The Study of Impervious versus Pervious Surfaces,

and Low Impact Development (LID) Designs

Within the City of Trinidad

Mission Statement

The City of Trinidad seeks to improve water quality and reduce water run off from its urban watershed into the Pacific Ocean. We will work collaboratively with Streamline Associates and other Trinidad area stakeholders to define, quantify, and analyze these water related problems and to suggest mitigation measures.

Senior Planning Practicum
Natural Resources Planning Interpretation 475
Humboldt State University
Arcata, California
Spring 2006

Nina Barboza
Michelle Bedard
Robert Jensen

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Introduction

The City of Trinidad has been selected as a pilot site for the Critical Coastal Areas (CCA) Program developed by the California Coastal Commission. This program will address the city's issues of polluted runoff, specifically focusing on the health of the Kelp Beds at Trinidad Head. The CCA Program aims to foster collaboration among local stakeholders and government agencies to better coordinate resources and focus efforts on coastal-zone watershed areas in critical need of protection from polluted runoff.

Currently the City of Trinidad has two major stormwater related concerns. These concerns include water pollution and stormwater runoff. Water pollution is primarily created from leaking septic systems and polluted surface runoff from roads, parking lots and driveways. Sedimentation is an additional form of water pollution. Sedimentation can be defined as solid fragments of organic or inorganic material that settles at the bottom of a water body. Stormwater is drainage runoff from various sources, such as streets, parking lots, driveways, roofs, and other impervious surfaces that is being deposited into the bay in excessive amounts. An impervious surface is a surface covered by any material that prevents water from infiltrating into the soil (Rhoads 1995) and increases the amount of surface runoff during storm events.

There are many possible factors contributing to these concerns. The entire City of Trinidad is dependant on septic systems. Consequently, there is a danger of these systems creating water pollution due to lack of public knowledge on proper maintenance of these systems. The large amounts of impervious surfaces and lack of stormwater treatment facilities contribute to an increase in stormwater runoff. The amount of stormwater runoff in Trinidad could be greatly reduced if the public were made aware of this situation and if both private citizens and businesses were encouraged to implement Low Impact Development (LID) for the capture and treatment of stormwater on their properties. Sedimentation and soil disturbance in Trinidad could also be alleviated by the use of water catchment systems. Furthermore, there are currently no data on the flow of water or the amount of impervious and pervious surfaces within the city.

Project Objectives

In order to resolve its water quality problems, Trinidad will need to increase pervious surfaces and infiltration; determine causes of road pollutants; determine sediment load to the bay; address septic system issues; involve citizens and improve public education; provide incentives to citizens; and monitor and enforce these practices. Throughout our project we intend to utilize the Geographical Information System (GIS) to spatially quantify and analyze the current impervious and permeable surfaces within the City of Trinidad. Once we generate this information it will allow us to calculate the percentage of both impervious and permeable surfaces. Then, the data will be utilized to help us analyze which LID techniques will be suitable for various locations of Trinidad aimed to reduce stormwater runoff. We will provide a brief introduction to Low Impact Development and discuss conventional and alternative techniques and technologies that communities can integrate into their existing land development practices. Criteria for the selection of LID technologies are presented as well as a selection of LID's that could be implemented for new developments, current residents, and the local municipalities.

Background

Conventional stormwater management systems rely on collection and conveyance systems to remove water safely from developed areas. These traditional systems are engineered and designed according to estimates of post-development stormwater flows and volumes from pervious and impervious areas (HUD 2003). An alternative to conventional stormwater systems is Low Impact Development, which "is an approach to land development that uses various land planning and design practices and technologies to simultaneously conserve and protect natural resource systems and reduce infrastructure costs" (PATH 2005). LID techniques aim to mimic natural hydrologic patterns in order to facilitate the capture, filtration, detention, evaporation, and infiltration of runoff close to its source.

LID techniques are based on the principle that stormwater should not be "disposed" of in large, costly end-of-pipe facilities, but should instead be retained at the lot level through small, cost-effective landscape features. LID designs are also known to conserve water, be environmentally friendly, and be resource-efficient. LID's can be used in residential, commercial, and industrial settings and are increasingly being integrated into community stormwater programs and watershed management plans.

History of LID

In other countries, the use of LID's has been applied in many ways and perhaps for many centuries, however the term LID is a relatively new name for the concept. For example in Switzerland individual residents have long utilized rain barrels for water catchments. Another example includes the use of vegetated roof tops in Germany. LID techniques have been applied explicitly in the United States since at least the early 1970's. Communities like Village Homes in Davis, CA, used LID's to retain stormwater flows in open space areas and use open conveyance rather than sewer systems to distribute stormwater (Corbet & Corbet 2000). In the late 1980's, communities in Prince George

County, Maryland began employing the use of rain gardens (gardens of native vegetation designed to mimic the hydrologic characteristics of a natural forest) (EPA 2006). Today, more local governments and state agencies are realizing the benefits of LID methods over traditional stormwater systems and are incorporating LID techniques into their stormwater management plans. Increasingly, LID techniques are being used in residential, commercial, and municipal developments. Communities across the globe have proven that the use of LID methods can be valuable tools to reduce the adverse effects of stormwater runoff on streams, lakes, wetlands, and coastlines. We believe that employing the use of LID techniques in Trinidad will help reduce the adverse effects of stormwater runoff on Trinidad Bay.

LID Designs

Traditionally stormwater, also referred to as wastewater, treatment facilities have been engineered to quickly remove the water from a development site and treat the problem elsewhere. Environmental problems such as pollution and erosion have been created by traditional practices, such as the digging up of the ground to place pipes, septic tanks, and storm drains in the earth and the collection of road surface material by wastewater as it quickly runs through the streets and into local water bodies. As rapid development continues, concern for the environment is rightfully and steadily increasing.

Treatment for stormwater is gaining increasing attention and the advancement of LID designs is becoming more prominent. “The primary goal of LID methods is to mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff. Use of these techniques help to reduce off-site runoff and ensure adequate groundwater recharge” (PGC 1999). LID’s can be applied in a variety of settings including large lots in rural areas; low, medium, and high-density development within urban growth boundaries; redevelopment of highly urbanized areas; and commercial and industrial development. LID's can also be designed for a variety of soil composites, such as those with low infiltration rates.

There are various LID methods available, most of which fall into four general categories: these include bioretention facilities, permeable and porous surfaces, low tech designs, and landscape development design methods. "Bioretention is an innovative urban stormwater practice that uses native forest ecosystems and landscape processes to enhance stormwater quality" (EPA 2000). Examples of bioretention include vegetated roof covers, vegetated swales, dry wells, filter/buffer strips, dry basins, and wet basins. Permeable and porous ground cover surfaces encourage water infiltration and filters pollutants. Pavers, porous pavement, adsorbent foams, filters, and crystals are examples of porous materials. Low tech designs are simple devices that serve as catchements and ultimately reduce stormwater runoff. These designs include rain barrels and rain spout diffusion. Slanted parking lots and curb cuts are landscape development methods designed to manipulate the flow of water and reduce runoff.

Bioretention

"Bioretention systems are designed based on soil types, site conditions and land uses. A bioretention area can be composed of a mix of functional components, each performing different functions in the removal of pollutants and attenuation of stormwater runoff" (EPA 2000). For example, the use of buffer strips made of grass slows the velocity of runoff and filters particulate matter. These strips can be placed along parking spaces, around the perimeter of driveways, around swimming pools, and other convenient places within a yard, landscape design, or parking area. Another method of bioretention is a sand bed, which is an enclosed space filled with sand. "Sand beds provide aeration and drainage of the planting soil and assists in the flushing of pollutants from soil materials" (EPA 2000). Sand beds may be used in planter boxes, at the edges of driveways and parking lots, within landscaping designs, and along sidewalks within parks, schools, and in people's yards.

Another LID method of bioretention is a ponding area, similar to a vernal pool; it is a graded area with a depressed center which provides storage of excess runoff and facilitates the settling of particulates and evaporation of excess water. A ponding area generally contains an organic layer, which degrades petroleum-based pollutants by providing a medium for microorganisms which decompose organic matter. On top of the organic layer is planting soil, which provides for stormwater storage, nutrient uptake by plants, and adsorbs pollutants such as hydrocarbons, heavy metals and nutrients. Hydrophilic vegetation (plants and grasses that can endure being submerged under water in times of heavy rain) serves in the removal of water through evapotranspiration and pollutant removal through nutrient cycling (EPA 2000). Ponding areas may be placed in many of the same places as sand beds.

Finally, a rain garden is another variation of LIDs. A rain garden is a landscaped area made up of native plants and vegetation (Fig 1). "The rain garden fills with a few inches of water after a storm and the water slowly filters into the ground rather than running off to a storm drain. Compared to a conventional patch of lawn, a rain garden allows about 30 percent more water to soak into the ground" (WDNR 2003). In addition to creating the rain gardens, homeowners can conserve water by redirecting downspouts (that divert roof runoff) to drain directly into the rain garden. Rain gardens not only increase the rate of infiltration but also allow for an increase in recharge of local and regional aquifers.


Fig. 1 - Example of a Rain Garden. Source: 10,000 Rain Gardens.

Permeable Surfaces

Permeable surfaces are ground covers that have pores which allow for on-site infiltration and reduction of surface flow runoff. Permeable surfaces involve a combination of mixtures of gravels, impervious concrete blocks, and reinforced grass pavements. These are ideally used in low traffic areas such as sidewalks and driveways. One such example is a paver, which is a concrete block with very large pores that are large enough to allow surrounding vegetation to grow through them (Fig 2). The vegetation serves as a water catchment system that holds the water until it has time to infiltrate. Permeable pavements resemble asphalt but have a slightly more porous top layer in addition to a much more porous sub-layer. This allows "stormwater to infiltrate into underlying soils promoting pollutant treatment and recharge, as opposed to producing large volumes of rainfall runoff requiring conveyance and treatment" (EPA 2000).


Fig 2 – Pavers. Nonpoint Education for Municipal Officials

Low Tech Designs

Rain barrels are simple devices that are designed to capture stormwater runoff from roof tops. "Water collection in a rain barrel prevents water from flowing across the yard or driveway into a storm drain or surface water area" (UCCES). The basic design is a barrel affixed to the base of rain gutters and downspouts (Fig 3a & 3b). These designs are simple but innovative; they not only reduce stormwater runoff but provide water for a variety of purposes. The ideal barrels will have a hose at the base in which the water can be dispersed and regulated as desired. One prime example of use is for watering gardens. These designs, vary in sizes, and are applicable to residential, commercial, and industrial sites. Ultimately they provide low cost, low maintenance, and effective retention strategies.

Cisterns are large containers similar to smaller rain barrels; these can be placed above or below ground and can hold up to 10,000 gallons of water (Fig 16). The use of cisterns can be very beneficial for the municipality and individual citizens of Trinidad. Water that is stored in cisterns can be used for irrigation, car washing, or other nonpotable uses. Property owners save money on water bills and public water systems experience lower peak demand and less stress on local water supplies (MLIDT Date Unknown). In addition, when the electricity is not working in Trinidad, cisterns can be utilized in order to supply residents with much needed water that usually is not available during power outages, when electric pumps on wells do not work. Another benefit is that water in cisterns can be treated in order to make is safe to drink. Cisterns may even make wells obsolete some day.

Fig. 3a Rain Barrels. Source: Clearwater Conservancy.

Fig. 3b Rain Barrels. Source WRD Environmentals.

Landscape Designs

Landscape design methods implement practical uses of LID methods within landscape architecture. Where and how vegetation is placed and planned within a developed site can have a tremendous effect on the percentage of imperviousness versus permeability. When considering new development on a site it is important to look at the existing vegetation and attempt to plan development around existing vegetation as well as including additional site appropriate vegetation. The purpose is to develop methods to increase the percentage of permeability and decrease the amount of impervious surfaces that lead to additional run off.

Taking into consideration the amount and width of sidewalks and roads is another important factor in landscape design. Conventional designs are centered around the automobile. Large road widths and many sidewalks signify a well established neighborhood and community. However, this pavement happy era has largely contributed to the current problems of sprawl, impervious surfaces, and excess stormwater runoff. Today, we are starting to realize these effects and have started planning design methods that minimize road and sidewalk widths and, when feasible, utilize permeable surfaces. “New designs for streets, sidewalks, and driveways can maintain the functions of circulation while helping to reduce expanses of impervious surfaces that can alter local hydrology and degrade water quality” (HUD 2003).

It is possible to integrate LIDs with existing development. The premise is to maintain predevelopment site runoff rates and minimize development impacts. Such ideas include reducing road widths, limiting lot disturbance, reducing storm pipes, and using open swales. Curb cuts, another LID design, were traditionally intended to allow easier access between sidewalks and intersections for pedestrians and bicyclists. However in relation to LID designs, curb cuts are created to allow stormwater runoff to reach a vegetated site and increase infiltration (Fig 4).

Fig 4 – Rain Garden and Curb Cut. Source: 10,000 Rain Gardens.

LID Benefits

In addition to the fact that LID makes good sense, these techniques can offer many benefits to a variety of stakeholders. LID goes beyond traditional development practices and technologies and focuses on identifying site-specific solutions that benefit the municipality, the developer, the home buyer, and the environment (HUD 2003).

For municipalities, LID can provide environmental, social, and regulatory benefits. LID protects the regional flora and fauna and balances growth needs with environmental protection by use of sustainable practices such as ponding areas that are planted with native vegetation. Our intent is for the use of LID's to foster public and private partnership and stewardship from the community members. In addition, LID's can reduce stormwater management costs and municipal infrastructure costs associated with maintenance of streets, curbs, gutters, and storm sewers by use of practices which maximize infiltration on site. Although there is an initial cost associated with implementation of LID's, the long term benefits outweigh these costs. LID's can be integrated into the infrastructure and are more aesthetically pleasing than traditional stormwater conveyance systems (EPA 2000). LID's provide additional benefits to local governments by offering a means to respond to and comply with increasingly stringent environmental regulations and water quality standards.

LID's can reduce development and maintenance costs for developers and those deciding to construct their own home. Developers benefit because a new development utilizing LID's, such as rain gardens and ponding areas, are more aesthetically pleasing than developments with plain lawns; this can increase the lot value and community marketability. Moreover, construction costs are reduced for land clearing and grading costs as well as reduced infrastructure costs associated with smaller streets, curbs, gutters, and sidewalks.

Home buyers receive further benefits from LID use on their property. For instance, water barrels at the base of gutter spouts, can reduce utility costs by providing an alternative water source for vegetation, as well as reduce sewer and septic loads and maintenance costs. In addition, planting trees and other native vegetation provides shade for homes, which results in reducing cooling costs in the summer.

The hydrologic cycle is a natural cycle that the environment uses to circulate water. The environment receives the most benefit from LID because it mimics this natural system. Conventional stormwater infrastructure methods generally cause unnecessary harm to the natural environment by use of practices and devices that alter this natural state. Low Impact Development protects site and regional water quality by reducing sediment, nutrient, and toxic loads to watersheds. Additionally, the integrity of ecological and biological systems is ensured because of the reduced impact on aquatic and terrestrial plants and animals (HUD 2003).

Site Analysis / Planning

With so many LID methods available it can be difficult for communities to determine which methods should be applied. Based on a comprehensive site analysis, the city and residents can decide which technology or combination of technologies will offer the best cost and environmental benefits taking into account the local ordinances. LID site planning is the practice of incorporating strategies for meeting beneficial and sustainable stormwater management goals and objectives into a plan for a specific site. Site plans must consider the natural topography; maintain hydrologic functions on site; and provide for aesthetically pleasing and low cost stormwater management controls. LID site planning is a method that results in the creation of functional landscapes that preserve and maintain the essential hydrologic functions of the development site and the local watershed (PGC 1999).

The first goal of site planning is to prevent negative impacts to the hydrologic regime that may be created by traditional development practices. Any unavoidable disturbances to the hydrologic regime that are created by such development should be mitigated. If impacts are mitigated close to their source, in contrast to the "end-of-pipe" control approach that is predominantly used, problems such as erosion and runoff will be minimized at the source and throughout the rest of the site.

A few important concepts that need to be considered when designing and implementing LID's are using hydrology as the integrating framework, controlling stormwater at the source, using simple, nonstructural methods, and creating a sustainable multifunctional landscape. In LID technology, the traditional approach to site drainage is to mimic the natural drainage functions. With development in an area, it is impossible to have completely pervious surfaces. However, bio-retention areas, increased flow paths, infiltration devices, drainage swales, retention areas, and many other practices can be used to control and break up these impervious areas.

Pre-development hydrologic functions may be restored while minimizing and mitigating the hydrologic impacts of land use activities. Simple systems, such as grass buffer strips and rain gardens can be more effective than standard engineered facilities such as sidewalks and storm drains in maintaining the hydrologic functions of the landscape. In addition, simple methods offer advantages, such as decreasing the use of materials such as steel and concrete by using native plants, soil and gravel, and can be more easily integrated into the landscape and appear to be more natural (this may also increase homeowner acceptance and willingness to adopt and maintain such systems). Urban landscaping can be multifunctional by incorporating various forms of LID in one area. It is simply a matter of developing numerous ways to creatively prevent, retain, detain, and treat runoff within multifunctional landscape features unique to that land use.

Criteria for Trinidad

There are many criteria to be considered when choosing which LID's to implement in a specific area. In addition to site specific considerations (Fig 8), there are social, economic, and developmental factors that must be evaluated at the local and regional scale. It would be difficult, for example, to implement LID technologies in a community whose residents lack fundamental stewardship ideals. Based on a variety of research sources, the specific criteria that are useful to the selection of LID methods are climate, hydrology, soil substrate, topography, and construction / maintenance costs of

LID technologies. For the City of Trinidad, these attributes were thoroughly considered when deciding which LID's would be best to implement.

Climate

The city of Trinidad has a Mediterranean climate with an annual rainfall amount of 60" occurring mostly November through May. Accordingly, high capacity LID technologies are needed in the winter season to catch rain water and to aid infiltration. One inch of rain on a 1,000-square foot roof yields about 620 gallons of water (HUD, 2003). Thus with such high annual precipitation amounts in the winter, large rain barrels or cisterns would be very effective. Cisterns can catch and store up to 5,000 gallons of water, which would greatly reduce the flow of stormwater in Trinidad. In addition, cisterns can supply water to residents when the electricity goes out and their wells won't pump. One way to accommodate cisterns could be for a few neighbors to pool their money, and place the cistern across a few properties.

If people do not want cisterns or large rain barrels on their properties however, small rain barrels would be effective in catching what little precipitation falls in the summer months. A 50-gallon rain barrel can provide storage for 0.5 inch of runoff from a rooftop measuring 158 square feet (PCG, 1999). Hence, a home in Trinidad with a few rain barrels would provide an alternative watering source for garden applications while retaining runoff.

The selection of LID's should also be tailored toward the amount of rainfall in an average storm event. In most regions, 75% of rainfall events are less than 0.5 inches at a time. In Trinidad, though, these rates are generally higher, with about 80% of rainfall events producing about 0.75 inches. The average annual maximum rainfall in a single event is 1.5 inches, thus the LID selected should be designed to accommodate this amount (Weather Underground 2006). For example, if an open swale is selected to catch runoff from a slope, the water volume capacity of the swale should be designed to accommodate the amount of water deposited from the slope in a single rainfall event.

Hydrology

Considering the hydrology of Trinidad is also important when selecting an LID. Trinidad has two coastal streams that run through or adjacent to the property boundary of the city. Mill Creek is located on the north end of the city, and Parker Creek is located at the south end of the city. There is no stream system running directly through the central developed area of the city. Therefore, runoff does not directly impact these streams; instead it is carried to the ocean by storm drains.

Proposition 50 dictates that stormwater must be treated prior to discharge into the ocean. This proposition is in place in order to maintain and improve the health of California's hydrological systems and the organisms that rely on these systems. Kelp Beds have been identified off the coast of Trinidad. These Kelp Beds have been recognized as Critical Coastal Areas by the California Coastal Commission. For this reason it is especially important that the amount of stormwater runoff discharged into the ocean is reduced and treated. Proposition 50 stipulates that a municipality may qualify for an exception if it's stormwater is clean enough to not have a significant negative affect on the waterway that it drains into. A municipality may apply for an exception annually. Currently, Trinidad is undergoing water treatment testing to determine if it qualifies for an exception. If the City does not qualify for an exception at this time, the implementation of LID's will help to allow the City to qualify for an exception in the future. Even if Trinidad does qualify for an exception, the implementation of LID's will help to improve the health of the Kelp Beds and maybe allow the City to continue to qualify for an exception in the future.

Soil Substrate / Topography

The makeup of the soil in an area is also an important criterion to consider when selecting which LID to implement. For instance, soil with high clay contents is more compacted (less porous) than soil with high sand contents (LEERIC 1999). This has an effect on the type of vegetation that is able to grow; the amount of runoff that is produced; and the type of development that can be placed in an area. The soil in the City of Trinidad is mostly classified as marine terrace deposits, which consists of uncemented sand with local graval, silt, and clay. This type of soil is ideal for the implementation of any number of LID's that utilize bioretention methods, such as rain gardens.

The type of topography to be found in an area is also important to consider when deciding what type of LID to use in an area. Topography refers to the "lie of the land" or the physiogeographic characteristics of land in terms of elevation, slope, and orientation (Wikipedia, 2000). These factors affect the direction and speed that stormwater flows in an area. Trinidad is on a plateau 170 feet above the sea with a gentle slope that is oriented east to west, which directs the stormwater flow toward the beach and ocean. Based on this information, the best LID to implement here would be curb cuts and rain gardens at the base of slopes. See Figure 5 below which represents the topography and the surrounding watersheds.

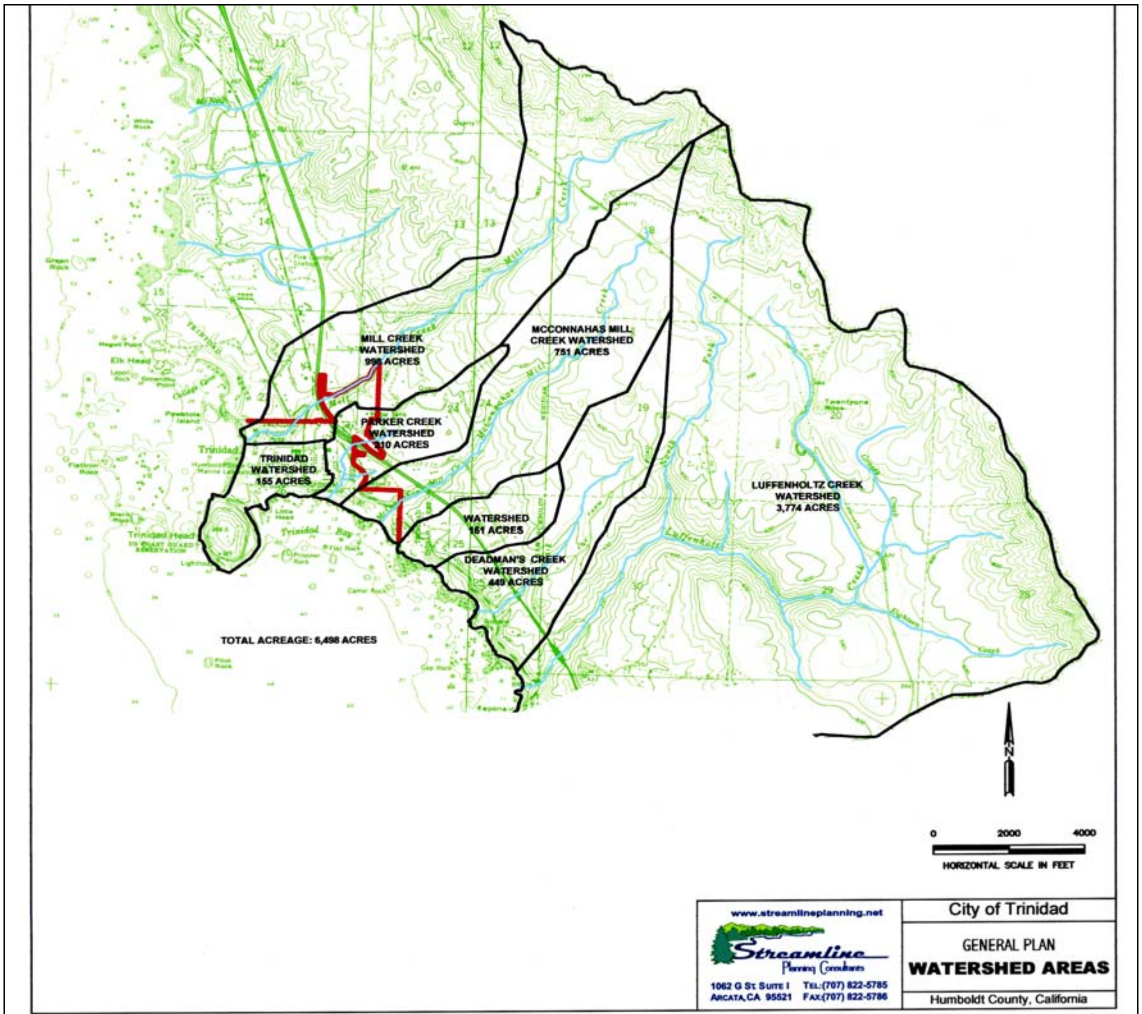

Figure 5 - Topographic map of the local watershed. Source: Streamline Planning Consultants.

Maintenance / Construction Costs

The primary factors involved in choosing a specific LID design include design and layout of the existing developments, density ratio of developments, percentage of impervious versus pervious surfaces, and costs of constructing, purchasing and maintaining the specific LID design. Trinidad is one of California's smallest cities with 311 residents and 228 households. The area of the boundary of the city limits of Trinidad is 0.5 mi^2, which is equivalent to 320 acres (Wikipedia, 2000). The developed area of Trinidad is mostly contained within a total area of 66.31 acres; the total impervious area is 29.30 acres, or 44 percent of the developed area (Fig 6a, 6b, & 22). This gives

Trinidad a high development density relative to its area. Thus when considering the density ratio for Trinidad, the use of permeable pavers, rain barrels, and/or rain gardens may be the most suitable for existing residential developments.

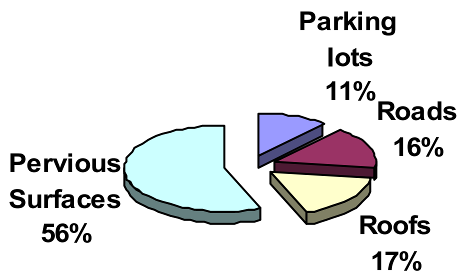

Fig 6a - Percent of Total Trinidad Surface Area

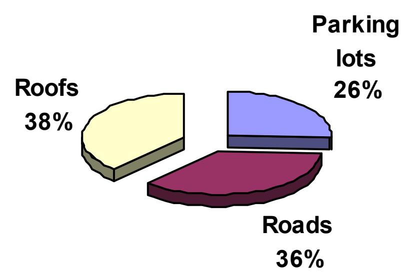

Fig 6b - Percent of Developed Impervious Surfaces

Given that LID designs may vary considerably in cost, cost is another important factor in the LID selection process. It is additionally important to look at the characteristics of the given city considering LID designs. Trinidad is made up of 228 households; however of that there are 105 owner-occupied housing units, 63 renter-occupied housing units, and 60 vacant housing units (2000 Census Bureau). A number of the 60 vacant housing units possibly serve as seasonal vacation rentals. While the average annual household working income is $40,000, many of the properties within Trinidad are currently valued at or around $1,000,000. The property value is reflective of the pristine location and beautiful ocean views.

Taking this information into consideration, some homeowners may very well be able to afford some of the high end LID designs; such as installing vegetated roofs, removing and replacing pavement driveways with permeable pavements and/or pavers.

In most cases the installation of vegetated roofs and permeable pavements are ideal LID methods for new developments. In other cases, purchasing and implementing the low end LID designs, such as bioretention systems, are a great possibility for all existing residential units. Additionally, bioretention systems at the lot-level can significantly reduce the amount of stormwater runoff at a reasonable cost. Rain gardens, for example, provide a cost effective means of treating water onsite. In one residential community in Prince George's County, Maryland, one developer (and, ultimately, residents) saved nearly $300,000 when the use of individual-lot bioretention practices alleviated the need for a pond (HUD 2003). Figure 7 below represents the advantages, disadvantages and approximate costs of various LID designs.

LID Design	Cost	Advantages	Disadvantages
Rain Garden	~$2.32 / sq. ft. 250 sq. ft. garden = $580.00	• Low maintenance • Low cost • High infiltration rates	• Proximity to septic leach fields.
Rain Barrels	55 gallon: ~ $69.00 + 100 gallon: ~ $180.00 +	• Landscaping water source in dry season. • Low maintenance	• Low capacity • Not practical in winter season.
Cisterns	1000 gallon: ~ $1,500 - $3,000 +	• High capacity • Emergency storage use • Practical in winter and summer season.	• High cost • Space requirements
Vegetative Swales	Construction Cost: $9.00 - $50.00 per sq. ft. Maintenance Cost: $ .60 per sq. ft. annually	• Large capacity • High infiltration rate	• Maintenance costs (ie: mowing & debris removal)
Permeable Pavement	Construction Cost: $ 6 per sq ft. Maintenance Cost: $.23 per sq ft. annually	• Allows up to 80% infiltration. • 25 year life	• Cost 50% more than pavement. • High maintenance cost.
Vegetative Buffers and Strips	Low to no cost. Variable depending on design and application.	• Allows some infiltration. • Slows water sheeting • Low maintenance	• May require mowing
Curb Cuts	Variable depending on design, permitting, and site characteristics.	• Allows water to reach permeable surfaces. • Reduces runoff rates	• Retrofitting may be expensive. • May be permitting and design constraints

Fig 7 - Comparison of Various LID designs. Sources: Fairfax Co.; Urban Waterways; Massachusetts LID Toolkit; U.S. EPA Stormwater Technology Fact Sheet Porous Pavement.

Stormwater Quality Facility	Contributing Drainage Area	Design Factors	Inappropriate Applications	Maintenance Requirements
Flow-through Water Quality Treatment Facilities – Section 3.0				
biofiltration swale & vegetated swale	up to 10 acres	• soil types B, C, or D (A with soil amendment) • slopes up to 4%, or 6% if check dams are used • flow velocity < 1.0 fps	• areas with high oil and grease concentrations • shaded areas • grades > 6% • soluble P removal • bacteria removal	• maintain vegetation (monthly) • remove debris (monthly) • remove sediment (annually) • inspect inlet and outlet (monthly)
vegetated filter strip	parking lots, driveways, roads, generally not more than 1,000 sq ft	• soil types B, C, or D (A with soil amendment) • slopes from 1% to 15% • flow velocity < 0.5 fps	• areas where runoff velocities are high and flow is concentrated • shaded areas	• maintain vegetation (monthly) • remove debris (monthly) • remove sediment (annually) • inspect inlet and outlet (monthly)
Flow-through planter box & infiltration planter box	Rooftops less than 15,000 SF	• soil types A & B • designed with impervious bottom or placed on impervious surface or infiltrates into soils • self-sustaining vegetation • minimum planter width is 18 to 30 inches, depending on type	• Discharge from any source other than a rooftop • Infiltration to UIC is not allowed without additional treatment	• maintain vegetation (monthly) • remove debris (monthly) • remove sediment (annually) • inspect inlet and outlet (monthly)
sand filter, sand filter vault, and linear sand filter	3-80 acres	• suitable for all soil types • facility should be off-line • pre-treatment of sediments required • impermeable liner may be required where groundwater protection is mandated	• areas where debris, heavy sediment loads, or oil and grease may clog the sand • nitrate removal	• remove debris (monthly) • remove sediment (annually) • inspect inlet and outlet (annually) • inspect filter media (monthly) • replace sand layer (1-2 years)

Fig 8. Selection of Stormwater Quality Facilities Based on Site Conditions. Source: SMP

<u>Site Selection of LID's for Trinidad</u>

Residential Units

Considering the criteria outlined above, we have identified LID methods that will be practical and effective for implementation in Trinidad. The selection of an LID design for a residence will be determined by the characteristics of the individual lot and surrounding parcels. Variables including the size of the lot, location of the septic systems, and the slope of property will determine which LID will be applicable and at what scale to build the LID. Low cost and easy to construct LID's, such as rain gardens, rain barrels, and pavers, will be the most effective considering the climate, soils, and hydrology of the city. Rain gardens in particular will be extremely effective in stormwater retention at the individual lot level. Since the topography of Trinidad is relatively flat and the soils are prime for infiltration, rain gardens will be effective in capturing the initial flush of stormwater from a rainfall event. Additionally, rain gardens are easy to construct and maintain at a relatively low cost. Figure 9 below represents the estimated costs of construction a rain garden on flat slopes with coastal soil compositions.

Estimated costs for 250 square foot rain garden.

Construction Element	Coastal plain	
	Unit Cost	Total
Excavation (including labor and equipment rental)	Cubic yard	$100
Hauling	Included in above price	Included in above price
Importing rock and sand	N/A	N/A
Piping and filter fabric	N/A	N/A
Mulch	$0.30/square foot	$80
Vegetation	$2/square foot (mature plants, somewhat dense)	$400
Total		$580
Total per square foot		$2.32

Figure 9 - Source: Designing Rain Gardens; Urban Waterways. College of Agriculture and Life Sciences, NC State University

Given that the entire city relies on the use of septic systems, the placement of rain gardens in relation to the septic leach fields will be very important. Too much water infiltration near the septic leach fields may cause septic discharge to leach too quickly. Therefore, to prevent impacts on septic wastewater, rain gardens should be not be placed directly above or too close to septic leach fields. Ideally, the rain garden should be constructed down slope from the leach field or in an adjacent area where infiltrated stormwater will not affect septic wastewater. A blueprint of the properties septic system should be obtained when planning for a rain garden. There are a range of “how to” manuals available on the design and construction of rain gardens that are free or low cost. The picture below (Fig 10) represents an ideal site for a rain garden. The detention area would capture stormwater sheeting off the road down slope. This would help to reduce the impact of bluff erosion and polluted discharge to the ocean. Additionally, given that the parking lot is gravel, and not pavement, it may also be economically feasible to install pavers, as displayed by figure 11 below. While gravel parking is better than pavement, overtime it becomes compacted and thus less impervious, the installation of pavers would permanently allow for moderate on site infiltration. Some of the homes in the area have rather large driveways, as shown below by figure 12. This site represents another ideal location for pavers.

Fig 10 - Possible site for rain garden and pavers. Photo by Robert Jensen.

Fig 11 – Pavers at a local Trinidad Residence. Photo by Robert Jensen.

Fig 12 – Possible site for paver or permeable pavement. Photo By Robert Jensen

Rain barrels are another LID technology that will be practical for the City of Trinidad. A fifty gallon rain barrel can be purchased for about $69 retail and be installed without much modification to the homes existing rain gutters (Fig. 15). While the typical rain barrel may have limits in the total storage capacity it is possible to connect rain barrels for additional holding capacity (Fig. 14). Additionally, high capacity 5,000 gallon cisterns are also available for those residents wishing to reclaim more stormwater than traditional rain barrels (Fig.16). Cisterns are similar in theory to rain barrels but considerably larger. They are typically used for water supply and have both above and underground designs. Some underground cisterns have a capacity of 10,000 gallons. "On-lot storage with later reuse of stormwater also provides an opportunity for water conservation and the possibility of reducing water utility costs" (LID Center 2005). Designing and utilizing rain barrels in conjunction with rain gardens provide an excellent example of efficient use of LID's. The model LID design would utilize rain barrels to capture stormwater from the roof and the overflow from the barrel would lead to a rain garden. The photograph below (Fig 13) represents a prime site for both a rain barrel and rain garden.

Fig 13. Ideal location for both a rain barrel and rain garden.
Photo by Robert Jensen.

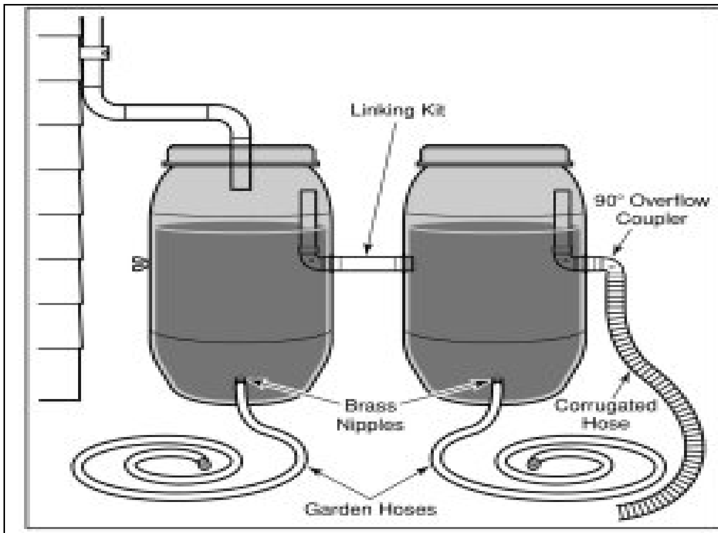

Fig. 14. Combining multiple rain barrels
Source: Low Impact Development Center

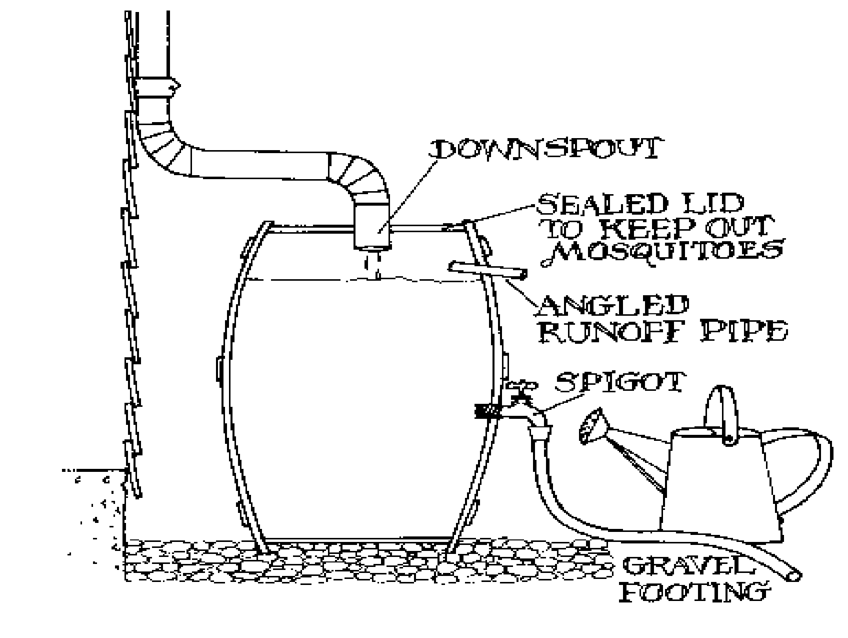

Figure 15. The typical rain barrel. Source: Designing Rain Gardens; Urban Waterways.

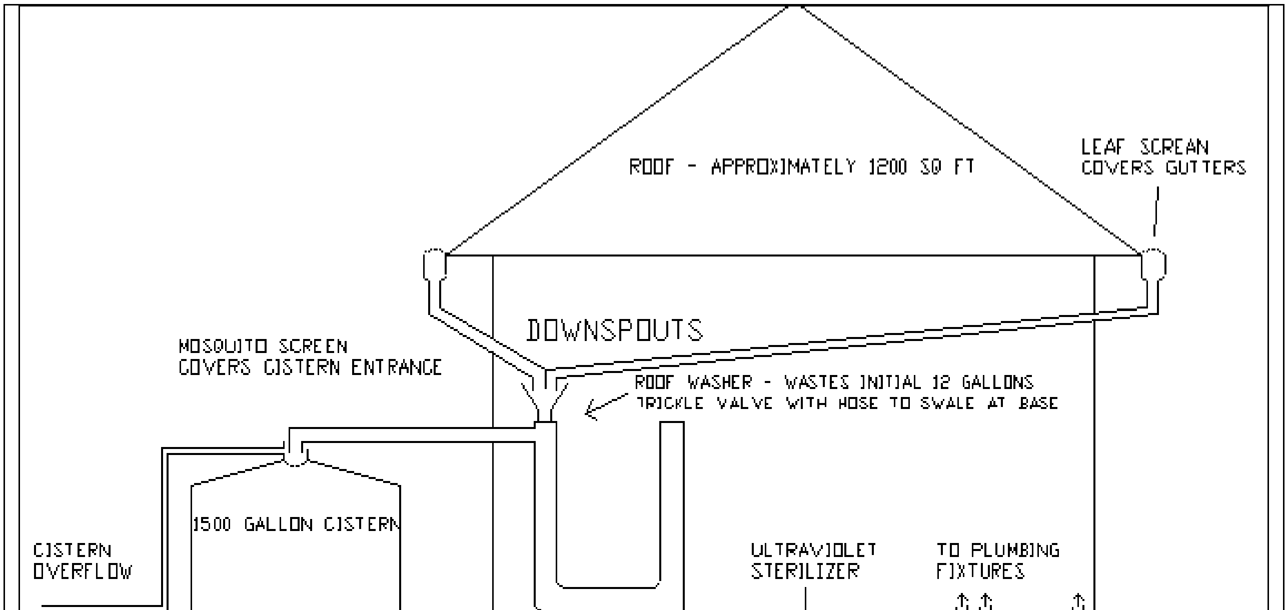

Fig 16. Home designed with a cistern. Source: Low Impact Development Center.

Commercial and City Property

Commercial businesses and city property, both which may have larger lot sizes than individual residential units, have additional LID options. For instance, they may have more space available for a large capacity cistern, rather than the individual residential units. Another example includes vegetated strips. Vegetated strips could be a relevant LID to utilize in the Murphy's Grocery store and the pier parking lots. In the photo below, a vegetated strip could be placed in between rows of parking spots (Fig #). For vegetated strips to be most efficient they should be placed slightly lower than the level of the parking lot, and they should not be blocked in by curbs. A curbed vegetated strip generally defeats the purpose as runoff is obstructed by the curb and will then follow conventional stormwater paths, which LID designs are trying to avoid (EPA 2006). The ideal LID design will result in on site stormwater retention.

Fig 17 - Possible site for vegetated strip. Photo by Robert Jensen.

Additionally, curb cuts are another practical LID design. With curb cuts we may take an existing vegetative patch that has a bordering curb and remove a portion of the curb to allow stormwater runoff to reach a vegetated patch. Originally curbed vegetative patches were designed with visual aesthetics in mind. The curb cut design takes the conventional vegetative patch and by cutting out a portion of the curb transforms it into an efficient LID design. The picture below (fig 18) is a possible location for a curb cut. This site is ideal as it has a rolling slope and would easily catch stormwater runoff prior to entering the conventional stormwater management system which drains untreated directly onto the beach and into the ocean. The existing foliage could also undergo observation and if necessary be replanted with differing vegetation with a greater capacity to retain water.

Fig 18 - Possible site for curb cut. Photo by Robert Jensen.

Grass buffer strips and pavers may provide an alternative to the typical gravel filled alley ways within the city limits (Fig 19). Implementing a grass strip in the center of the alley way will increase site retention while still allowing vehicle access. While implementing pavers in the existing alley ways could be an additional alternative, when considering cost and maintenance grass buffer strips would be the more practical method. Implementation of pavers would be more cost effective in smaller areas.

Fig. 19 - Possible site for grass buffer strip. Photo by Robert Jensen

The undeveloped city right of ways are another area to consider the implement-tation of various LID designs. Right of ways are areas on both sides of a public road that the city maintains ownership of. In many cities these rights of ways may be used and reserved for side walks. In Trinidad these areas are currently mixed use. Some are paved extensions of the road, others are gravel, and some areas have grass and trees (Fig ##). However, many of these areas are typically utilized as on street parking. Thus the installation of pavers could provide additional on site stormwater retention while remaining available on street parking. Fig 20c below, is one example of an undeveloped city right of way where pavers would be an efficient LID. In other areas, the right of ways could be transformed into vegetated strips.

Various Right of Ways		
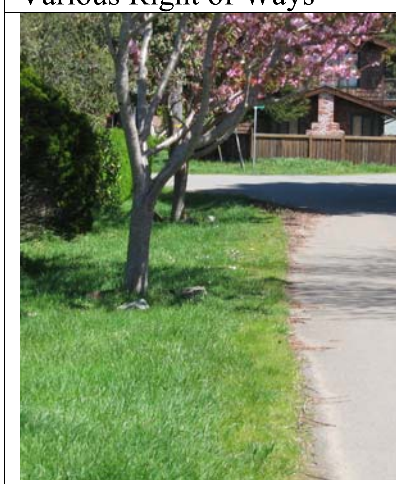		
Fig. 20a - Grass and Tree right of way.	Fig 20b - Gravel right of way	Fig 20c - Right of way – ideal site for pavers.

Lastly, new developments should highly consider implementing various LID designs into the development plans. This site could utilize any combination of LID designs, but porous pavements and vegetated roofs are two great examples of LID designs that may be more practical for new developments. While these methods may typically cost more than standard pavements and roofs, they provide great methods of efficient on site stormwater retention. Trinidad is considering building a Museum on a large undeveloped site on the northeast edge of town, directly behind the Chevron gas station. The implementation of porous pavements and vegetated roofs on this new site would be a great opportunity to both treat and reduce stormwater runoff. Additionally this site could serve as an educational source and onsite demonstration for the residents and the general public.

Conclusion

There are many different types of LID's, some of which have been used for thousands of years. LID's may be categorized into the four broad groups including bioretention facilities, permeable and porous surfaces, low tech designs, and landscape development design methods. It is important that proper site analysis and planning are exercised when deciding which LID will be the most practical and efficient to install on a particular site. The most appropriate LID's that may be implemented in Trinidad both by individual citizens and the City are outlined in the "Site Selections of LID's" portion of this paper above.

The purpose of this study was to determine the best ways to remedy Trinidad's two main stormwater problems. These problems are pollution (including sedimentation) and runoff. The use of LID's can greatly reduce these problems for the citizens of Trinidad. We have found that some LID's are already being used within Trinidad. For instance, there are many properties that utilize planter boxes and rain gardens (Fig. 21a & 21b). In addition, there is one residence that is using permeable pavers as their driveway (Fig. 11). The implementation of more LID's by citizens and the City can only have a positive effect on the watersheds in and around Trinidad. The collaborative effort of both the City government and the citizens of Trinidad in the implementation of LID's will help to fulfill the CCA Program's directive to promote better coordination of protection of coastal-zone watershed areas from polluted runoff; in addition to improving the health of the Kelp Bed off of Trinidad Head.

	
Fig 21a – Residence with planter boxes	Fig 21b – Residence with Rain Garden.

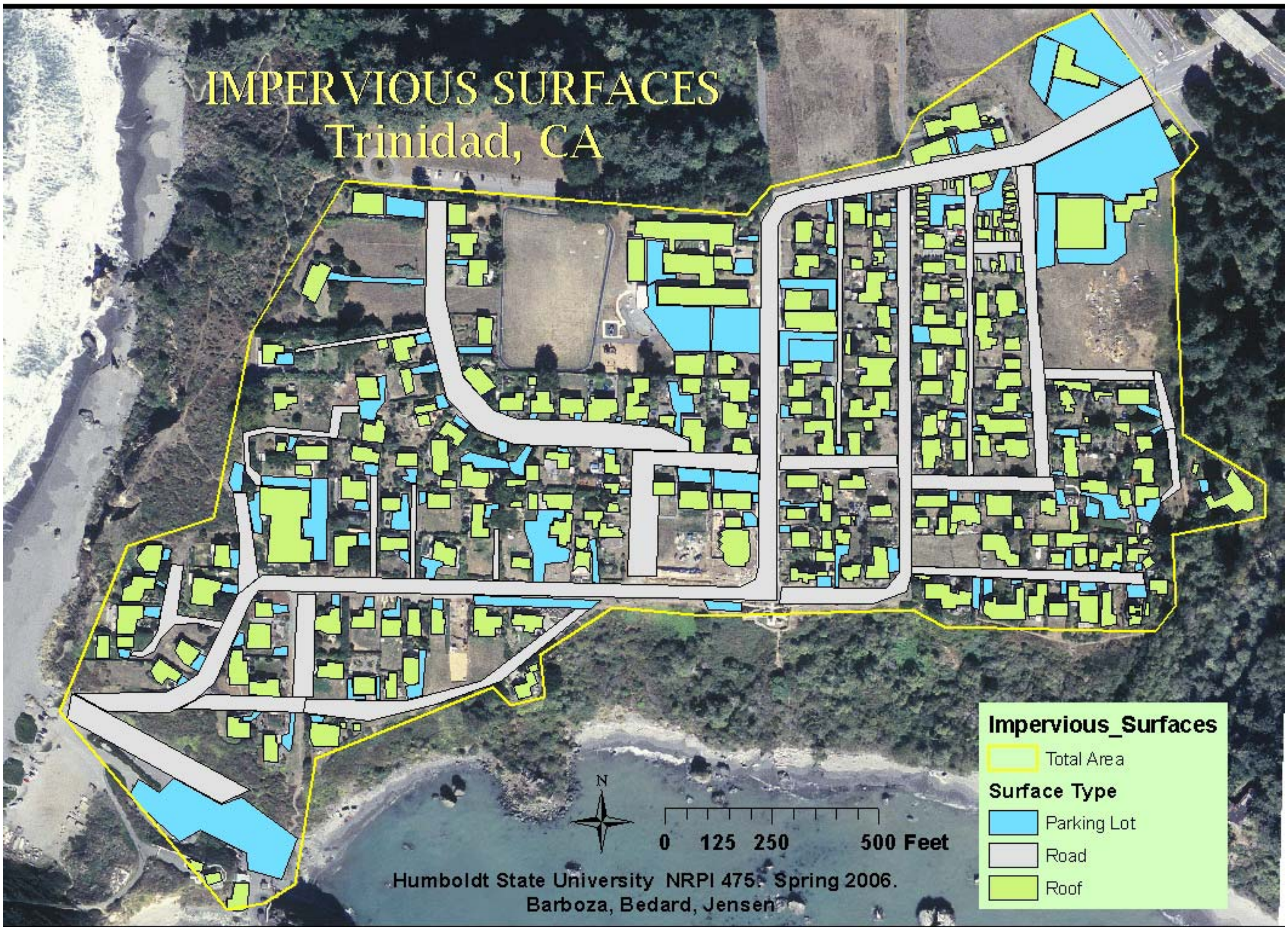

Figure 22 – Impervious Surfaces of Trinidad. Produced by Barboza, Bedard, and Jensen.

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