoint lot has no turf grass at all.

GreenPoint and One Planet each have substantial amounts of sparse vegetation. This is, in part, because each development uses drought-sensitive landscaping. It is also because the vegetation is not mature yet; one of the limitations of this method is that is difficult to differentiate planting style and age of vegetation.

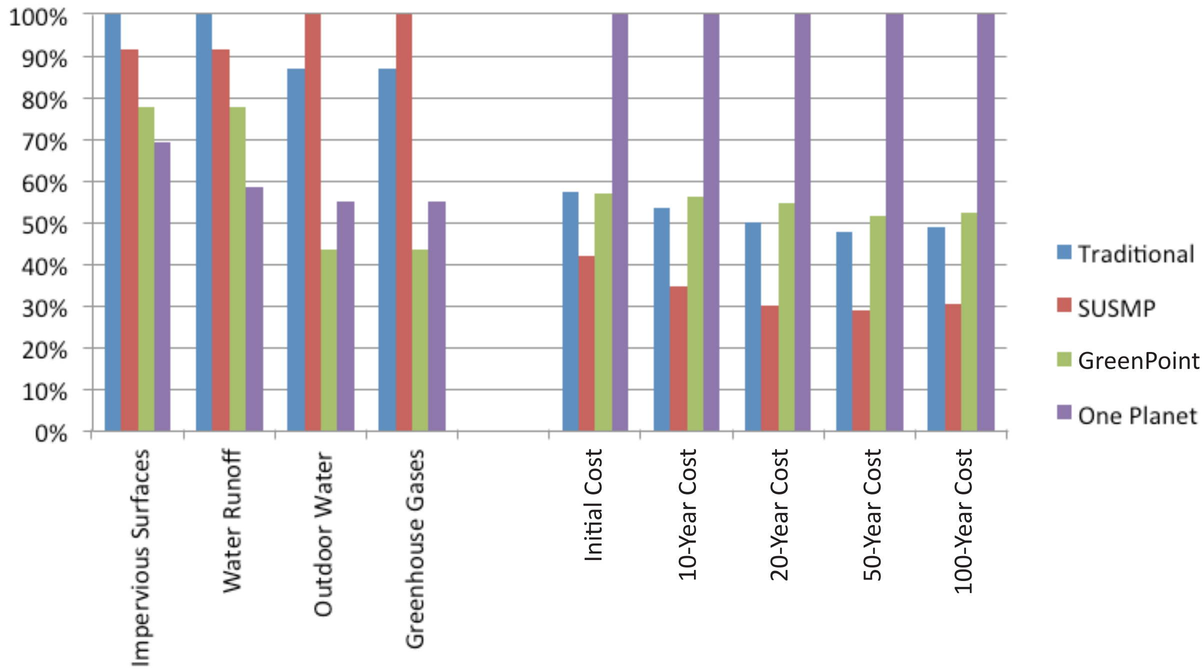
Finally, Local Standard (SUSMP) has many more trees than the other developments.

## Outputs

The different input values from the lots are reflected in similarly different output values. Lot size (an input value) is included for reference.

| | Traditional | SUSMP | GreenPoint | One Planet |
|---|---|---|---|---|
| **Total lot size (sf)** | 5,589 | 4,712 | 4,918 | 5,509 |
| **Impervious land cover (sf)** | 2,996 | 2,738 | 2,331 | 2,080 |
| **Peak monthly water runoff from impervious cover (gal)** | 13,943 | 12,742 | 10,848 | 8,184 |
| **Peak monthly outdoor water consumption (gal)** | 3,738 | 4,291 | 1,874 | 2,653 |
| **Peak monthly $CO_2$ emissions from outdoor water use (lbs)** | 3.8 | 4.4 | 1.9 | 2.7 |
| | | | | |
| **Cost of program** | | | | |
| **Initial cost** | $23,876 | $17,458 | $23,716 | $41,727 |
| **10-year cost** | $34,916 | $22,540 | $36,651 | $65,134 |
| **20-year cost** | $45,956 | $27,622 | $50,116 | $91,971 |
| **50-year cost** | $92,510 | $56,368 | $100,233 | $193,838 |
| **100-year cost** | $174,578 | $108,780 | $187,000 | $357,169 |

Again, variation between the lots for each output metric can be visualized simultaneously on a normalized table:




The Traditional lot has the greatest amount of impervious surfaces, followed by Local Standard (SUSMP). While the Traditional lot has approximately half as much concrete as SUSMP, the larger square footage of its roof contributes to site imperviousness.

The monthly water runoff from Traditional is also the highest because it has the greatest amount of impervious surfaces.

Because of its large turf grass areas, Local Standard (SUSMP) has the highest monthly outdoor water use, followed by Traditional. GreenPoint's outdoor water use is the lowest because it has no turf grass or other high water-use outdoor planting. The One Planet lot has both turf grass and a cultivated vegetable garden, which pushes its use slightly higher.

Because of its relatively high outdoor water use, Local Standard (SUSMP) also has the highest greenhouse gas production. Traditional is close behind Local Standard (SUSMP), followed by GreenPoint and One Planet.

Based on the cost metrics of the tool (initial cost of supplies and labor plus replacement costs), the most expensive home to develop initially and maintain over the long term is One Planet. With more expensive permeable pavers, rain barrels that require occasional replacement, and annual gardens, the One Planet home requires the most money to maintain. In addition, it is on the largest lot, so there is a larger area to build and maintain.

The least expensive lot to build and maintain over time is Local Standard (SUSMP). Not only is it the smallest lot, but its simple outdoor design—relatively inexpensive concrete and turf grass—requires less money per lot to install and replace.

## Sensitivity Testing

The values used to calculate tool outputs are the best available information. Over time, there will be changes in the marketplace and local conditions that impact costs and water consumption, however. To assess the vulnerability of the tool to market and environmental variations, we examined two basic scenarios: (1) Concrete costs decrease by 20%; (2) plants consume 10% more water. We selected these scenarios because they represent extreme cases.

### Scenario 1. Concrete costs decrease by 20%.

Recent reports indicate that concrete costs have risen 3% in the past year (Construction Economics, 2012), but we chose to assess the impact of decreased concrete costs because this should privilege status quo development styles. This sensitivity testing analyzes how much the total costs of the full lot program change if concrete prices drop by 20%.

The following table summarizes the existing cost metrics and the change in cost if concrete prices drop by 20%.

| | Traditional | SUSMP | GreenPoint | One Planet |
|---|---|---|---|---|
| **Cost of program, standard concrete cost** | | | | |
| **Initial cost** | $23,876 | $17,458 | $23,716 | $41,727 |
| **10-year cost** | $34,916 | $22,540 | $36,651 | $65,134 |
| **20-year cost** | $45,956 | $27,622 | $50,116 | $91,971 |
| **50-year cost** | $92,510 | $56,368 | $100,233 | $193,838 |
| **100-year cost** | $174,578 | $108,780 | $187,000 | $357,169 |
| | | | | |
| **Cost of program, concrete down 20%** | | | | |
| **Initial cost** | $23,173 (-3%) | $16,222 (-7%) | $23,267 (-2%) | $41,727 (0%) |
| **10-year cost** | $34,213 (-2%) | $21,304 (-5%) | $36,202 (-2%) | $65,134 (0%) |
| **20-year cost** | $45,253 (-2%) | $26,386 (-4%) | $49,667 (-2%) | $91,971 (0%) |
| **50-year cost** | $91,104 (-2%) | $53,898 (-4%) | $99,334 (-2%) | $193,838 (0%) |
| **100-year cost** | $171,767 (-2%) | $103,838 (-5%) | $185,202 (-2%) | $357,169 (0%) |

With a 20% decrease in the price of concrete, the total monetary cost declines for all lots except One Planet, which shows no change because there is no concrete on the lot. The changes, however, are relatively small compared with the large price change. Because concrete represents only one of the costs folded into the total cost at Traditional, SUSMP, and GreenPoint, a large decrease in the price of concrete had far smaller impacts on the program cost calculations. This indicates that the tool results will be robust with normal price variability.

### Scenario 2. Plants consume 10% more water.

Plant water consumption is very sensitive to local environmental conditions. In the tool, we assumed that all plants were exposed to equal conditions. In reality, some places are sunny and windy, while some are sheltered and damp. In addition, climate variability may influence consumption. This sensitivity test analyzes how much the total water consumption will change if all plants are exposed to a hotter, drier environment and consequently consume 10% more water.

The following table summarizes the existing water consumption and the change in each lot's water consumption if all plants consume 10% more water.

| | Traditional | SUSMP | GreenPoint | One Planet |
|---|---|---|---|---|
| **Outdoor water consumption, standard** | | | | |
| **July H2O consumption (gal)** | 3,738 | 4,291 | 1,874 | 2,363 |
| | | | | |
| **Outdoor water consumption, plants consume 10% more** | | | | |
| **July H2O consumption (gal)** | 4,112 (+10%) | 4,720 (+10%) | 2,061 (+10%) | 2,653 (+12%) |

Since this change was applied across all plants, in the Traditional, Local Standard (SUSMP), and GreenPoint lots the total water use increased 10%. The change in the One Planet lot is higher than 10%, though. This is because part of the monthly water landscaping needs are met with local water storage. As the water budget of the plants goes up but the volume of the rain barrels does not change, the lot consumes more municipal water.

This test on outdoor water use demonstrates that the model is approximately linearly sensitive to changes in local environmental conditions. It will be necessary for users of the tool to carefully examine the Water Consumption tab within the Excel tool and consider how the default values should be modified to match local conditions.

For this reason, too, comparisons across sites in different microclimates should be approached with caution.

## ➤ NEIGHBORHOODS

Unlike the lots, which are similarly sized, the neighborhoods are vastly different sizes. The neighborhoods also have different proportions of single-family and multifamily units. The One Planet development even includes a commercial core and office space. Comparing among the developments is difficult because of their variation in size and number of units, and differences in land uses.

After assessing the input values (below), we determined it was currently necessary to:

1. Compare the developments by evaluating resource/monetary intensity per acre
2. Limit comparisons to residential-only developments

In the future, when the tool is developed to handle non-residential and mixed use developments, it will be possible to compare all of the case studies side-by-side.

## Inputs

Following is a table summarizing the land covers and water infrastructure recorded for each neighborhood. One Planet is provided for reference in this table but will not be evaluated further.

| | | Traditional | SUSMP | GreenPoint | One Planet |
|---|---|---|---|---|---|
| **Total neighborhood size** | *sq ft* | 2,453,620 | 752,184 | 1,304,277 | 8,712,000 |
| **Total number of single-family homes** | *count* | 224 | 88 | 138 | 743 |
| **Total number of multifamily homes/apartments** | *count* | | 62 | 24 | 951 |
| **Total dwelling units** | *count* | 224 | 150 | 162 | 1,694 |
| **Density** | *du/ac* | 4.0 | 8.5 | 5.5 | 8.5 |
| | | | | | |
| **Lot Land Cover** | | | | | |
| Concrete | *sq ft* | 261,222 | 93,909 | 50,219 | |
| Pavers, brick or natural stone | *sq ft* | 29,577 | 3,047 | | |
| Permeable pavement—pavers | *sq ft* | 22,699 | 364 | | 165,600 |
| Deck | *sq ft* | 16,190 | | | |
| Turf grass | *sq ft* | 314,462 | 64,405 | 527 | 72,800 |
| Artificial turf grass | *sq ft* | 425 | | | |
| Cultivated flower or vegetable garden | *sq ft* | 3,783 | | | 37,000 |
| Sparse irrigated vegetation | *sq ft* | 144,322 | 50,704 | 314,172 | 410,400 |
| Dense irrigated vegetation | *sq ft* | 87,551 | 54,850 | | |
| Pool/fountain/hot tub | *sq ft* | 2,691 | | | |
| Pond | *sq ft* | 165 | | | |
| Existing trees (canopy) | *sq ft* | 388,209 | 6,136 | 7,081 | |
| Existing trees (count) | *count* | 1,587 | 227 | 872 | 800 |
| Composition roof | *sq ft* | 780,087 | 220,978 | 259,664 | 416,000 |
| | | | | | |
| **Lot Water Infrastructure** | | | | | |
| Rain barrels | *gal* | | | | 110,000 |
| Downspout disconnection | *%* | 100 | | | |
| Rain garden | *sq ft* | | | | 40,000 |
| Irrigation controllers | *1 or 0* | | | | 1 |

| | | Traditional | SUSMP | GreenPoint | One Planet |
|---|---|---|---|---|---|
| **Neighborhood Transportation Infrastructure (Hardscape)** | | | | | |
| Street, asphalt | *sq ft* | 425,993 | 117,559 | 186,119 | 1,651,200 |
| Curbs and gutters, concrete | *sq ft* | 24,161 | 7,395 | 13,919 | 31,840 |
| Sidewalk, concrete | *sq ft* | 110,296 | 54,860 | 95,219 | 315,920 |
| Parking lot, asphalt | *sq ft* | | | 16,809 | 90,000 |
| **Neighborhood Water Infrastructure** | | | | | |
| **Corrugated Metal Pipe (CMP)** | | | | | |
| 15 in | *lf* | 2,528 | 551 | 474 | |
| 18 in | *lf* | 575 | 1,220 | 1,380 | |
| 24 in | *lf* | | 135 | 291 | |
| 30 in | *lf* | | 250 | 442 | |
| 36 in | *lf* | | | 423 | |
| 42 in | *lf* | | | 691 | |
| 48 in | *lf* | | | | 22,844 |
| **Reinforced Concrete Pipe (RCP)** | | | | | |
| 21 in | *lf* | 119 | | | |
| 24 in | *lf* | 19 | | | |
| 27 in | *lf* | 523 | | | |
| 30 in | *lf* | 760 | | | |
| 36 in | *lf* | 304 | | | |
| 46 in | *lf* | 340 | | | |
| 54 in | *lf* | 700 | | | |
| 96 in | *lf* | | | 31 | |
| Bioswales | *sq ft* | 9,807 | 31,103 | 34,939 | 813,520 |
| Managed open space | *sq ft* | 244,967 | 6,760 | 145,725 | 422,532 |
| Naturalized open space | *sq ft* | 38,486 | 423,555 | 61,399 | 766,656 |

While there are many differences among the input values for the residential developments, one of the largest differences relates to the amount of open space within each development. The following table summarizes the open space as a proportion of the total development:

| | Traditional | SUSMP | GreenPoint |
|---|---|---|---|
| **Managed open space** (percent of total development area) | 10% | 1% | 11% |
| **Naturalized open space** (percent of total development area) | 1.6% | 56% | 4.7% |

As a percent of total area, SUSMP has by far the largest naturalized open space at 56%. Its managed open space area is comparatively very small. Traditional and GreenPoint have much less open space, and of that, the majority is managed.

While the neighborhood open space is different, the neighborhoods all had very similar amounts of neighborhood transportation infrastructure:

| | Traditional | SUSMP | GreenPoint |
|---|---|---|---|
| **Neighborhood asphalt and concrete** (percent of total development area) | 23% | 24% | 24% |

## Outputs

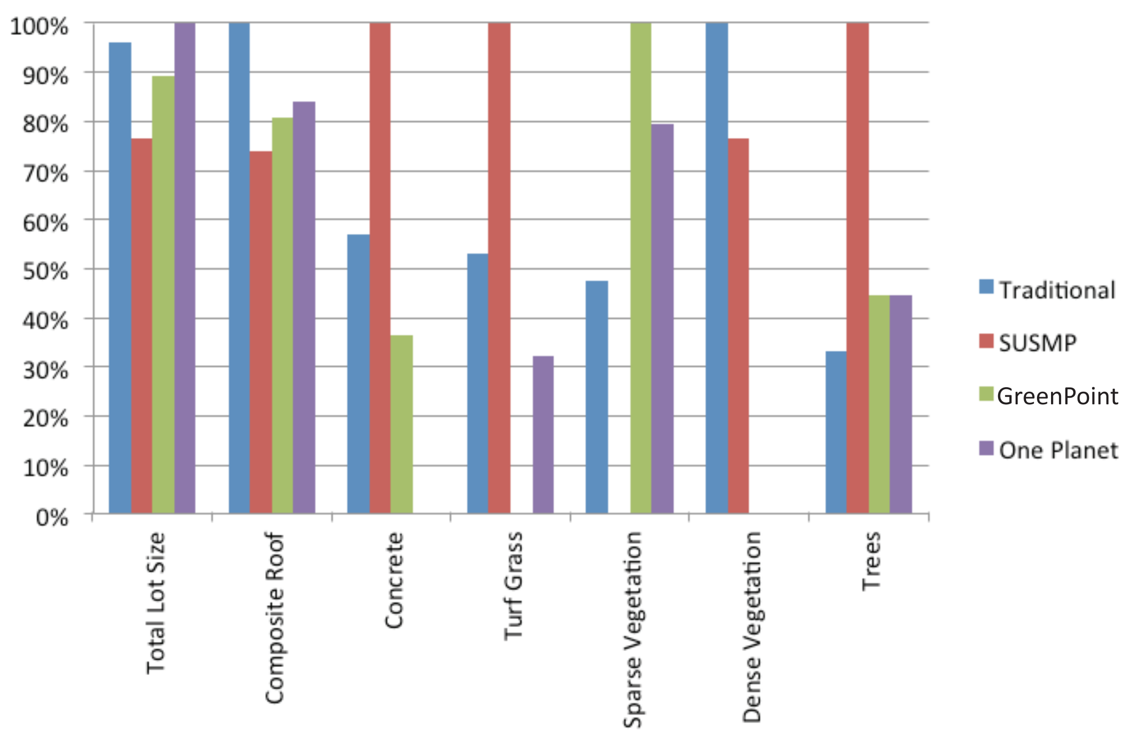
Following are the raw output values from the tool. Note that Traditional has almost twice the land area of GreenPoint and is three times the size of SUSMP.

| | Traditional | SUSMP | GreenPoint |
|---|---|---|---|
| **Total land area (sq ft)** | 2,453,620 | 752,184 | 1,304,277 |
| **Total impervious land cover (residential + community infrastructure) (sq ft)** | 1,684,603 | 541,456 | 657,234 |
| **Percent impervious land cover (of whole development)** | 69% | 72% | 50% |
| **Peak monthly water runoff from impervious cover (gal)** | 7,765,232 | 2,287,181 | 2,797,296 |
| **Peak monthly outdoor water consumption (gal)** | 2,658,985 | 342,715 | 837,076 |
| **Peak monthly $CO_2$ emissions (lbs)** | 2,713 | 350 | 854 |
| | | | |
| **Cost of program** | | | |
| **Initial cost** | $12,438,947 | $4,091,335 | $5,808,093 |
| **10-year cost** | $15,127,732 | $4,923,281 | $7,613,167 |
| **20-year cost** | $18,415,843 | $5,836,997 | $9,637,315 |
| **50-year cost** | $37,163,690 | $12,025,476 | $19,563,875 |
| **100-year cost** | $70,900,508 | $22,861,913 | $37,031,521 |

To compare among the developments, we calculated the resource consumptions per acre:

| | Traditional | SUSMP | GreenPoint |
|---|---|---|---|
| **Total impervious land cover (residential + community infrastructure) (acres/acre)** | 0.69 | 0.72 | 0.50 |
| **Peak monthly water runoff from impervious cover (acre-feet/acre)** | 0.42 | 0.41 | 0.29 |
| **Peak monthly outdoor water consumption (acre-feet/acre)** | 0.14 | 0.06 | 0.09 |
| **Peak monthly $CO_2$ emissions (lbs/acre)** | 48.17 | 20.25 | 28.53 |
| | | | |
| **Cost of program** | | | |
| **Initial cost** | $12,438,947 | $4,091,335 | $5,808,093 |
| **10-year cost** | $15,127,732 | $4,923,281 | $7,613,167 |
| **20-year cost** | $18,415,843 | $5,836,997 | $9,637,315 |
| **50-year cost** | $37,163,690 | $12,025,476 | $19,563,875 |
| **100-year cost** | $70,900,508 | $22,861,913 | $37,031,521 |

Visualized simultaneously, trends across the neighborhoods are more evident:




This chart demonstrates that, on a per acre basis, the results are fairly different than the lot-scale analysis. After folding in neighborhood infrastructure, SUSMP has the lowest outdoor water requirements and greenhouse gas impacts. SUSMP's outdoor water needs are low because, as a development, it has very little managed open space.

Notably, while the individual lot costs are different, as a development the costs are fairly similar over time. This is because the cost of the neighborhood infrastructure is sufficiently large that differences in specific lot-by-lot land cover choices are relatively small.

GreenPoint initially has a slightly lower implementation cost, though. This is because, summed across all of the lots, GreenPoint has fewer hard surfaces to construct. To some degree this was evident at the lot level—GreenPoint has fewer impervious surfaces per lot—but it is also because the density of the development is lower. This reveals a disadvantage of calculating costs per acre—this development is less expensive, because there are fewer units being constructed.

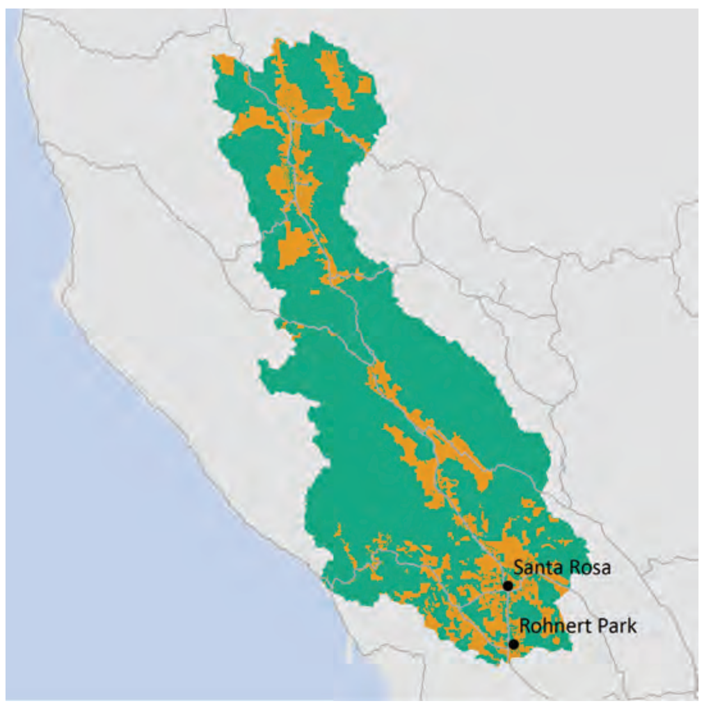
## ➤ BEYOND THE CASE STUDIES: CITY, COUNTY, AND WATERSHED

Beyond the neighborhood, the results of the tool have not been ground-tested or compared with case studies. This scale of analysis is simply for visioning purposes and to allow users to create and test alternative development scenarios.

In this analysis we will consider how any of the neighborhood development choices might scale if a single development style were implemented across the whole watershed. While we are coarsely applying the same neighborhood type across an entire watershed, it is also possible for a user to mix development types.

### Inputs

We summed all of the land that is zoned as residential in the Russian River watershed. This watershed encompasses all of the case study sites. It also includes the cities of Santa Rosa and Rohnert Park, all of Sonoma County, and portions of Mendocino and Lake Counties. All of the residential land in the Russian River watershed is shown below in orange. The total residential land is approximately 194,555 acres.



## Outputs

The tool multiples the neighborhood resource consumption per acre calculations by the input acreage. Following is a table summarizing the tool metrics at a regional scale, if all of the residential land in the Russian River watershed were developed in the Traditional, SUSMP, or GreenPoint approach.

| | Traditional | SUSMP | GreenPoint |
|---|---|---|---|
| Percent impervious land cover (acres) | 133,577 | 140,049 | 98,038 |
| Peak monthly water runoff from impervious cover (acre-feet) | 82,311 | 79,084 | 55,780 |
| Peak monthly outdoor water consumption (acre-feet) | 28,185 | 11,850 | 16,692 |
| Peak monthly $CO_2$ emissions (lbs) | 9,371,366 | 3,940,069 | 5,549,956 |
| | | | |
| Cost of program | | | |
| Initial cost | $42,964,186,743 | $46,096,849,129 | $37,739,313,445 |
| 10-year cost | $52,251,260,871 | $55,470,339,001 | $49,468,163,724 |
| 20-year cost | $63,608,415,192 | $65,765,126,970 | $62,620,493,675 |
| 50-year cost | $128,363,573,505 | $135,490,377,308 | $127,120,419,341 |
| 100-year cost | $244,890,710,824 | $257,583,916,914 | $240,620,145,783 |

Comparing one development approach across the whole of the Russian River watershed is a simple method of demonstrating that different development approaches have cumulative impacts. While the costs of the development styles do not vary substantially (approximately a 2%–12% difference in the range of values, depending on the time frame), some of the water-related metrics are quite different. For example, if the whole watershed were developed in the style of GreenPoint, there would be approximately one-third less runoff than if it were developed in the style of Traditional. If the whole watershed were developed in the style of the SUSMP development, less than half the amount of outdoor water would be required than if it were all developed like Traditional. As absolutes, these numbers should be approached with skepticism, but they are still valuable for envisioning alternatives.

# 4. FINDINGS AND CONCLUSIONS

This study advances efforts to quantify the cumulative impacts of local development choices over space and time. The Integrated Water and Land Management Tool allows people without highly technical backgrounds to compare and contrast development approaches, test the impacts of small choices, and evaluate a suite of water and monetary metrics.

After the tool was applied to four case study sites in Sonoma County, initial results indicate that smart land use and land cover choices have the potential to simultaneously save on construction costs and benefit water quality, flood safety, and water supply reliability. The case studies demonstrate that more recent projects with innovative water management standards show less overall water consumption and runoff than older developments. It is noted that there are not that many variations in the style of development and that the case studies are a fair representation; nonetheless, with the limited number of case studies, it is not yet possible to make broad generalizations. Further studies evaluating built developments at different densities and with different stormwater approaches are necessary. Even so, applying the tool to the case study sites clearly demonstrates that it is possible to compare and contrast land use and land cover choices with relation to water and cost metrics.

Developing the tool is a work in progress. It is an open-source tool that can be easily accessed, scrutinized, and expanded. As the tool is revised and used to study more development approaches, its utility and value will grow.

A summary of findings and conclusions from the process of developing the tool and from applying the tool to the case studies follows. We conclude with suggested next steps.

## 4.1 TOOL DEVELOPMENT

### ➤ SUMMARY OF FINDINGS

- There are few user-friendly tools that test and compare Low Impact Development scenarios. The existing tools either are not specific to California or are more narrowly and technically focused on reducing stormwater runoff. There is a lack of tools that are transparent, accessible, modifiable, scalable, and comprehensive.
- Calculating specific runoff volumes with simple inputs is not possible—at a minimum, these calculations require information on slope, soil, and surface roughness. Instead, the tool delivers metrics of percent imperviousness and peak runoff from impervious surfaces. The first is a useful indicator of watershed health; the second may help approximate the size of stormwater retention interventions (rainfall data can be updated to reflect the design storm of interest).
- The tool relies on the crop coefficient method (WUCOLS) for assessing applied outdoor water needs. The crop coefficient method is sensitive to local environmental conditions, so depending on a site's microclimate, actual landscaping needs may be higher or lower.
- The greenhouse gases associated with municipal water vary by region. Embedded greenhouse gases depend on the amount of energy used in the process of conveying and treating water and on the local power supply profile.
- It is challenging to find reliable price data for green infrastructure. The components are less standardized, there are few companies installing green infrastructure technology, and the field has a shorter history.
- Maintenance costs are not well documented for many construction components. While more maintenance information is available for traditional infrastructure and land cover choices than for newer LID/LEED materials and approaches, full operations and maintenance cost schedules are rare.
- Lifecycle costs are difficult to calculate, due to lack of data. In addition to operations and maintenance data, it is necessary to have information on the costs of replacing infrastructure (rather than new construction), which is not widely available for all components.

## ➤ TOOL CONCLUSIONS: CHALLENGES AND OPPORTUNITIES

The Integrated Water and Land Management Tool links land cover and water infrastructure choices to four water and five monetary metrics. The tool effectively demonstrates real differences in consumption when applied to case study sites. While there is still more work to be done to validate the output data, it seems the existing metrics can reveal a strong case for different land cover and water infrastructure decisions.

This starting point for the tool was focusing on lower-density, suburban developments, but it will be necessary to grow the scope of the tool to reflect more of the land cover decisions facing planning and development practitioners today. Many newer developments are beginning to incorporate commercial and office space. At present, the tool is not equipped to handle mixed use developments. This will be a critical next step.

As the scope of the tool expands, it will be necessary to further refine the metrics. The combination of refining metrics and extending scope will be an iterative process—as the scope grows, it will be necessary to reevaluate the metrics, ensuring that the metrics best capture the most critical information in the context of other land uses and densities.

The issues of refining metrics and expanding scope are evident in three urgent challenges facing the tool: expanding lifecycle costs calculations, refining metrics to fairly evaluate denser developments, and determining the best method for evaluating resource consumption in mixed use environments.

### Lifecycle Cost Calculations

Calculating accurate lifecycle costs in the tool was a major challenge. This is primarily due to a lack of ongoing operations and maintenance data. One reason these data are difficult to find may be that operations and maintenance costs often accrue to several different people or agencies. Furthermore, the allocation of maintenance responsibility may change over time. For example, a developer may initially build a road, but a municipality may take over for maintenance.

Understanding not just lifecycle costs but *who* bears cost burdens over time may change the interpretation of the lifecycle cost metrics. It is possible, for example, that such cost metrics would reveal that short-term savings at the lot or neighborhood level lead to onerous, long-term expenses carried by the municipality.

Revealing not only the total lifecycle cost but who is responsible for the cost is likely a key component to supporting responsible long-term development choices.

### Evaluating Higher Densities

The first version of the tool calculates resource consumption per acre as a method of comparing neighborhood developments. One of the challenges of examining per acre metrics is that dense developments intrinsically use more resources per acre. For this reason, it may seem as though the tool opposes density. This is not the case.

Instead, results from the tool highlight that it is likely more appropriate to consider calculating density per person or per household, rather than per acre. This may be a better method of evaluating relative impacts through different densities of development. Per acre calculations may still prove to be useful for visioning exercises, however.

### Metrics for Mixed Use Developments

More challenging than denser developments will be developing comparative metrics for neighborhoods with non-residential uses. The primary difficulty is determining how to allocate resource consumption. Non-residential uses consume resources without adding people. If the tool calculated per capita metrics, mixed use development would likely appear to have a high per capita resource use, even though this may not accurately portray resource consumption. In actuality, there are likely people traveling from beyond the neighborhood boundary who patronize the services in a mixed use neighborhood, just as people who live within the neighborhood travel beyond its boundaries for shopping or work. This makes it challenging to calculate either per capita or per acre resource consumption metrics. Determining fair metrics will require analysis of many mixed use developments and, possibly, surveys of shopping and work travel patterns.

## 4.2 IMPLEMENTING THE TOOL

### ➤ SUMMARY OF FINDINGS

- In Sonoma County, at the time of this study, the developments with the most innovative approaches to water management were either partially built or approved and not yet built. There were no residential developments that were built to CALGreen standards.
- The four case studies selected for this study have different stormwater approaches. One was built pre-regulation, one adheres to local codes, one meets GreenPoint standards, and one achieved One Planet certification. There is no single rating system by which all the developments can be evaluated (a table comparing the stormwater policies can be found in Appendix 5.5).
- Using GIS, we digitized and summarized the land covers and water infrastructure for each case study at the lot and neighborhood scales. The case studies show different land cover types and water infrastructure profiles, resulting in different consumption metrics.
- As a proportion of total land cover, all case study neighborhoods have approximately the same amount of transportation infrastructure.
- As a proportion of total land cover, the neighborhoods all have very different amounts of green space.
- Reducing hardscape is a critical component of minimizing water resource impacts. In the context of the case studies, it was possible to minimize impacts while using standard building materials, like concrete.
- Neighborhood infrastructure choices are sufficiently large and impactful that they have the potential to dwarf lot-level performance. The design that had the worst overall environmental performance at the lot level had the best environmental performance at the neighborhood level, due to a large constructed wetland. Similarly, the development that had the least applied outdoor water per lot did not have the least as a neighborhood because of a moderately sized shared turf grass park.
- The most environmentally sensitive development was also the most expensive, due to high-end land cover choices, more elaborate site infrastructure, and full costs that are often not calculated.

### ➤ DESIGN CONCLUSIONS: CHALLENGES AND OPPORTUNITIES

Applying the Integrated Water and Land Management Tool to the case studies reveals some challenges as follows:

#### Connecting Stormwater Policies and Project Outcomes

In this study, we reviewed four case studies with different stormwater policies. With only one case study from each policy framework, it is impossible to draw definitive conclusions on the impact of policies on resource consumption.

Furthermore, the water management plans of the case study developments were influenced by local condition, not just influenced by stormwater policies. In particular, the City of Santa Rosa conditioned the approval of the Local Standard (SUSMP) development to have no net increase in stormwater flows. In response, the development included a large constructed wetland, which positively impacted its neighborhood water metrics. In this development, teasing apart the impacts of Local Standard (SUSMP) and local planning is very difficult.

Due to low sample size and site-specific conditions, it is premature to extrapolate major conclusions on stormwater policies. A possible extension to the study would be to evaluate a larger sample of developments with the tool and more comprehensively document the relationships between policies and outcomes.

### Linking LID and Floodwater Management

One of the implicit objectives of the tool is linking costs and water impacts to help users to minimize costs while maximizing water benefits. When designing the cost metrics, we initially thought that one method of saving costs would be to implement LID techniques and then downsize some of the piped, hard infrastructure. Yet, due to local stormwater regulations, in Sonoma County implementing LID techniques has no influence on sizing the conventional stormwater systems. Although LID components impact volumes and rates of stormwater runoff, LID infrastructure is typically sized for a 24-hour storm, while conventional stormwater systems are sized for 100-year flood events. For this reason, implementing LID techniques onsite does not currently allow developers to recalculate the size of needed stormwater pipes.

Resizing stormwater pipes to account for upstream green infrastructure has the potential for measurable cost savings. Further study of the watershed-wide impacts of LID implementation will be required, but the benefits of aggregating small changes should not be overlooked by local and state regulatory agencies.

### Evaluating Materials in the Context

The outputs from the tool indicate that it is imperative to reduce hardscape in order to both minimize costs and minimize water impacts. In the context of the suburban case studies explored in this report, an important aspect of this finding was that it was possible to have low-impact developments using inexpensive building materials. Newer porous building materials proved to be expensive, without necessarily performing significantly better. When reduced hardscape is not an option, more expensive porous materials may be a viable alternative.

This finding may not hold true in dense urban environments, however. When it is difficult to reduce the footprint of hardscape, it may be necessary to reduce imperviousness with more innovative, porous materials. Matching design recommendations with development context may be a useful future trajectory of the tool.

## ➤ DESIGN ACTIONS

Following is an initial list of design actions indicated by the case study analysis. As the tool continues to be applied to more developments in different climates and with higher densities, this set of actions may be able to be translated into a more formalized set of guidelines.

### Reduce Hardscape

Hardscaping, such as asphalt and concrete, is expensive to build and maintain. By decreasing the footprint of hardscaping, projects save money while simultaneously reducing water runoff.

In general, reducing total square footage is more important than substituting for more porous, LID-friendly materials.

### Site Materials Intelligently

Common building materials can be intelligently sited to further decrease impacts on water resources. For example, if a small concrete driveway is graded to drain into a permeable surface, the impacts will be even less than if it's graded to drain into the street. By minimizing new hardscape and creatively draining and diverting water, it is possible to create a low-cost development that is also low impact.

### Plan for Water-Smart Public Infrastructure

In all of the case studies, the environmental and monetary impacts of public infrastructure were sufficiently large that they overwhelmed many of the lot-by-lot choices. Public infrastructure may be the most critical component of a development. With further development of lifecycle costs calculations, it is likely there will be an increasingly strong case for green infrastructure.

## 4.3 REFINING THE TOOL: NEXT STEPS

This tool was designed to be open source and accessible. Anyone can test, criticize, modify, and redistribute the tool. Following are areas of future research that we have identified as necessary to increase the robustness of the tool.

**1. Distribute and test the Integrated Water and Land Management Tool at local water agencies, planning, building, and public works departments. Feedback on the application of the tool by local government agencies, design professionals, and homeowners will as**sist in refining the model and expanding its use. Moving the User Guide to a publicly editable document (e.g., a wiki) may also be an important step in sharing the tool.

**2. Validate tool results against recorded outdoor water use and cost data in different climates.** There are no similar tools that have been measured against real data outcomes, but doing so is an important step in ensuring the accuracy of the tool.

**3. Conduct case studies of higher-density residential and mixed use urban projects.** With legislation like SB 375, there will likely be an increasing amount of more densely settled, mixed use development.

**4. Conduct case studies at broader spatial levels, including the city, county, and watershed.** Will the model be useful in evaluating land use alternatives and water conservation measures for resource planning and the preparation of general plans? What are methods for evaluating the accuracy of tool results?

**5. Improve cost calculations by revising lifecycle costs and folding externalities into per unit valuations.** Averted costs may also be a useful addition. (For example, growing vegetables onsite likely has a positive economic impact, which would offset the costs of the annual garden.)

# 5. APPENDICES

## 5.1 USER GUIDE

The Integrated Water and Land Management Tool is designed for homeowners and professionals. All users must be familiar with Microsoft Excel to comfortably work with the tool.

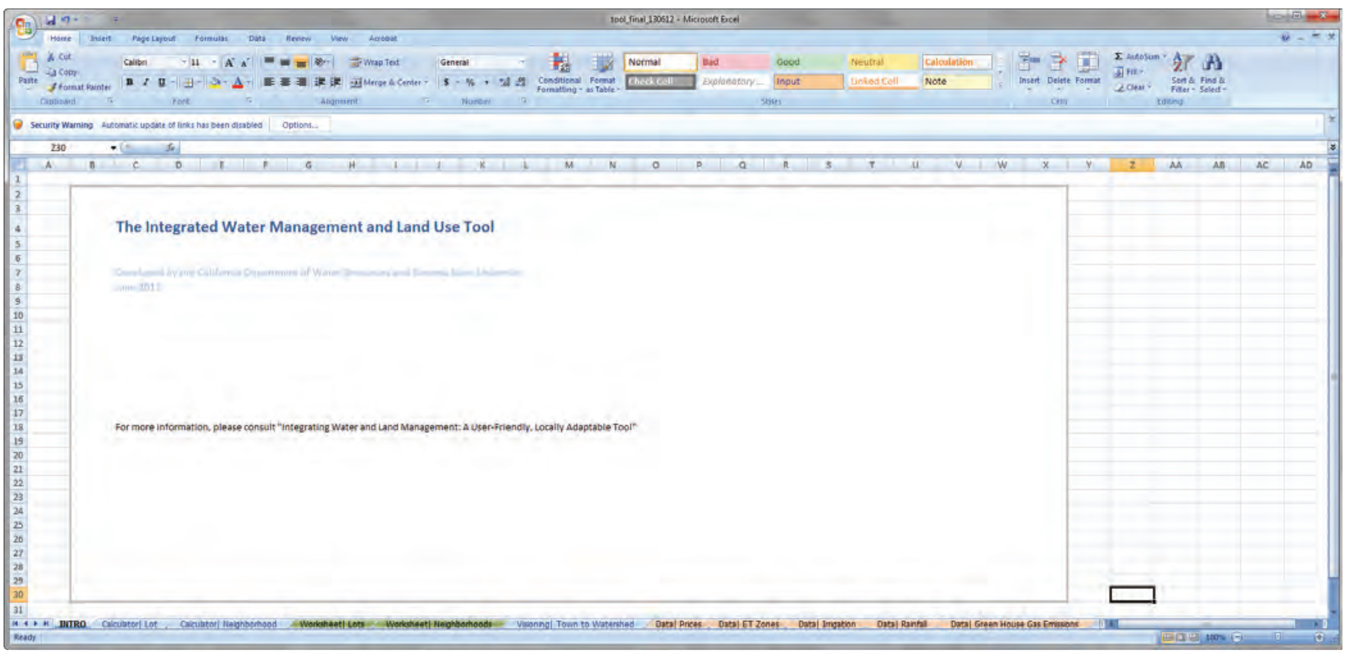
The User Guide progresses through increasingly difficult tasks. The first two tasks, opening the tool and evaluating Lots, require basic Excel experience. The next two tasks, evaluating Neighborhoods and Visioning, require intermediate Excel experience. The last two tasks, editing background data and calculations, require the most Excel experience.

All of the formulas and data within the tool are visible and editable so that the tool is as transparent and accessible as possible. The consequence is that users must be cautious when navigating through the tool. It is possible that a user could unintentionally edit or erase a workbook formula.

For detailed information on development of the tool and the rationale behind the calculations, see Section 2.

### ➤ TASK 1. NAVIGATING THE TOOL

Open the Integrated Water and Land Management Tool with Microsoft Excel.



At the bottom of the workbook are 11 tabs. Each tab performs a different function.

## Intro

The first tab, **INTRO**, includes information on the version of the tool and date of the update.

## Calculators

The calculators are the workhorses of the tool. **Calculator|Lot** calculates the nine output metrics for lots. **Calculator|Neighborhood** provides additional calculations that are relevant only to neighborhoods.

## Worksheets

The worksheets are where the user stores data from the calculators. **Worksheet|Lots** is designed for lot data, and **Worksheet|Neighborhoods** is designed for neighborhood data. Sample data is provided in each of these worksheets.

## Visioning

The **Visioning|Town to Watershed** tab is where a user can test how development choices scale across a larger spatial area.

## Data

There are five data tabs that store all of the background information used in the calculators.

**Data|Prices** contains all of the prices for traditional and green construction components in Sonoma County. There is also information on component lifespans. This data is used to calculate the tool's five monetary output metrics.

**Data|ET Zones** has monthly evapotranspiration data for the state of California by zone.

**Data|Irrigation** has all the information needed for calculating the water needs of plants, including crop coefficients and data on the efficiency of different irrigation methods. When this is combined with **Data|ET Zones**, the tool can calculate how much water is required by outdoor landscaping.

**Data|Rainfall** has information on rainfall in Sonoma County, which is used to calculate water runoff volumes.

**Data|Greenhouse Gas Emissions** contains all of the necessary information to calculate the amount of carbon dioxide emissions embedded in each gallon of water in Sonoma County.

## ➤ TASK 2. LOT CALCULATIONS

All home-based calculations are executed by the **Calculator|Lot** tab. This task will step through where to enter the necessary input data, how to measure the input data, how to read the output data, and how to store all the data in a worksheet.

### Entering Data

Click the **Calculator|Lot** tab and look at the first three columns in the worksheet: Component, Value, and Unit.

| COMPONENT | VALUE | UNIT |
|---|---|---|
| **Lot land cover** | | |
| Asphalt | | sq ft |
| Concrete | | sq ft |
| Pavers, brick or nautral stone | | sq ft |
| Permeable pavement - pavers | | sq ft |
| Permeable pavement - porous asphalt | | sq ft |
| Permeable pavement - porous concrete | | sq ft |
| Permeable pavement - gravel | | sq ft |
| Deck | | sq ft |
| Turf grass | | sq ft |
| Artificial turf grass | | sq ft |
| Cultivated flower or vegetable garden | | sq ft |
| Sparse irrigated vegetation | | sq ft |
| Dense irrigated vegetation | | sq ft |
| Natural/naturalized vegetation | | sq ft |
| Pool | | sq ft |
| Pond | | sq ft |
| Existing trees (canopy) | | sq ft |
| Trees (count) | | count |
| Roof | | |
| Composition Roof | | sq ft |
| Slate Roof | | sq ft |
| Wood Roof | | sq ft |
| Clay Roof | | sq ft |
| Green roof | | sq ft |
| | | |
| **Water Infrastructure** | | |
| Rain barrels | | gal |
| Downspout disconnection | | percent |
| French drains | | cu ft |
| Rain garden | | sq ft |
| Grey water system | | gal/mo |
| Irrigation controllers | | 1= yes<br>0 = no |

The first column, Component, lists common types of land cover and water infrastructure on lots in suburban California. More advanced users can add to this list of components as necessary, while altering background calculations.

The second column, Value, is where the user enters all of the necessary data. This information is based on measurements from the lot.

The third column, Unit, describes the units that the input data must be in. For example, land cover values must be entered in square feet. It is critical to ensure that the input data is in the correct units.

### Measuring Data

There are two main methods of collecting the data to enter into the tool. The user can either visit the lot of interest in person and measure land covers, or calculate values by digitizing in a geographic information system (GIS) or Google Earth Pro. After digitizing, it may also be useful to field-verify data.

In general, the more accurate the input data, the more accurate the output will be. Nonetheless, any homeowner should be able to implement the tool after taking some rough measurements with a measuring tape.

## Reading Output Data

There are two places in the tool to find output data. Intermediate output values are to the right of the worksheet. Final metrics are at the bottom of the worksheet.

The intermediate values—Cost values and Water Intensity—are used as stepping-stones before deriving the final Cost and Applied Outdoor Water values.

| A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|
| **COMPONENT** | **VALUE** | **UNIT** | Initial cost | Cost over 10 years | Cost over 20 years | Cost over 50 years | Cost over 100 years | Water Intensity |
| **Lot land cover** | | | | | | | | |
| Asphalt | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Concrete | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Pavers, brick or nautral stone | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Permeable pavement - pavers | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Permeable pavement - porous asphalt | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Permeable pavement - porous concrete | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Permeable pavement - gravel | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Deck | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Turf grass | | sq ft | 0 | 0 | 0 | 0 | 0 | 0 |
| Artificial turf grass | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Cultivated flower or vegetable garden | | sq ft | 0 | 0 | 0 | 0 | 0 | 0 |
| Sparse irrigated vegetation | | sq ft | 0 | 0 | 0 | 0 | 0 | 0 |
| Dense irrigated vegetation | | sq ft | 0 | 0 | 0 | 0 | 0 | 0 |
| Natural/naturalized vegetation | | sq ft | 0 | 0 | 0 | 0 | 0 | 0 |
| Pool | | sq ft | 0 | 0 | 0 | 0 | 0 | 0 |
| Pond | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Existing trees (canopy) | | sq ft | | | | | | 0 |
| Trees (count) | | count | 0 | 0 | 0 | 0 | 0 | 0 |
| Roof | | | | | | | | |
| Composition Roof | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Slate Roof | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Wood Roof | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Clay Roof | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Green roof | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| | | | | | | | | |
| **Water Infrastructure** | | | | | | | | |
| Rain barrels | | gal | 0 | 0 | 0 | 0 | 0 | |
| Downspout disconnection | | percent | | | | | | |
| French drains | | cu ft | 0 | 0 | 0 | 0 | 0 | |
| Rain garden | | sq ft | 0 | 0 | 0 | 0 | 0 | |
| Grey water system | | gal/mo | | | | | | |
| Irrigation controllers | | 1= yes 0 = no | 0 | 0 | 0 | 0 | 0 | |

The Cost columns show the price of each component over time.

The Water Intensity column indicates which land cover requires the most water. This number is primarily intended to be used as a multiplier when calculating applied outdoor water. It is not a standalone value and should not be reported outside the tool. Users may find the relative measures of each land cover's water consumption interesting, however—it may be possible to see, for example, that a small garden of high-water-use flowers requires more water than a large bed of drought-tolerant plants.

The intermediate outputs, combined with the input values, lead to the final metrics of the tool:

| | | |
|---|---|---|
| Total lot size | 0 | sq ft |
| Impervious land cover | 0 | sq ft |
| Pct Impervious land cover | 0% | percent |
| Peak monthly water runoff from impervious cover | 0 | gal |
| Peak monthly applied outdoor water consumption | 0 | gal |
| Peak monthly CO2 emissions (from outdoor water use) | 0.0 | lbs |
| Cost of program | | |
| Initial cost | $0 | dollars |
| 10 year cost | $0 | dollars |
| 20 year cost | $0 | dollars |
| 50 year cost | $0 | dollars |
| 100 year cost | $0 | dollars |

The metrics are discussed in detail in Sections 2.3 and 4 of the report.

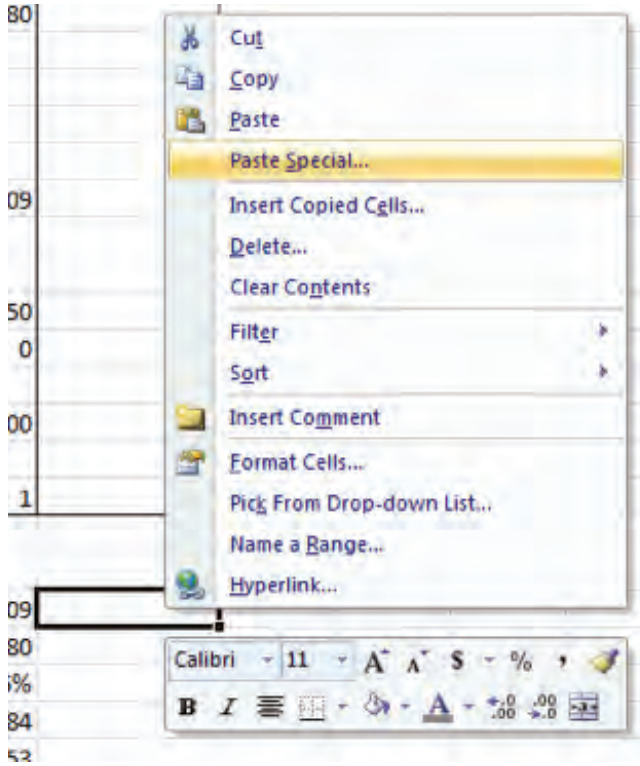
## Storing Data

Users can store the input data and final metrics from **Calculator|Lot** in **Worksheet|Lots**. Presently, in **Worksheet|Lots**, information is available from the four case study sites described in the report.

| Lot Landcover | | Traditional | SUSUMP | Greenpoint | One Planet | Custom |
|---|---|---|---|---|---|---|
| Asphalt | sq ft | | | | | |
| Concrete | sq ft | 516 | 907 | 330 | | |
| Pavers, brick or nautral stone | sq ft | | | | | |
| Permeable pavement - pavers | sq ft | | | | 828 | |
| Permeable pavement - porous asphalt | sq ft | | | | | |
| Permeable pavement - porous concrete | sq ft | | | | | |
| Permeable pavement - gravel | sq ft | | | | | |
| Deck | sq ft | | | | | |
| Turf grass | sq ft | 598 | 1125 | | 364 | |
| Artificial turf grass | sq ft | | | | | |
| Cultivated flower or vegetable garden | sq ft | | | | 185 | |
| Sparse irrigated vegetation | sq ft | 1228 | | 2587 | 2052 | |
| Dense irrigated vegetation | sq ft | 463 | 354 | | | |
| Natural/naturalized vegetation | sq ft | | | | | |
| Pool | sq ft | | | | | |
| Pond | sq ft | | | | | |
| Existing trees (canopy) | sq ft | 304 | 495 | | | |
| Existing trees (count) | count | 3 | 9 | 4 | 4 | |
| New trees | count | | | | | |
| Roof | | | | | | |
| Composition Roof | sq ft | 2480 | 1831 | 2001 | 2080 | |
| Slate Roof | sq ft | | | | | |
| Wood Roof | sq ft | | | | | |
| Clay Roof | sq ft | | | | | |
| Green roof | sq ft | | | | | |
| TOTAL AREA | sq ft | 5318 | 5562 | 5023 | 5509 | |
| **Lot Water Infrastructure** | | | | | | |
| Rain barrels | gal | | | | 550 | |
| Downspout disconnection | percent | 100 | | | 0 | |
| French drains | count | | | | | |
| Rain garden | sq ft | | | | 200 | |
| Grey water system | gal/day | | | | | |
| Irrigation controllers | 1 or 0 | | | | 1 | |
| Total lot size | sq ft | 5589 | 4712 | 4918 | 5509 | |
| Impervious land cover | sq ft | 2996 | 2738 | 2331 | 2080 | |
| Pct Impervious land cover | percent | 54% | 58% | 47% | 37.76% | |
| Peak monthly water runoff from impervious cover | gal | 13943 | 12742 | 10848 | 8184 | |
| Peak monthly applied outdoor water consumption | gal | 3738 | 4291 | 1874 | 2653 | |
| Peak monthly CO2 emissions (from outdoor water use) | lbs | 3.8 | 4.4 | 1.9 | 2.7 | |
| Cost of program | | | | | | |
| Initial cost | dollars | $23,876 | $17,458 | $23,716 | $41,727 | |
| 10 year cost | dollars | $34,916 | $22,540 | $36,651 | $65,134 | |
| 20 year cost | dollars | $45,956 | $27,622 | $50,116 | $91,971 | |
| 50 year cost | dollars | $92,510 | $56,368 | $100,233 | $193,838 | |
| 100 year cost | dollars | $174,578 | $108,780 | $187,000 | $357,169 | |

The Custom tab is included to encourage users to add their own data. Users can compare their lot against the case studies or delete the case study data and personalize the tool.

Note that when copying and pasting data between sheets, we suggest using the Paste Special command. Right-click on the destination location, choose Paste Special, and then choose "Values and number formats." This will ensure that the cells copy as cleanly as possible, retaining the final output values and formatting without copying over the cell formulas. In general, the Paste Special > Values command is the best way to copy and paste data throughout the tool.




## ➤ TASK 3. NEIGHBORHOOD CALCULATIONS

The neighborhood calculations require more steps than the lot calculations. Because neighborhoods are composed of both lots and public infrastructure, this task uses **Calculator|Lot** and **Calculator|Neighborhood**, then adds the outputs from both of these calculators together in **Worksheet|Neighborhoods**.

### Lots

The lot calculations for the neighborhood are performed in exactly the same way as the individual lot calculations. For the neighborhood, however, the user should enter aggregated lot data instead of individual lot information. For example, the concrete value should include all of the concrete that exists in lots across the whole neighborhood (it should not include public infrastructure, like sidewalks). This information is most easily derived by digitizing all of the land cover types in the lots and summarizing the values using GIS or Google Earth Pro (see Section 3.3 for more information).

Sample data from the case study sites is available on the **Worksheet|Lots** tab.

| | | Traditional | SUSUMP | Greenpoint | One Planet | Custom |
|---|---|---|---|---|---|---|
| **Total neighborhood size** | sq ft | 2,453,620 | 752,184 | 1,304,277 | 8,712,000 | |
| **Total residential area** | acres | | | | 200 | |
| **Total number of SF homes** | count | 224 | 88 | 138 | 743 | |
| **Total number of MF/apts** | count | | 62 | 24 | 951 | |
| | | | | | | |
| **Lot Landcover** | | | | | | |
| Asphalt | sq ft | | | | 0 | |
| Concrete | sq ft | 261,222 | 93,909 | 50,219 | 0 | |
| Pavers, brick or nautral stone | sq ft | 29,577 | 3,047 | | 0 | |
| Permeable pavement - pavers | sq ft | 22,699 | 364 | | 165,600 | |
| Permeable pavement - porous asphalt | sq ft | | | | 0 | |
| Permeable pavement - porous concrete | sq ft | | | | 0 | |
| Permeable pavement - gravel | sq ft | | | | 0 | |
| Deck | sq ft | 16,190 | | | 0 | |
| Turf grass | sq ft | 314,462 | 64,405 | 527 | 72,800 | |
| Artificial turf grass | sq ft | 425 | | | 0 | |
| Cultivated flower or vegetable garden | sq ft | 3,783 | | | 37,000 | |
| Sparse irrigated vegetation | sq ft | 144,322 | 50,704 | 314,172 | 410,400 | |
| Dense irrigated vegetation | sq ft | 87,551 | 54,850 | | 0 | |
| Natural/naturalized vegetation | sq ft | | | | 0 | |
| Pool/Fountain/Hot Tub | sq ft | 2,691 | | | 0 | |
| Pond | sq ft | 165 | | | 0 | |
| Trees (canopy) | sq ft | 388,209 | 6,136 | 7,081 | 0 | |
| Trees (count) | count | 1,587 | 227 | 872 | 800 | |
| Roof | | | | | | |
| Composition Roof | sq ft | 780,087 | 220,978 | 259,664 | 416,000 | |
| Slate Roof | sq ft | | | | 0 | |
| Wood Roof | sq ft | | | | 0 | |
| Clay Roof | sq ft | | | | 0 | |
| Green roof | sq ft | | | | 0 | |
| | | | | | | |
| **Lot Water Infrastructure** | | | | | | |
| Rain barrels | gal | | | | 110,000 | |
| Downspout disconnection | percent | 100% | | | | |
| French drains | count | | | | 0 | |
| Rain garden | sq ft | | | | 40,000 | |
| Grey water system | gal/day | | | | 0 | |
| Irrigation controllers | 1 or 0 | | | | 1 | |

When creating a custom scenario, after inputting the combined lot data into **Calculator| Lot**, copy and paste the output metrics from the lot tab in the worksheet under ALL LOTS.

| ALL LOTS | | | | | | |
|---|---|---|---|---|---|---|
| **Total impervious land cover** | sq ft | 1,071,311 | 317,934 | 309,883 | 416,000 | 0 |
| **Peak monthly water runoff from impervious cover** | gal | 4,984,444 | 1,479,604 | 1,442,137 | 1,636,785 | 0 |
| **Peak monthly outdoor water consumption** | gal | 1,651,472 | 314,912 | 237,731 | 472,306 | 0 |
| **Peak monthly CO2 emissions (from outdoor water use)** | lbs | 1,685 | 321 | 243 | 482 | 0 |
| **Cost of program** | | | | | | |
| **Initial cost** | dollars | $8,154,374 | $2,343,625 | $2,952,034 | $8,324,894 | 0 |
| **10 year cost** | dollars | $10,451,211 | $3,164,755 | $4,523,948 | $12,927,888 | 0 |
| **20 year cost** | dollars | $13,251,123 | $3,985,885 | $6,095,862 | $18,274,882 | 0 |
| **50 year cost** | dollars | $26,898,059 | $8,036,175 | $12,192,252 | $38,471,064 | 0 |
| **100 year cost** | dollars | $50,679,814 | $15,252,157 | $22,813,117 | $70,919,234 | 0 |

## Public infrastructure

For the neighborhood scale, it is also necessary to calculate metrics for public infrastructure. In the sample data in the worksheet, this is called Neighborhood Transportation Infrastructure and Neighborhood Water Infrastructure.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Neighborhood Transportation Infrastructure** | | | | | | |
| Street | | | | | | |
| Asphalt | sq ft | 425,993 | 117,559 | 186,119 | 1,651,200 | |
| Concrete | sq ft | | | | | |
| Curbs and Gutters - concrete | sq ft | 24,161 | 7,395 | 13,919 | 31,840 | |
| Sidewalk - concrete | sq ft | 110,296 | 54,860 | 95,219 | 315,920 | |
| Parking Lot - asphalt | sq ft | | | 16,809 | 90,000 | |
| | | | | | | |
| **Neighborhood Water Infrastructure** | | | | | | |
| Grey infrastructure | | | | | | |
| Corrugated Metal Pipe (CMP) | | | | | | |
| 8 in | lf | | | | | |
| 10 in | lf | | | | | |
| 12 in | lf | | | | | |
| 15 in | lf | 2,528 | 551 | 474 | | |
| 18 in | lf | 575 | 1,220 | 1,380 | | |
| 24 in | lf | | 135 | 291 | | |
| 30 in | lf | | 250 | 442 | | |
| 36 in | lf | | | 423 | | |
| 42 in | lf | | | 691 | | |
| 48 in | lf | | | | | |
| 60 in | lf | | | | | |
| 72 in | lf | | | | | |
| Reinforced Concrete Pipe (RCP) | | | | | | |
| 12 in | lf | | | | | |
| 15 in | lf | | | | | |
| 18 in | lf | | | | | |
| 21 in | lf | 119 | | | | |
| 24 in | lf | 19 | | | | |
| 27 in | lf | 523 | | | | |
| 30 in | lf | 760 | | | | |
| 36 in | lf | 304 | | | | |
| 42 in | lf | | | | | |
| 46 in | lf | 340 | | | | |
| 48 in | lf | | | | 22,844 | |
| 54 in | lf | 700 | | | | |
| 60 in | lf | | | | | |
| 72 in | lf | | | | | |
| 84 in | lf | | | | | |
| 96 in | lf | | | 31 | | |
| Green Infrastructure | | | | | | |
| Vegetated Filter Strips/Bioswales | sq ft | 9,807 | 31,103 | 34,939 | 813,520 | |
| Neighborhood open space | | | | | | |
| Managed open space | sq ft | 244,967 | 6,760 | 145,725 | 422,532 | |
| Naturalized open space | sq ft | 38,486 | 423,555 | 61,399 | 766,656 | |

All of the neighborhood data can be input into **Calculator|Neighborhood** in the same manner as **Calculator|Lot**. As with the lots, it is critical to enter the values in the appropriate units.

| COMPONENT | VALUE | UNIT | Initial cost | Cost over 10 years | Cost over 20 years | Cost over 50 years | Cost over 100 years |
|---|---|---|---|---|---|---|---|
| **Total Neighborhood size** | | acres | | | | | |
| | | | | | | | |
| **Neighborhood transportation infrastructure** | | | | | | | |
| Street | | | | | | | |
| Asphalt | | sq ft | 0 | 0 | 0 | 0 | 0 |
| Concrete | | sq ft | 0 | 0 | 0 | 0 | 0 |
| Curbs and Gutters - concrete | | lf | 0 | 0 | 0 | 0 | 0 |
| Sidewalk - concrete | | sq ft | 0 | 0 | 0 | 0 | 0 |
| Parking Lot - asphalt | | sq ft | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | |
| **Neighborhood water infrastructure** | | | | | | | |
| Grey infrastructure | | | | | | | |
| Corrugated Metal Pipe (CMP) | | | | | | | |
| 8 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 10 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 12 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 15 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 18 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 24 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 30 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 36 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 42 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 48 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 60 in | | lf | 0 | 0 | 0 | 0 | 0 |
| 72 in | | lf | 0 | 0 | 0 | 0 | 0 |
| Reinforced Concrete Pipe (RCP) | | | | | | | |
| 12 in | | lf | 0 | 0 | 0 | 0 | 0 |

While the input values for **Calculator|Neighborhood** are different, the outputs are very similar. The exception is that the neighborhood calculator does not have Water Intensity as an intermediary output. For lots, Water Intensity was useful when deriving applied outdoor water because there are many land cover components, each contributing to outdoor water consumption. In neighborhoods, there is only one land cover that uses outdoor water—managed open space. Because this is a simpler calculation, it was not necessary to calculate Water Intensity as an intermediary.

After completing the neighborhood calculations, copy and paste the outputs to **Worksheet|Neighborhoods** under NEIGHBORHOOD INFRASTRUCTURE.

| | | | | | | |
|---|---|---|---|---|---|---|
| NEIGHBORHOOD INFRASTRUCTURE | | | | | | |
| Total impervious land cover | sq ft | 613,292 | 223,522 | 347351 | 2250132 | 0 |
| Peak monthly water runoff from impervious cover | gal | 2,780,788 | 807,576 | 1355160 | 4386557 | 0 |
| Peak monthly outdoor water consumption | gal | 1,007,513 | 27,803 | 599345 | 1737812 | 0 |
| Peak monthly CO2 emissions (from outdoor water use) | lbs | 1,028 | 28 | 612 | 1773 | 0 |
| Cost of program | | | | | | |
| Initial cost | dollars | $4,284,573 | $1,747,710 | $2,856,059 | $24,417,333 | $0 |
| 10 year cost | dollars | $4,676,520 | $1,758,526 | $3,089,219 | $25,093,384 | $0 |
| 20 year cost | dollars | $5,164,720 | $1,851,112 | $3,541,453 | $28,419,339 | $0 |
| 50 year cost | dollars | $10,265,631 | $3,989,301 | $7,371,623 | $64,032,781 | $0 |
| 100 year cost | dollars | $20,220,694 | $7,609,756 | $14,218,405 | $118,151,556 | $0 |

## Combining Lots and Infrastructure in the Worksheet

Automatically, the worksheet adds together ALL LOTS and NEIGHBORHOOD INFRASTRUCTURE to create combined neighborhood output metrics. The combined metrics are labeled TOTAL CONSUMPTION.

| | | | | | | |
|---|---|---|---|---|---|---|
| ALL LOTS | | | | | | |
| Total impervious land cover | sq ft | 1,071,311 | 317,934 | 309,883 | 416,000 | 0 |
| Peak monthly water runoff from impervious cover | gal | 4,984,444 | 1,479,604 | 1,442,137 | 1,636,785 | 0 |
| Peak monthly outdoor water consumption | gal | 1,651,472 | 314,912 | 237,731 | 472,306 | 0 |
| Peak monthly CO2 emissions (from outdoor water use) | lbs | 1,685 | 321 | 243 | 482 | 0 |
| Cost of program | | | | | | |
| Initial cost | dollars | $8,154,374 | $2,343,625 | $2,952,034 | $8,324,894 | 0 |
| 10 year cost | dollars | $10,451,211 | $3,164,755 | $4,523,948 | $12,927,888 | 0 |
| 20 year cost | dollars | $13,251,123 | $3,985,885 | $6,095,862 | $18,274,882 | 0 |
| 50 year cost | dollars | $26,898,059 | $8,036,175 | $12,192,252 | $38,471,064 | 0 |
| 100 year cost | dollars | $50,679,814 | $15,252,157 | $22,813,117 | $70,919,234 | 0 |
| | | | | | | |
| NEIGHBORHOOD INFRASTRUCTURE | | | | | | |
| Total impervious land cover | sq ft | 613,292 | 223,522 | 347351 | 2250132 | 0 |
| Peak monthly water runoff from impervious cover | gal | 2,780,788 | 807,576 | 1355160 | 4386557 | 0 |
| Peak monthly outdoor water consumption | gal | 1,007,513 | 27,803 | 599345 | 1737812 | 0 |
| Peak monthly CO2 emissions (from outdoor water use) | lbs | 1,028 | 28 | 612 | 1773 | 0 |
| Cost of program | | | | | | |
| Initial cost | dollars | $4,284,573 | $1,747,710 | $2,856,059 | $24,417,333 | $0 |
| 10 year cost | dollars | $4,676,520 | $1,758,526 | $3,089,219 | $25,093,384 | $0 |
| 20 year cost | dollars | $5,164,720 | $1,851,112 | $3,541,453 | $28,419,339 | $0 |
| 50 year cost | dollars | $10,265,631 | $3,989,301 | $7,371,623 | $64,032,781 | $0 |
| 100 year cost | dollars | $20,220,694 | $7,609,756 | $14,218,405 | $118,151,556 | $0 |
| | | | | | | |
| | | | | | | |
| TOTAL CONSUMPTION | | | | | | |
| Total land area | sq ft | 2,453,620 | 752,184 | 1,304,277 | 8,712,000 | 0 |
| Total impervious land cover (residential + community infrastructure) | sq ft | 1,684,603 | 541,456 | 657,234 | 2,666,132 | 0 |
| Percent impervious land cover (of whole development) | percent | 69% | 72% | 50% | 31% | #DIV/0! |
| Peak monthly water runoff from impervious cover | gal | 7,765,232 | 2,287,181 | 2,797,296 | 6,023,342 | 0 |
| Peak monthly outdoor water consumption | gal | 2,658,985 | 342,715 | 837,076 | 2,210,118 | 0 |
| Peak monthly CO2 emissions (from outdoor water use) | lbs | 2,713 | 350 | 854 | 2,255 | 0 |
| Cost of program | | | | | | |
| Initial cost | dollars | $12,438,947 | $4,091,335 | $5,808,093 | $32,742,227 | $0 |
| 10 year cost | dollars | $15,127,732 | $4,923,281 | $7,613,167 | $38,021,272 | $0 |
| 20 year cost | dollars | $18,415,843 | $5,836,997 | $9,637,315 | $46,694,221 | $0 |
| 50 year cost | dollars | $37,163,690 | $12,025,476 | $19,563,875 | $102,503,845 | $0 |
| 100 year cost | dollars | $70,900,508 | $22,861,913 | $37,031,521 | $189,070,790 | $0 |

Note that the Custom column seems to contain a divide by zero error—this formula will calculate if a user enters custom neighborhood data.

In addition to total consumption, this worksheet also calculates the output metrics per acre. These data are available under CONSUMPTION PER ACRE.

| CONSUMPTION PER ACRE | | Traditional | SUSMP | Greenpoint | One Planet | Custom |
|---|---|---|---|---|---|---|
| Percent impervious land cover (of whole development) | acre/acre | 0.69 | 0.72 | 0.50 | 0.31 | #DIV/0! |
| Peak monthly water runoff from impervious cover | acre-foot/acre | 0.42 | 0.41 | 0.29 | 0.09 | #DIV/0! |
| Peak monthly outdoor water consumption | acre-foot/acre | 0.14 | 0.06 | 0.09 | 0.03 | #DIV/0! |
| Peak monthly CO2 emissions (from outdoor water use) | lbs/acre | 48.17 | 20.25 | 28.53 | 11.28 | #DIV/0! |
| Cost of program | | | | | | |
| Initial cost | dollars/acre | $220,833.12 | $236,934.80 | $193,977.61 | $163,711.13 | #DIV/0! |
| 10 year cost | dollars/acre | $268,568.07 | $285,113.92 | $254,263.13 | $190,106.36 | #DIV/0! |
| 20 year cost | dollars/acre | $326,943.10 | $338,028.46 | $321,865.25 | $233,471.11 | #DIV/0! |
| 50 year cost | dollars/acre | $659,780.39 | $696,411.69 | $653,390.66 | $512,519.23 | #DIV/0! |
| 100 year cost | dollars/acre | $1,258,722.27 | $1,323,964.52 | $1,236,771.84 | $945,353.95 | #DIV/0! |

## ➤ TASK 4. VISIONING

The visioning tab uses the resource consumption per acre (described above) to calculate total consumption over a broader land area. A user can enter acre values for default neighborhood types and examine how the neighborhood metrics would scale. This calculation is a simple extrapolation from the consumption per acre, so it should be approached with caution. More information is available in the report in Section 3.4.

| Land Use | Value | Unit |
|---|---|---|
| Residential Land | | |
| Tradtional | | acres |
| SUSMP | | acres |
| Greenpoint | | acres |
| Custom | | acres |
| Percent impervious land cover (of whole development) | 0 | acres |
| Peak monthly water runoff from impervious cover | 0 | acre-feet |
| Peak monthly outdoor water consumption | 0 | acre-feet |
| Peak monthly CO2 emissions (from outdoor water use) | 0 | lbs |
| Cost of program | | |
| Initial cost | $0 | dollars |
| 10 year cost | $0 | dollars |
| 20 year cost | $0 | dollars |
| 50 year cost | $0 | dollars |
| 100 year cost | $0 | dollars |

More advanced Excel users can add new neighborhood types to **Visioning|Town to Watershed**.

## ➤ TASK 5. VIEWING AND EDITING THE DATA

Editing the background information is necessary to customize a tool to a new locality. All data and calculations in the tool are currently tailored to Sonoma County.

Some data is more straightforward to update than other data. Crop coefficients and monthly water data are the easiest data sources to alter, requiring no change in formulas in the tool. Price data is slightly more challenging—it is necessary to make sure the costs are in the appropriate units before updating costs per unit. ET Zones and Greenhouse Gases are the most challenging. ET Zones requires changes to the applied outdoor water formulas, while Greenhouse Gases requires the user to perform some research on area-specific multipliers.

### Prices

Prices for construction components are based on the best available information for Sonoma County, from June to November 2012. For descriptions of many of the components, please refer to Appendix 5.2. More detail on the price quotes (including sources) is available in Appendix 5.4.

| Component | Unit | Cost per unit | Lifespan | Cost per unit for 10 years | Cost per unit for 20 years | Cost per unit for 50 years | Cost per unit for 100 years |
|---|---|---|---|---|---|---|---|
| Concrete Sidewalk and Driveway | Sq Ft | 6.81 | 30 | 6.81 | 6.81 | 13.62 | 27.24 |
| Curbs and Gutters | Lf | 24.74 | 30 | 24.74 | 24.74 | 49.48 | 98.96 |
| Street | Sq Ft | 4.775 | 30 | 4.775 | 4.775 | 9.55 | 19.1 |
| Parking Lot | Sq Ft | 4.1 | 30 | 4.1 | 4.1 | 8.2 | 16.4 |
| Conventional Stormwater Conveyance | | | | | | | |
| Channelized Creeks | acres | 11272 | 999 | 11272 | 11272 | 11272 | 11272 |
| Corrugated Metal Pipe (CMP) | | | | | | | |
| 8 in | Lf | 17.55 | 20 | 17.55 | 35.1 | 52.65 | 105.3 |
| 10 in | Lf | 21.5 | 20 | 21.5 | 43 | 64.5 | 129 |
| 12 in | Lf | 26 | 20 | 26 | 52 | 78 | 156 |
| 15 in | Lf | 30 | 20 | 30 | 60 | 90 | 180 |
| 18 in | Lf | 35.5 | 20 | 35.5 | 71 | 106.5 | 213 |
| 24 in | Lf | 43 | 20 | 43 | 86 | 129 | 258 |
| 30 in | Lf | 64.5 | 20 | 64.5 | 129 | 193.5 | 387 |

## ET Zones

Evapotranspiration information is necessary for the applied outdoor water calculations. The tool includes evapotranspiration information for the whole state by month. Currently, the tool only relies on data from Zone 5 (Sonoma County). See Applied Outdoor Water in Section 2.3 for more information.

| A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sept | Oct | Nov | Dec |
| 1 | 0.93 | 1.4 | 2.48 | 3.3 | 4.03 | 4.5 | 4.65 | 4.03 | 3.3 | 2.48 | 1.2 | 0.62 |
| 2 | 1.24 | 1.68 | 3.1 | 3.9 | 4.65 | 5.1 | 4.96 | 4.65 | 3.9 | 2.79 | 1.8 | 1.24 |
| 3 | 1.86 | 2.24 | 3.72 | 4.8 | 5.27 | 5.7 | 5.58 | 5.27 | 4.2 | 3.41 | 2.4 | 1.86 |
| 4 | 1.86 | 2.24 | 3.72 | 4.8 | 5.27 | 5.7 | 5.89 | 5.58 | 4.5 | 3.41 | 2.4 | 1.86 |
| 5 | 0.93 | 1.68 | 2.79 | 4.2 | 5.58 | 6.3 | 6.51 | 5.89 | 4.5 | 3.1 | 1.5 | 0.93 |
| 6 | 1.86 | 2.24 | 3.41 | 4.8 | 5.58 | 6.3 | 6.51 | 6.2 | 4.8 | 3.72 | 2.4 | 1.86 |
| 7 | 0.62 | 1.4 | 2.48 | 3.9 | 5.27 | 6.3 | 7.44 | 6.51 | 4.8 | 2.79 | 1.2 | 0.62 |
| 8 | 1.24 | 1.68 | 3.41 | 4.8 | 6.2 | 6.9 | 7.44 | 6.51 | 5.1 | 3.41 | 1.8 | 0.93 |
| 9 | 2.17 | 2.8 | 4.03 | 5.1 | 5.89 | 6.6 | 7.44 | 6.82 | 5.7 | 4.03 | 2.7 | 1.86 |
| 10 | 0.93 | 1.68 | 3.1 | 4.5 | 5.89 | 7.2 | 8.06 | 7.13 | 5.1 | 3.1 | 1.5 | 0.93 |
| 11 | 1.55 | 2.24 | 3.1 | 4.5 | 5.89 | 7.2 | 8.06 | 7.44 | 5.7 | 3.72 | 2.1 | 1.55 |
| 12 | 1.24 | 1.96 | 3.41 | 5.1 | 6.82 | 7.8 | 8.06 | 7.13 | 5.4 | 3.72 | 1.8 | 0.93 |
| 13 | 1.24 | 1.96 | 3.1 | 4.8 | 6.51 | 7.8 | 8.99 | 7.75 | 5.7 | 3.72 | 1.8 | 0.93 |
| 14 | 1.55 | 2.24 | 3.72 | 5.1 | 6.82 | 7.8 | 8.68 | 7.75 | 5.7 | 4.03 | 2.1 | 1.55 |
| 15 | 1.24 | 2.24 | 3.72 | 5.7 | 7.44 | 8.1 | 8.68 | 7.75 | 5.7 | 4.03 | 2.1 | 1.24 |
| 16 | 1.55 | 2.52 | 4.03 | 5.7 | 7.75 | 8.7 | 9.3 | 8.37 | 6.3 | 4.34 | 2.4 | 1.55 |
| 17 | 1.86 | 2.8 | 4.65 | 6 | 8.06 | 9 | 9.92 | 8.68 | 6.6 | 4.34 | 2.7 | 1.86 |
| 18 | 2.48 | 3.36 | 5.27 | 6.9 | 8.68 | 9.6 | 9.61 | 8.68 | 6.9 | 4.96 | 3 | 2.17 |

## Irrigation

The irrigation tab calculates the relative amount of water required by each landscaping component and includes figures on the efficiency of irrigation equipment. It contains three separate tables that are all needed for Irrigation calculations.

## Water Use Multiplier

This multiplier is combined with area and evapotranspiration data in the calculator to determine applied outdoor water. The main objective of this table is to enter Crop Coefficient, Density Coefficient, and Exposure Coefficient multipliers.

| Land cover | Crop Coefficient | Density Coefficient | Exposure Coefficient |
|---|---|---|---|
| Turf grass | High | Moderate | Moderate |
| Cultivated flower or vegetable garden | High | Moderate | Moderate |
| Sparse irrigated vegetation | Moderate | Low | Moderate |
| Dense irrigated vegetation | Moderate | High | Moderate |
| Natural/naturalized vegetation | Very Low | Moderate | Moderate |
| | | | |
| Trees | | | |
| If canopy is specified | Moderate | Moderate | Moderate |
| If canopy is not specfieid (i.e., trees are immature) | Moderate | Low | Moderate |

Updating these variables is valuable and easy, even for novice Excel users. Sensitivity testing in the report determined that the water output metrics are sensitive to changes in local environmental conditions. In order for the tool to give as accurate measurements as possible, it is best to alter the Crop, Density, and Exposure coefficients as is appropriate for the study area. For example, in some places the land cover "sparse irrigated vegetation" may be drought tolerant vegetation, in which case it would be appropriate to revise the Crop Coefficient from Moderate to Low. Similarly, if a site were located in a hot and sunny microclimate, it would be appropriate to increase the Exposure Coefficient to High. Changes in the coefficients can be made through pop-up menus:

| Land cover | Crop Coefficient | Density Coefficient | Exposure Coefficient |
|---|---|---|---|
| Turf grass | High | Moderate | Moderate |
| Cultivated flower or vegetable garden | High | Moderate | Moderate |
| Sparse irrigated vegetation | Moderate (pop-up menu: Very Low / Low / Moderate / High) | w | Moderate |
| Dense irrigated vegetation | | gh | Moderate |
| Natural/naturalized vegetation | | oderate | Moderate |
| | | | |
| Trees | | | |
| If canopy is specified | Moderate | Moderate | Moderate |
| If canopy is not specfieid (i.e., trees are immature) | Moderate | Low | Moderate |

The coefficient inputs are used to determine the Water Use Multiplier.

| Land cover | Crop Coefficient | Density Coefficient | Exposure Coefficient | Crop Coefficient | Density Coefficient | Exposure Coefficient | Water Use Multiplier |
|---|---|---|---|---|---|---|---|
| Turf grass | High | Moderate | Moderate | 0.9 | 1 | 1 | 0.9 |
| Cultivated flower or vegetable garden | High | Moderate | Moderate | 0.9 | 1 | 1 | 0.9 |
| Sparse irrigated vegetation | Moderate | Low | Moderate | 0.5 | 0.5 | 1 | 0.25 |
| Dense irrigated vegetation | Moderate | High | Moderate | 0.5 | 1.3 | 1 | 0.65 |
| Natural/naturalized vegetation | Very Low | Moderate | Moderate | 0.1 | 1 | 1 | 0.1 |
| | | | | | | | |
| Trees | | | | | | | |
| If canopy is specified | Moderate | Moderate | Moderate | 0.5 | 1 | 1 | 0.5 |
| If canopy is not specfieid (i.e., trees are immature) | Moderate | Low | Moderate | 0.5 | 0.5 | 1 | 0.25 |

Note that the grayed-out values in the Water Use Multiplier calculations are exact duplicates of the values in the Water Use Coefficients table.

| Water Use Coefficients | Very Low | Low | Moderate | High |
|---|---|---|---|---|
| Crop | 0.1 | 0.2 | 0.5 | 0.9 |
| Planting density | | 0.5 | 1 | 1.3 |
| Exposure | | 0.5 | 1 | 1.4 |

We decided it would be easier for most users to select coefficients with the pop-up menus rather than manipulate water coefficients directly. More advanced gardeners may wish to alter the raw numbers, however. See Applied Outdoor Water in Section 2.3 for more information.

## Irrigation Efficiency

Lastly, this worksheet includes data on irrigation efficiency and irrigation controllers. For more information, see Applied Outdoor Water in Section 2.3.

| Irrigation Method | Efficiency |
|---|---|
| Drip | 90% |
| Sprinkler | 50% |
| DWR default efficiency | 71% |
| | |
| Irrigation controller | 6.10% |

## Rainfall

Like most of the other data in the tool, rainfall information is specific to Sonoma County. The tool relies on monthly rainfall data—design storm information is available for reference (the tool could be altered to calculate runoff volumes per design storm). Users can update monthly rainfall data as appropriate.

| By: Design Storm | Rain (in) |
|---|---|
| 85th percentile of 24-hour storm event | 0.92 |

| By: Month | Rain (in) |
|---|---|
| January | 4.05 |
| February | 4.78 |
| March | 3.83 |
| April | 2.18 |
| May | 1.62 |
| June | 0.43 |
| July | 0 |
| August | 0 |
| September | 0 |
| October | 1.79 |
| November | 2.19 |
| December | 7.47 |

## Greenhouse Gas Emissions

The **Data|Green House Gas Emission**s tab calculates the amount of carbon dioxide embedded in water in Sonoma County. The first column contains the components of Sonoma's water system that consume energy. The tool examines only outdoor water, and some of the components are not relevant to outdoor water. These values are grayed out and available for reference.

| Water system component | Energy Intensity Ratio (kWh/Mgal) | Carbon Dioxide Intensity (lbs/yr) | Carbon Dioxide Emissions (lbs/Mgal) | Carbon Dioxide Emissions (lbs/gal) |
|---|---|---|---|---|
| Groundwater Pumps | 1851.5 | 0.445 | 823.9175 | 0.000823918 |
| Booster Pumps | 441.5 | 0.445 | 196.4675 | 0.000196468 |
| Wastewater Treatment | 3376.5 | 0.445 | 1502.5425 | 0.001502543 |
| Waste Water Pumps | 2 | 0.445 | 0.89 | 0.00000089 |
| Recycled Water Pumps | 359.5 | 0.445 | 159.9775 | 0.000159978 |
| | | | | |
| TOTAL (for Sonoma County) | | | | 0.001020385 |

Each water system component has a reported energy intensity ratio (Column B). Each utility has a carbon dioxide coefficient, which is consistent across all components because it is contingent on the utility's energy portfolio (Column C). Multiplied together, this gives the carbon dioxide emissions per million gallons (Column D). Since the tool calculates gallons of applied outdoor water, however, it is necessary to find the pounds of carbon dioxide per gallon of water (Column E). Summing across the relevant components, the tool calculates the total carbon dioxide per gallon in Sonoma County.

For more information on where to find these figures for another locality, see Greenhouse Gas Emissions from Outdoor Water, Section 2.3.

## ➤ TASK 6. ALTERING CALCULATIONS

All calculations take place in either the data sheets or the output value. It is possible for anyone to click on one of these cells, see the formula, and change it.

The primary challenge when changing calculations is ensuring that all of the formulas point to the expected cells. Because some of the formulas refer to data on several different worksheets, it can be difficult to visually ensure that all the cells are correct. Use caution when editing the background data. Reordering components can be particularly difficult.

Before you make any changes, we suggest carefully reading Sections 2.3, 3.2, and 4 of the report.

## 5.2 GLOSSARY OF LID TERMS

**Bioswale:** A gently sloped drainage canal filled with vegetation, compost, and gravel or rock. Bioswales are similar to rain gardens in that they are designed to reduce runoff volume and remove pollutants from surface runoff. Bioswales are commonly constructed around parking lots or in areas where heavily polluted runoff can be treated before it reaches the watershed or drainage sewer.

**Cisterns:** Similar to rain barrels, cisterns hold rainwater captured from impervious surfaces, only cisterns are generally much larger. Cisterns are commonly constructed out of concrete, steel, or synthetic material and can be stored above or below ground. Depending on the filtration and water purification system, water collected in cisterns may be used for human consumption.

**Cultivated flower or vegetable garden:** An area of land used for the cultivation of flowers, vegetables, herbs, or fruit.

**Deck:** An outdoor structure commonly constructed of wood and consisting of a raised floor with surrounding railing and steps leading to ground level.

**Downspout Disconnection:** Downspouts are a common adaptation to drains, which collect water from rooftop gutters that redistribute water runoff onto pervious surfaces that would otherwise be directed into the sewer system. The existing sewer connection is capped, and the water runoff can be used, collected, or redistributed to water surrounding vegetation.

**French Drain:** French drains consist of a trench containing a perforated pipe covered with gravel or rock that redirects water runoff away from an area. French drains are commonly constructed around the perimeter of a structure or home in order to prevent ground or surface water from damaging a building's foundation.

**Graywater system:** A system that captures, filters, and cleans wastewater from bathtubs or sinks and directs it to be used for irrigation purposes.

**Green Roof:** A green roof, also known as a living roof or eco-roof, is a roof of a building either partially or completely covered with vegetation planted over a waterproofing membrane. Low-profile and lightweight green roofs that consist of mosses, sedums, herbs, and perennials are known as "extensive." Roofs with deeper growth consisting of trees, shrubs, and activity areas are known as "intensive."

**Hollywood Driveway:** A driveway consisting of mostly vegetated or grassy area and two parallel narrow strips of concrete spaced so that a vehicle's wheels can drive on them.

**Native Plants:** Plants or vegetation indigenous to a given area.

**Permeable Pavement:** Permeable or porous pavements are a paving system designed to allow water to percolate through the pavement in order to restore the pre-development hydrologic cycle and reduce water runoff. Permeable pavements include porous asphalt, porous concrete, gravel, and modular pavers.

**Planter Box:** A box, concrete or wooden, containing a growing medium such as soil or mulch and vegetation. Planter boxes are an effective way to treat water runoff in urban areas while also providing valuable green space and aesthetics.

**Pond:** A still body of water that is smaller than a lake and is often artificially constructed.

**Pool:** Also known as a recreational swimming pool, a pool is a small area of still water that sits in an impervious bowl. Pools are usually located in backyards of single-family homes, in a shared multifamily development, or in a publicly shared space.

**Rain Barrel:** An artificial water reservoir that collects and stores rainwater from downspouts and rooftops to be used for watering surrounding vegetation and lawns. Rain barrels can be constructed in a variety of ways, but all serve the purpose of collecting rainwater and decreasing the amount of runoff from a given property.

**Rain Garden:** A shallow depression with deep-rooted native plants, grasses, shrubs, and mulch. Rain gardens are usually positioned near a rainwater runoff source such as a parking lot or traffic median. The runoff slowly percolates through the soil, is filtered, and then infiltrates into a surrounding soil medium.

**Rain Harvesting System:** The process of capturing, filtering, and utilizing rainfall from impervious surfaces such as roofs, driveways, or parking lots.

**Soil Amendments:** Soil amendments, which include soil conditioners and fertilizers, make soil more suitable for plant growth and increase water retention capabilities. Introducing compost and soil amendments to disturbed and compacted soils changes the physical, chemical, and biological characteristics of the soil, effectively reducing runoff volume and enhancing pollutant removal.

**Tree Box Filters:** Small bioretention areas consisting of soil, mulch, and drainage systems installed beneath a shrub or tree. Tree box filters effectively collect stormwater runoff directly from impervious surfaces and filter it through vegetation and a soil medium to enhance overall pollutant removal.

**Turf (Artificial):** An area of synthetic fibers that mimic the aesthetic of natural grass. Artificial turf grass is often used in sports arenas in order to take advantage of the low maintenance costs and high level of durability.

**Turf (Lawn):** An area of land planted with grasses that are maintained at a short height and used for aesthetic and recreational purposes. Commonly featured in the front yards and/or backyards of private households, public parks, and assorted sports fields.

**Vegetated Filter Strips:** Bands of vegetation designed to catch, filter, and slow runoff volumes. Filter strips also enhance the reduction of pollutants found in stormwater runoff through the process of absorption, filtration, and evapotranspiration.

## 5.3 TOOL REVIEW TABLE

| Toolkit Name | Green Infrastructure Valuation Toolkit | National Stormwater Management Calculator | LID Runoff Volume Calculator |
|---|---|---|---|
| Type | Calculator | Calculator | Calculator |
| Toolkit Type | Excel-based tool | Web-based tool | Excel-based tool |
| Year Published/Last Updated | 2010 | 2010 | |
| Location | England | Chicago, Illinois | California |
| Creator | Collaboration of several businesses and nonprofits | Center for Neighborhood Technology | Los Angeles County, Department of Public Works |
| Description | The Green Infrastructure Valuation Toolkit includes both a User Guide and an Excel-based calculator. The calculator consists of a set of individual spreadsheet-based tools to assess the value of green assets or projects across a wide range of potential areas of benefit—such as climate change, health, or property values. Wherever possible, results are given in monetary terms. | The National Green Values™ Calculator is a tool for quickly comparing the performance, costs, and benefits of Green Infrastructure, or Low Impact Development (LID), with conventional stormwater practices. | The LID Calculator allows the site designer/engineer to calculate runoff rates and volumes from the water quality storm. |
| Additional Details | The User Guide sets out the evidence base and rationale supporting each of the assessment tools, and provides case studies giving practical examples of how the Toolkit can be applied and the results presented. The Guide also discusses the strengths and weaknesses of the Toolkit and highlights areas where further research or development work is needed. | The GVC is designed to take you step-by-step through a process of (1) determining the average precipitation at your site, choosing a stormwater runoff volume reduction goal, (2) defining the impervious areas of your site under a conventional development scheme, and then choosing from a range of Green Infrastructure Best Management Practices (BMPs) to find the combination that meets the necessary runoff volume reduction goal in a cost-effective way. They also have a PDF of "Calculator methodology" at http://greenvalues.cnt.org/calculator/downloads/methodology.pdf | |
| Tool Scope | | National | |
| Inputs | | Lot information (zip code, annual rainfall, storm rainfall, lot size, soil type), land cover, runoff reduction goal, green improvements, cost parameters, impervious area | Area, soil type, rainfall amount, flow path length, flow path slope, proportion impervious |
| Outputs | Monetary, Quantitative, and Qualitative (outputs vary) | Req. volume capture, runoff, construction costs, maintenance costs, lifecycle costs, other benefits (carbon dioxide sequestration, reduction in air pollutants, reduced energy use) | Intensity, undeveloped runoff coefficient, developed runoff coefficient, TC value, 24-hour runoff volume |
| Website | http://www.greeninfrastructurenw.co.uk/html/index.php?page=projects&GreenInfrastructureValuationToolkit=true | http://greenvalues.cnt.org/national/calculator.php | http://dpw.lacounty.gov/wmd/dsp_LowImpactDevelopment.cfm |

| Toolkit Name | BMP Sizing Calculators | LID BMP Sizing Calculator for Kitsap County | Green Infrastructure Whole-Life Cost Tool |
|---|---|---|---|
| Type | Calculator | Calculator | Calculator |
| Toolkit Type | Excel-based tool | Excel-based tool | Excel-based tool |
| Year Published/Last Updated | 2011 | | |
| Location | San Francisco | Washington | Chesapeake Bay Watershed |
| Creator | San Francisco, Public Utilities Commission | Home Builders Association of Kitsap County—Low Impact Development | Water Environment Research Foundation |
| Description | The LID Calculator allows the site designer/engineer to characterize existing surfaces and choose from a suite of green infrastructure strategies to reduce runoff rates and volumes. | This spreadsheet tool guides the user through selecting and sizing pre-designed stormwater management best management practices (BMPs) in Kitsap County, Washington. The 8-6-10 versions provide a "Project Information" box at the top of the sheets and has added some clarification on the minimum aggregate depth for permeable pavement surfaces. | The whole life cost (WLC) models are a set of spreadsheet tools that have been developed to facilitate automation of a whole life costing approach. The models allow users to systematically identify and combine capital costs and ongoing maintenance expenditures in order to estimate whole life costs. Costing tools for: Cisterns, Curb-Contained Bioretention, Extended Detention Basins, Green Roofs, In-Curb Planters, Permeable Pavement, Rain Gardens, Retention Ponds, and Swales |
| Additional Details | New and redevelopment projects built in San Francisco can create increases in stormwater flows that can affect San Francisco's wet weather capacity and permit compliance. SFPUC conducts project review to ensure that new and redevelopment projects reduce their impacts on the wastewater system. This review process applies to all projects disturbing 5,000 square feet or more of the ground surface, including emerging communities like Hunters Point Shipyard, Treasure Island, Visitacion Valley, and Executive Park. | | These spreadsheets were developed under two efforts. Under the first effort, extended detention basin, retention pond, swale, and permeable pavement spreadsheets were developed in a joint project between the Water Environment Research Foundation (WERF) and United Kingdom Water Industry Research (UKWIR). The second effort included collaboration between the WERF and the U.S. Environmental Protection Agency to expand the original suite of tools to include bioretention, green roofs, and cisterns. |
| Tool Scope | | | National |
| Inputs | Area, soil type, rainfall amount, proportion impervious | | |
| Outputs | Undeveloped runoff coefficient, developed runoff coefficient, runoff volume and rate. | | Capital costs, maintenance costs, cost summary, whole life costs, NPV graph |
| Website | http://sfwater.org/index.aspx?page=446http://sfwater.org/index.aspx?page=446 | http://www.kitsaphba.org/LID/resources.html | http://www.region9wv.com/bay/LIDtools.html |

| Toolkit Name | LID Versus Conventional Development: Literature Review of Developer-Related Costs and Profit Margins | Low Impact Development at the Local Level: Developers' Experiences and City and County Support | The Economics of Low-Impact Development: A Literature Review |
|---|---|---|---|
| Type | Report | Report | Report |
| Toolkit Type | | | |
| Year Published/Last Updated | December 2009 | February 2009 | November 2007 |
| Location | | Oregon | Oregon |
| Creator | Auckland Regional Council | ECONorthwest | ECONorthwest |
| Description | | This part of the analysis looked beyond the study site and relied on descriptions of LID case studies from across the U.S. This report describes the second part of the analysis, which focused on two aspects of LID adoption at the local level: the experiences that developers have had with LID, and actions that local jurisdictions can take to increase LID use. | Literature review of the methods, data sources economists use to do cost-benefits analysis of LID, and conventional stormwater controls. |
| Additional Details | | In this report, ECONorthwest describes the second part of a two-part study organized by the Rock Creek Sustainability Initiative (RSCI).<br>(1) Summary of the major challenges that can inhibit developers' use of LID.<br>(2) Results of economic analyses of developments that included LID vs. conventional stormwater controls. Under the conditions described in these studies, developments with LID can cost less than comparable developments with conventional stormwater controls, can sell for more, or both.<br>(3) Describes actions taken by local jurisdictions that increase LID adoption, summarizes some of the steps taken by local jurisdictions that modify building and inspection codes to include LID, and then list the types of incentives that local jurisdictions use to promote LID.<br>(4) Actions that the RSCI partners and stakeholders can take to increase LID adoption in their jurisdictions. | This literature review has three objectives.<br>(1) Describe briefly the methods economists use when measuring the costs and benefits of LID and conventional stormwater controls. This information provides the reader with a context for the economic descriptions of costs and benefits that follow.<br>(2) Summarize the literature that identifies and measures the economic costs and benefits of managing stormwater using LID, or that compares costs or benefits, or both, between LID and conventional controls.<br>(3) Organize and present this information in a way that non-economist municipal officials, stormwater managers, ratepayer stakeholders, and others can use as they consider and deliberate stormwater-management plans. |
| Tool Scope | | | |
| Inputs | None | None | None |
| Outputs | None | None | None |
| Website | | http://econw.com/our-work/publications/low-impact-development-at-the-local-level-developers-experiences-and-city-a/ | http://econw.com/our-work/publications/the-economics-of-low-impact-development-a-literature-review/ |

| Toolkit Name | Low-Impact Development, an Economic Fact Sheet | Low-Impact Development Hydrologic Analysis | Cost-Estimating Tools for Low-Impact Development Best Management Practices: Challenges, Limitations, and Implications |
|---|---|---|---|
| Type | Report | Report | Report |
| Toolkit Type | | Guide | |
| Year Published/Last Updated | | 1999 | March 2011 |
| Location | | Maryland | |
| Creator | NC State University Cooperative Extension | Prince George's County, Maryland: Department of Environmental Resources | American Society of Civil Engineers |
| Description | The purpose of this fact sheet is to provide basic economic information on low-impact development. This simplified overview of a complicated topic is intended to help citizens, developers, and policy-makers have an informed discussion about the costs, benefits, and trade-offs of LID in their community. | Hydrologic analysis of LID | Tools were developed for estimating costs of vegetative roofs, rainwater catchment systems, and bioretention facilities. These tools provide a detailed framework to facilitate cost estimation for capital costs, operation and maintenance costs, and life-cycle net present value. |
| Additional Details | | | **[MUST PURCHASE PDF]** The tools can provide users with planning-level cost estimates and serve as a format for cost-reporting for past, current, and future projects. Very little cost data was available in the public forum, and prolific inconsistencies of supporting details were found in the available cost data. To address this, design assumptions were established for each facility type, and professionally prepared cost estimates based on these design assumptions were used. Electives in design, such as plant selection and media depth, also greatly affected costs. To make the user aware of these effects, the model separates each option into line items that can be elected or excluded as appropriate. To facilitate collecting future cost data, best management practice (BMP) designers and builders should use these tools to record actual costs and report them to a clearinghouse such as the BMP Database. |
| Tool Scope | | | |
| Inputs | None | | None |
| Outputs | None | | None |
| Website | http://www.ces.ncsu.edu/depts/agecon/WECO/nemo/documents/WECO_LID_econ_factsheet.pdf | | http://ascelibrary.org/iro/resource/1/jidedh/v137/i3/p183_s1?isAuthorized=no |

| Toolkit Name | A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds | Integrating Valuation Methods to Recognize Green Infrastructure's Multiple Benefits | Portland's Green Infrastructure: Quantifying the Health, Energy, and Community Livability Benefits |
|---|---|---|---|
| Type | Report | Report | Report |
| Toolkit Type | | | |
| Year Published/Last Updated | 2009 | | 2010 |
| Location | | | Portland |
| Creator | City of Philadelphia Water Department by Stratus Consulting | Center for Neighborhood Technology, University of Illinois at Urbana-Champaign, Low Impact Development Center, ECO Northwest, Drexel University, Forest Trends Association, U.S. Forest Service, Northern Research Station, Green Roofs for Healthy Cities, University of Chicago | City of Portland, Bureau of Environmental Services |
| Description | This report compares the benefits provided by a green infrastructure approach to CSO control with the benefits provided by a traditional tunnel approach. The report monetizes a range of environmental, social, and public health benefits. | | This report quantifies the positive effects of using LID, including energy use and reduction in GHG emissions. (See Section 4.) |
| Additional Details | | | |
| Tool Scope | | | |
| Inputs | None | None | None |
| Outputs | None | None | None |
| Website | http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_philadelphia_bottomline.pdf | http://www.igoplat.com/repository/CNT-LID-paper.pdf | http://www.portlandonline.com/bes/index.cfm?c=52055&a=298042 |

| | |
|---|---|
| **Toolkit Name** | **Low-Impact Development Strategies and Tools for Local Governments—Comprehensive Cost Estimating Worksheet** |
| **Type** | Report |
| **Toolkit Type** | Worksheet |
| **Year Published/Last Updated** | |
| **Location** | |
| **Creator** | LMI Government Consulting |
| **Description** | "Comprehensive Cost Estimating Worksheet" (Page 20) calculates (1) Estimate Life-Cycle Cost, (2) Effectiveness Factor, and (3) Secondary Benefits Factor |
| **Additional Details** | **Life-Cycle Cost.** Insert cost data for each phase and component of the project using the best available information. The table presents the typical cost components for each phase of the project. Considering all the components and entering the net present value for future investments using an appropriate discount factor are critical. As a simplified approach, consider all dollars in current year value, negating estimates of price escalation or discounting. Add the costs up from each phase to determine the LCCs.<br><br>**Effectiveness Factor.** This section of the worksheet is a simple way to apply the concept of cost-effectiveness to the decision-making process and does not require the use of complex calculations. Specify the specific goals (or minimum requirements) of the project, adding rows to the worksheet if necessary. Use knowledge of conventional stormwater management and LID to determine whether the project will meet, exceed, or fall short of the objective. Enter the corresponding number into the appropriate field. The total of these numbers will provide an effectiveness factor. Each alternative must have the same objectives listed in this section of the sheet. Since these numbers simply represent a concept, they must be entered for each alternative to be comparable.<br><br>**Secondary Benefits Factor.** A LID project often offers secondary benefits, such as increased green space, protected habitat, and other amenities. The secondary benefits portion of Table 3-2 lists a number of these, merely asking whether a particular project alternative offers them or not. The sum of "yes" answers represents a summation for these secondary effectiveness factors. In a few cases, it may be possible to quantify the value of some of these secondary factors (such as improved land values surrounding a LID alternative). Typically, however, quantifying environmental benefits (in terms of dollars) to analyze costs and benefits is difficult because few markets are available for obtaining the relevant values.<br>In the next chapter (Table 4-1), we summarize this information on the benefits of LID and provide references. If value data can be applied to secondary benefits, the total should be considered in the decision-making process. The worksheet in Table 3-2 represents a simplified approach to applying the concepts discussed in this report. This approach is designed to set the stage for an extensive, yet practical, analysis for LID projects. |
| **Tool Scope** | |
| **Inputs** | Costs by project phase |
| **Outputs** | |
| **Website** | http://lowimpactdevelopment.org/lidphase2/pubs/LMI%20LID%20Report.pdf |

# 5.4 COST SOURCES

| | Construction Cost ($) | | | Maintenance Cost ($) | | | Lifespan (Years) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low | Mid | High | Low | Mid | High | Short | Mid | Long |
| **Component (Traditional)** | | | | | | | | | |
| Concrete Sidewalk and Driveway (Sq Ft) | 6 | 8.5 | 11 | | | | | | |
| Concrete Sidewalk and Driveway (Sq Ft) | 5 | 7.5 | 10 | | | | | | |
| Concrete Sidewalk and Driveway (Sq Ft) | 4 | 6 | 8 | 6 | 8 | 10 | 10 | 20 | 30 |
| Concrete Sidewalk and Driveway (Sq Ft) | 2.67 | 3.05 | 3.51 | | | | | | |
| Concrete Sidewalk and Driveway (Sq Ft) | | 9 | 10.5 | | | | | | |
| Average | 4.4175 | **6.81** | 8.602 | 6 | **8** | 10 | 10 | **20** | 30 |
| Curbs and Gutters | 28 | 30 | 32 | | | | | | |
| Curbs and Gutters | 15 | 25 | 35 | | | | | | |
| Curbs and Gutters | 20 | 25 | 30 | 22 | 27 | 32 | 10 | 20 | 30 |
| Curbs and Gutters | 15.3 | 17.2 | 20.21 | | | | | | |
| Curbs and Gutters | | 26.5 | | | | | | | |
| Average | 19.575 | **24.74** | 29.3025 | 22 | **27** | 32 | 10 | **20** | 30 |
| Street (Sq Ft) | 2 | 3.25 | 4.5 | | | | | | |
| Street (Sq Ft) | 4 | 6 | 8 | 2 | 3 | 4 | 10 | 20 | 30 |
| Street (Sq Ft) | 2.6 | 3.8 | 4.2 | | | | | | |
| Street (Sq Ft) | | | | | 0.83 | | 20 | 30 | 40 |
| Street (Sq Ft) | 5.9 | 6.05 | 6.19 | | | | | | |
| Average | 3.625 | **4.775** | 5.7225 | 2 | **1.915** | 4 | 15 | **25** | 35 |
| Parking Lot (Sq Ft) | 1.5 | 2.5 | 3.5 | | | | | | |
| Parking Lot (Sq Ft) | 4 | 6 | 8 | 2 | 3 | 4 | 10 | 20 | 30 |
| Parking Lot (Sq Ft) | 2.6 | 3.8 | 4.2 | | | | | | |
| Average | 2.7 | **4.1** | 5.23333 3333 | 2 | **3** | 4 | 10 | **20** | 30 |
| Conventional Stormwater Storage | 4 | 6 | 8 | 5 | 7 | 9 | 10 | 20 | 30 |
| Conventional Stormwater Storage | | | | | | | 50 | 62.5 | 75 |
| Conventional Stormwater Storage | | 11272 | | | | | | | |
| Corrugated Metal Pipe (CMP) | | | | | | | 20 | 22.5 | 25 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 8 In | | 17.55 | | | | | | | |
| 10 In | | 21.5 | | | | | | | |
| 12 In | | 26 | | | | | | | |
| 15 In | | 30 | | | | | | | |
| 18 In | | 35.5 | | | | | | | |
| 24 In | | 43 | | | | | | | |
| 30 In | | 64.5 | | | | | | | |
| 36 In | | 82 | | | | | | | |
| 48 In | | 116 | | | | | | | |
| 60 In | | 155 | | | | | | | |
| 72 In | | 241 | | | | | | | |
| Reinforced Concrete Pipe (RCP) | | | | | | | | 70 | |
| 12 In | | 29.5 | | | | | | | |
| 15 In | | 33 | | | | | | | |
| 18 In | | 36 | | | | | | | |
| 21 In | | 43.5 | | | | | | | |
| 24 In | | 50.5 | | | | | | | |
| 27 In | | 69.5 | | | | | | | |
| 30 In | | 74 | | | | | | | |
| 36 In | | 97.5 | | | | | | | |
| 42 In | | 121 | | | | | | | |
| 48 In | | 144 | | | | | | | |
| 60 In | | 216 | | | | | | | |
| 72 In | | 289 | | | | | | | |
| 84 In | | 450 | | | | | | | |
| 96 In | | 550 | | | | | | | |
| Standard Roof | | | | | | | | | |
| Composition (Sq Ft) | 1.5 | 4 | 6 | | | | 12 | 21 | 30 |
| Metal (Sq Ft) | 5 | 6 | 7 | | 1 | | 20 | 40 | 60 |
| Slate (Sq Ft) | 30 | 40 | 50 | | | | 40 | 70 | 100 |
| Wood (Sq Ft) | 4 | 5 | 6 | | | | 10 | 20 | 30 |
| Clay Tile (Sq Ft) | | 10 | 20 | | | | 20 | 35 | 50 |
| | | | | | | | | | |
| **Component (LID)** | | | | | | | | | |
| Green Roof (Sq Ft) | 10 | 25 | 35 | | 0.75 | 1.5 | 20 | 25 | 30 |
| Permeable Pavement—Paving Blocks (Sq Ft) | 17 | 19.5 | 22 | | 4.36 | | 25 | 37.5 | 50 |
| Permeable Pavement—Porous Asphalt (Sq Ft) | 2 | 3.75 | 5.5 | | 4.36 | | | | |
| Permeable Pavement—Porous Concrete (Sq Ft) | 4.5 | 7.25 | 10 | | 4.36 | | 20 | | |
| Permeable Pavement—Gravel (Sq Ft) | 6 | 7 | 8 | | | | 25 | 37.5 | 50 |
| Turf (Artificial) (Sq Ft) | 9 | 10 | 11 | | | | 15 | 20 | 25 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Turf (Lawn) (Sq Ft) | 0.75 | 1 | 1.25 | | | | 10 | 15 | 20 |
| Native Plants (1 Gallon/1 Sq Ft) | | 8.45 | | | | | | | |
| Bioretention Basin (Sq Ft) | | 16.7 | | | 0.61 | | | 25 | |
| Rain Garden (Sq ft) | 5 | 8.05 | 11.1 | | 0.61 | | | 25 | |
| Bioretention Slope (Sq Ft) | | 3.3 | | | 0.07 | | | 25 | |
| Trees (15 Gallon Tree) | 115 | 132.5 | 150 | | | | | 15 | |
| Tree Box Filters (One 6' x 6' Unit) | 6,000 | 7,750 | 9,500 | 75 | 287.5 | 500 | | 25 | |
| Bioswales (Sq Ft) | 6.67 | 11.1 | 16.7 | 0.22 | 0.415 | 0.61 | | 25 | |
| Grassed Water Quality Swale (Sq Ft) | | 6.7 | | | 0.22 | | | 25 | |
| Downspout Disconnection | | 13 | | | | | | | |
| Planter Boxes—Concrete (Sq Ft) | | 8 | | | 0.8 | 1.8 | | 25 | |
| Planter Boxes—Wooden (Sq Ft) | | 11.1 | | | | | | | |
| Rain Barrels (per 100 Gallon Reservoir) | 245.3 | 412.65 | 580 | | 10.38 | | | 25 | |
| Rain Harvesting System—Welded Steel Tank | | 6,900 | | | | | | 35 | |
| Rain Harvesting System—Poly Tank | | 3,810.4 | | | | | | 20 | |
| Vegetated Filter Strips (Sq Ft) | 0.3 | 0.49 | 0.68 | 0.22 | 0.415 | 0.61 | | 25 | |
| Amended Soil (Cubic Yd) | 35 | 42.5 | 50 | | | | | | |
| French Drain (Cubic Ft) | 10 | 12.5 | 15 | | | | | | |
| Graywater System ($/System or House) Low- to High-End System | 700 | 3,000 | 10,000 | | | | | | |
| Irrigation Controller (Includes Instillation and Wiring) | | 394 | | | | | 5 | 10 | 15 |
| Cultivated Flower or Vegetable Garden | 3 | 6.5 | 10 | | | | | | |
| Sparse Irrigated Vegetation | | 5 | | | | | 5 | 10 | 15 |
| Dense Irrigated Vegetation | | 8 | | | | | 5 | 10 | 15 |
| Natural/Naturalized Vegetation (Un-irrigated) | | 0 | | | 0 | | | 999 | |
| Pool (Sq Ft) | | 50 | | | | | 20 | 25 | |
| Pond (Sq Ft) | 6 | 7 | 8 | | | | | | |
| Brick (Sq Ft) | 12 | 18.5 | 25 | | | | | | |
| Deck (Sq Ft) | 10 | 22.5 | 35 | | | | 10 | 15 | 20 |

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|---|---|---|---|---|---|---|---|---|---|
| Small Cistern System (100–500 Gallons) | 250 | 1,000 | 2,500 | | | | 20 | 35 | 50 |
| Large Cistern System (Over 1,000 Gallons) | 5,000 | 10,000 | 15,000 | | | | 20 | 35 | 50 |
| Open Space Acquisition ($/Acre) | 3,330 | 6,704.5 | 10,079 | 25 | 212.5 | 400 | | 999 | |
| | | | | | | | | | |

**Sources and Notes:**

| | Sources | Notes |
|---|---|---|
| | | |
| **Component (Traditional)** | | |
| Concrete Sidewalk and Driveway (Sq Ft) | Jim Murphy Associates [6.26.12] | |
| Concrete Sidewalk and Driveway (Sq Ft) | Ghilotti Bros [6.27.12] | |
| Concrete Sidewalk and Driveway (Sq Ft) | Engineering firm, confidential [7.2.12] | |
| Concrete Sidewalk and Driveway (Sq Ft) | Homewyse [6.25.12] | |
| Concrete Sidewalk and Driveway (Sq Ft) | Town of Windsor [7.2.12] | |
| Average | | |
| Curbs and Gutters | Town of Windsor [7.2.12] | |
| Curbs and Gutters | Ghilotti Bros [6.27.12] | |
| Curbs and Gutters | Engineering firm, confidential [7.2.12] | |
| Curbs and Gutters | Homewyse [6.25.12] | |
| Curbs and Gutters | Rohnert Park Public Facilities Finance Plan [7.6.12] | |
| Average | | |
| Street (Sq Ft) | Ghilotti Bros [6.27.12] | |
| Street (Sq Ft) | Engineering firm, confidential [7.2.12] | |
| Street (Sq Ft) | Town of Windsor [7.2.12] | Asphalt Concrete Type "A" |
| Street (Sq Ft) | Patrick Barnes, Rohnert Park [7.6.12] | |
| Street (Sq Ft) | Rohnert Park Public Facilities Finance Plan [7.6.12] | Pavement (6"AC/13"AB), Pavement (6"AC/18"AB) |
| Average | | |
| Parking Lot (Sq Ft) | Ghilotti Bros [6.27.12] | |
| Parking Lot (Sq Ft) | Engineering firm, confidential [7.2.12] | |

| | | |
|---|---|---|
| Parking Lot (Sq Ft) | Town of Windsor [7.2.12] | Asphalt Concrete Type "A" |
| Average | | |
| Conventional Stormwater Storage | Engineering firm, confidential [7.2.12] | |
| Conventional Stormwater Storage | Patrick Barnes, Rohnert Park [7.6.12] | Estimated lifespan for stormwater drains, catch basins are less. |
| Conventional Stormwater Storage | Rohnert Park Public Facilities Finance Plan [7.6.12] | Copeland Creek Stormwater Drainage Ditch. Measured in amount of impervious acres added to Copeland's watershed by new residential development. |
| Corrugated Metal Pipe (CMP) | RS Means, Building Construction Cost Data, 2006 | |
| 8 In | RS Means, Building Construction Cost Data, 2006 | |
| 10 In | RS Means, Building Construction Cost Data, 2006 | |
| 12 In | RS Means, Building Construction Cost Data, 2006 | |
| 15 In | RS Means, Building Construction Cost Data, 2006 | |
| 18 In | RS Means, Building Construction Cost Data, 2006 | |
| 24 In | RS Means, Building Construction Cost Data, 2006 | |
| 30 In | RS Means, Building Construction Cost Data, 2006 | |
| 36 In | RS Means, Building Construction Cost Data, 2006 | |
| 48 in | RS Means, Building Construction Cost Data, 2006 | |
| 60 In | RS Means, Building Construction Cost Data, 2006 | |
| 72 In | RS Means, Building Construction Cost Data, 2006 | |
| Reinforced Concrete Pipe (RCP) | | |
| 12 In | RS Means, Building Construction Cost Data, 2006 | |
| 15 In | RS Means, Building Construction Cost Data, 2006 | |
| 18 In | RS Means, Building Construction Cost Data, 2006 | |
| 21 In | RS Means, Building Construction Cost Data, 2006 | |
| 24 in | RS Means, Building Construction Cost Data, 2006 | |
| 27 In | RS Means, Building Construction Cost Data, 2006 | |
| 30 In | RS Means, Building Construction Cost Data, 2006 | |
| 36 In | RS Means, Building Construction Cost Data, 2006 | |
| 42 In | RS Means, Building Construction Cost Data, 2006 | |
| 48 In | RS Means, Building Construction Cost Data, 2006 | |
| 60 In | RS Means, Building Construction Cost Data, 2006 | |
| 72 In | RS Means, Building Construction Cost Data, 2006 | |
| 84 In | RS Means, Building Construction Cost Data, 2006 | |
| 96 In | RS Means, Building Construction Cost Data, 2006 | |
| Standard Roof | | |
| Composition (Sq Ft) | Dikey Inspection Group [6.27.12], National Roofing Contractors Association [7.11.12] | |
| Metal (Sq Ft) | Dikey Inspection Group [6.27.12], National Roofing | |

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| | Contractors Association [7.11.12], (http://www.homewyse.com/costs/cost_of_metal_roofing.html), (http://www.themetalinitiative.com/content/building_with_metal/benefits/costefficiency/ce_lifecyclecosting_analysis.cfm) | |
| Slate (Sq Ft) | Dikey Inspection Group [6.27.12], National Roofing Contractors Association [7.11.12] | |
| Wood (Sq Ft) | Dikey Inspection Group [6.27.12], National Roofing Contractors Association [7.11.12] | |
| Clay Tile (Sq Ft) | Dikey Inspection Group [6.27.12], National Roofing Contractors Association [7.11.12] | |
| | | |
| **Component (LID)** | | |
| Green Roof (Sq Ft) | Bertotti Landscaping, Inc. [7.3.12], (http://www.epa.gov/hiri/mitigation/greenroofs.htm), (http://www.epa.gov/hiri/resources/pdf/GreenRoofsCompendium.pdf) - (pg.10), | Includes basic irrigation. |
| Permeable Pavement—Paving Blocks (Sq Ft) | Bertotti Landscaping, Inc. [7.3.12], (http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf) | Life expectancy depends on traffic and use on pavers. |
| Permeable Pavement—Porous Asphalt (Sq Ft) | Empire Asphalt and Engineering Co. Inc. [7.3.12], (http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf) | (Low Cost) Based on estimates of material and installation with a typical 2-inch thickness. (High cost conversion calculation.) 1/2 acre=21780 Sq. Ft x .1 (10%)= 2178, $12,000/2178= $5.50/Sq. Ft |
| Permeable Pavement—Porous Concrete (Sq Ft) | Empire Asphalt and Engineering Co. Inc. [7.3.12], (http://www.wbdg.org/ccb/AF/AFSUSTTOOLKIT/PolicyLibrary/ufc_3_210_10.pdf)-(pg.53) | Based on estimates of material and installation with a typical 4-inch thickness. |
| Permeable Pavement—Gravel (Sq Ft) | Bertotti Landscaping, Inc. [7.3.12] | Life expectancy depends on maintenance and frequency of replenishment of gravel. |
| Turf (Artificial) (Sq Ft) | http://winecountrygreens.com/contact-us/ | Price reflects material and installation on a 1,200 sq ft area (July 2, 2012). |
| Turf (Lawn) (Sq Ft) | Bertotti Landscaping, Inc. [7.3.12], http://www.wbdg.org/ccb/AF/AFSUSTTOOLKIT/PolicyLibrary/ufc_3_210_10.pdf | Price reflects material and installation of turf, no irrigation system. Maintenance cost reflects the do-it-yourself cost of relatively $0 to hiring a gardener for $25/week. |
| Native Plants (1 Gallon/1 Sq Ft) | Details Landscape Art, Contact: Travis Bradley | |
| Bioretention Basin (Sq Ft) | (http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf) | For larger drainage areas than rain gardens. Useful to be |

| | | |
|---|---|---|
| | | incorporated within impervious areas (parking lots). |
| Rain Garden (Sq Ft) | (http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf) | Useful for small drainage areas and within impervious areas. Commercial/industrial rain garden costs are much higher due to additional curbing and filtration construction techniques required in a development. |
| Bioretention Slope (Sq Ft) | (http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf) | Useful for sloped medians and for edges of elevated impervious areas |
| Trees (15-Gallon Tree) | Ron DeNicola, Parks Manager, Arborist, City of Petaluma [7.5.12], Details Landscape Art, Contact: Travis Bradley | Price reflects 15-gallon-size tree, including installation. Average life expectancy in an urban setting is 15 years. |
| Tree Box Filters (One 6' x 6' Unit) | Details Landscape Art, Contact: Travis Bradley, http://www.wbdg.org/ccb/AF/AFSUSTTOOLKIT/PolicyLibrary/ufc_3_210_10.pdf, http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf | Often, maintenance costs are included by the manufacturer for up to two years after purchase, a $1,500 value. |
| Bioswales (Sq Ft) | (Lifespan): http://www.deq.state.or.us/wq/stormwater/docs/nwr/biofilters.pdf, (cost estimate): http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf, http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=75&minmeasure=5 | Useful along roadsides and other impervious areas such as parking lots. |
| Grassed Water Quality Swale (Sq Ft) | (http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf) | Used for small drainage areas with low water velocities. Usually installed in existing natural low areas to treat stormwater. |
| Downspout Disconnection | http://www.swfwmd.state.fl.us/files/database/social_research/Downspout_Disconnection_Final_Report.pdf | In some cities (Portland, OR) the city actually pays the homeowners either $53 per downspout incentive to do it themselves, or the city provides the service for free. (This price includes disconnecting an existing downspout.) |
| Planter Boxes— Concrete (Sq Ft) | http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf | Every 5 years the concrete may have to be repaired changing the maintenance cost to increase to $1.8/Sq. Ft |
| Planter Boxes—Wooden (Sq Ft) | Details Landscape Art, Contact: Travis Bradley | |

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|---|---|---|
| Rain Barrels (per 100 Gallon Reservoir) | Details Landscape Art, Contact: Travis Bradley (lifespan)(http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf) | This is an average cost. There exists a large variation of rain barrel sizes and material types, which all play a role in cost. More specific information at http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf (pg. 54). |
| Rain Harvesting System—Welded Steel Tank | Nicole Oblad, Project Manager, National Storage Tank, Inc. [7.6.12] | Standard (common household size) 5,000 gallon steel tank w/internal epoxy coating, fittings, pump, hydroscreen, and gravel ring. NOTE: Price reflects material only, delivered but uninstalled. |
| Rain Harvesting System—Poly Tank | Nicole Oblad, Project Manager, National Storage Tank, Inc. [7.6.12] | Standard (common household size) 5,000-gallon poly tank, gravel ring, standard pump, and hydroscreen downspout filter plus tax and freight. NOTE: Price reflects material cost only if picked up from Santa Rosa location, uninstalled. |
| Vegetated Filter Strips (Sq Ft) | http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=76, http://www.wbdg.org/ccb/AF/AFSUSTTOOLKIT/PolicyLibrary/ufc_3_210_10.pdf (pg. 45) | |
| Amended Soil (Cubic Yd) | Bertotti Landscaping, Inc. [7.3.12] | |
| French Drain (Cubic Ft) | Details Landscape Art, Contact: Travis Bradley | |
| Graywater System ($/System or House) Low- to High-End System | Details Landscape Art, Contact: Travis Bradley, http://greywateraction.org/content/cost-greywater-systems | The price range covers the basic cost of a low-tech system to the highest price and complexity system. |
| Irrigation Controller (Includes Instillation and Wiring) | Details Landscape Art, Contact: Travis Bradley | For single-family lot (6,000 Sq Ft) approx. Costs $200–$300 and can be self-installed. |
| Cultivated Flower or Vegetable Garden | Josiah Cain, Design Ecology | Annual |
| Sparse Irrigated Vegetation | Josiah Cain, Design Ecology | Perennials: 10 years |
| Dense Irrigated Vegetation | Josiah Cain, Design Ecology | Perennials: 10 years |
| Natural/Naturalized Vegetation (Un-irrigated) | | Undeveloped, not maintained |
| Pool (Sq Ft) | http://www.landscapingnetwork.com/swimming-pool/cost.html | |
| Pond (Sq Ft) | http://www.homewyse.com/services/cost_to_dig_pond. | Average pond of 1,000 Sq Ft |

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| | html, Details Landscape Art, Contact: Travis Bradley | |
| Brick (Sq Ft) | http://www.landscapingnetwork.com/patios/brick.html, http://www.homewyse.com/costs/cost_of_brick_patio.html | |
| Deck (Sq Ft) | http://home.costhelper.com/deck.html | |
| Small Cistern System (100–500 Gallons) | Lifespan data: (http://www.portlandoregon.gov/bes/article/127468) | |
| Large Cistern System (over 1,000 Gallons) | (http://home.costhelper.com/cistern.html), (http://www.lid-stormwater.net/raincist_cost.htm), lifespan data: (http://www.portlandoregon.gov/bes/article/127468) | |
| Open Space Acquisition ($/Acre) | Acre cost: (http://www.sonomafb.org/Farm+News/Farm+News+Archive/2012/Jun+12/Land+Conservation+At+What+Cost.htm) Maintenance cost: (http://www.watchsonomacounty.com/2012/11/county/sonoma-county-votes-to-accelerate-transfers-of-open-space-land-to-other-agencies/) | Price varies significantly on factors that dictate the value of land. This value is a Sonoma County average cost per acre. |
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## 5.5 OUTDOOR WATER PRACTICES AT CASE STUDY SITES

| | Traditional (1977) | SUSMP (2005) | GreenPoint (2005) | One Planet (2010) |
|---|---|---|---|---|
| SUSMP | | | | |
| **Source Controls** | | | | |
| | | | | |
| Downspouts—Drain to Landscaping | • | • | | |
| Benign Roof Materials (e.g., Tile) | | | | |
| Roof Gardens | | | | • |
| Cluster Unit Development | | • | | |
| Multi-Story Buildings | | • | • | • |
| Avoid Exposing Bare Earth (e.g., Bark, Mulch, Gravel) | | • | • | • |
| Vegetated Strips | • | • | • | • |
| Hollywood Driveways | | • | | |
| Minimize Directly: Connected Impervious Areas | | • | • | • |
| Flow Through Landscaped Area Before Going to Storm Drain | | • | • | • |
| Label Inlets: "No Dumping—Drains to Creek" | | • | • | |
| Spray Irrigation | | • | • | |
| Targeted Spray Irrigation | | | | • |
| Drip Irrigation | | • | • | • |
| Bubblers | | | | • |
| Subsurface Irrigation | | | | • |
| Plants Maintained through Minimal Water Use | | • | • | • |
| Naturally Treat Stormwater | | • | • | • |
| Avoidance of Natural Areas (e.g., Wetlands) | | • | • | • |
| Naturally Vegetated Setback | • | | • | • |
| Buildings Away from Natural Areas | | • | • | • |

| | **Traditional (1977)** | **SUSMP (2005)** | **GreenPoint (2005)** | **One Planet (2010)** |
|---|---|---|---|---|
| | | | | |
| **Treatment Controls** | | | | |
| | | | | |
| Vegetated Swale | | | • | • |
| Bioretention Area | • | | • | • |
| Extended Detention Basin | | | • | • |
| Vegetated Buffer Strips | • | • | • | • |
| Constructed Wetlands | | | • | |
| Wet Pond | | | | |
| Media Filter | | | | |
| Manufactured Media Filter | | | | |
| Infiltration Basin | | | | • |
| Manufactured Vortex Separator | | | • | |
| Manufactured Drain Inserts | | • | | |
| | | | | |
| CALGREEN | | | | |
| Rain Barrels | | | | • |
| Permeable Pavers (No Less Than 20%) | | | | • |
| Shade Trees | | | • | • |
| Limit Turf (Not More Than 50%) | | | • | • |
| 75% Native California / Drought-Resistant Plants | | | • | • |
| Hydro-zone Irrigation Techniques | | | • | • |
| Automatic Irrigation Controllers | | | • | • |
| Rainwater Capture System | | | | • |
| Landscape Irrigation Design Reduces Use of Potable Water | | | | • |
| | | | | |
| LEED | | | | • |
| | | | | |
| One Planet | | | | • |

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