Volume One Unabridged
Watershed Characteristics Report

Chapter 4
Land Use in the Santa Clara Basin

SANTA CLARA BASIN

WMI

WATERSHED
MANAGEMENT INITIATIVE

Prepared for the
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by

Land Use Subgroup

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Watershed Characteristics Report
Chapter 4: Land Use in the Santa Clara Basin

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Effects of Land Use on Watersheds

This chapter was prepared by the Land Use Subgroup, with assistance from the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP). This chapter is intended to assist urban planners, development project reviewers, and other stakeholders in understanding the effects of land uses on waterbodies in the Santa Clara Basin (the Basin).

This introduction reviews the literature relating land use to watershed characteristics and provides an overview of current issues relating to land use and watershed protection in the Basin. The introduction concludes with an idea, developed by the Land Use Subgroup, for advancing the process of land use planning for watershed protection.

The following sections discuss:

- Existing land uses and projected development
- Distribution of imperviousness in the basin
- Land uses within riparian corridors

Section 6.7 (Regulation of Land Use) in Chapter 6 (Regulatory Setting) provides additional information needed to develop the land use element of a watershed management plan. In particular, Section 6.7.1 describes the state laws and enabling legislation that empower municipalities to protect watersheds, and Section 6.7.4 compares and contrasts existing municipal watershed protection policies.

4.1.1 Overview: Spatial Pattern Matters

Meaningful assessment of the effects of land use on the beneficial uses of creeks, rivers or estuaries requires a watershed-level analysis. Since the era of the New Deal (Riley 1998), the effects of forestry, grazing, or agriculture on rural watersheds have been addressed by conservation districts, and more recently, through local Coordinated Resource Management and Planning (CRMP) stakeholder processes. In general, successful rural watershed management plans have considered how land uses relate spatially to watershed features (e.g., location of grazing or manure storage relative to streams, maintenance of riparian corridors). They have also explicitly integrated social and demographic considerations—such as who owns and takes care of the land—in selecting and implementing appropriate “best management practices” (BMPs).

By contrast, federal mandates (Clean Water Act) have required urban areas to implement BMPs to prevent pollutants from reaching stormdrains to the “maximum extent practicable.” There has been little systematic analysis of the spatial relationships between land uses and streams in urban areas, nor assessment of how social and economic factors affect these spatial relationships.

Nevertheless, the impacts of urbanization are closely linked to the spatial pattern of development. The pattern matters more than the proportion of the entire watershed that is urbanized, more than the relative proportions of urban land uses.

In her book *Restoring Streams in Cities,* Ann Riley concludes: "Of all the land-use changes that can impact a watershed and its hydrology, urbanization is by far the most significant" (Riley 1998).

As Dr. Riley states:

> The worst physical modification of urban watersheds is the relegation of stream channels and tributaries to underground culverts. Riparian zones are eliminated or separated from the stream channels. Removal of streamside vegetation results in the loss of nutrients to the aquatic organisms, loss of shade, increased bank erosion, lateral movement of the stream channel, increased sedimentation, and decreased pool depths. Floodplains become separated from the stream channels because the channels have become incised or deepened, or the previous land-use practices have added large layers of fill to floodplains, or both these things have happened. Structural barriers such as levees and floodwalls and channelization can be added causes of this separation. Floodplains can be one of the most biologically productive parts of the watershed system as well as a storage and conveyance area for floodwater, but they are often impacted by urbanization….
>
> Urbanization tends to increase the volume and peak of streamflows. The delivery of runoff to streams after the beginning of rainfall becomes flashier, reducing the lag time between the rainfall and the peak of a stream's flood stage (Riley 1998).

Nonurban land uses, such as grazing and agriculture, also affect watersheds. The most severe impacts to Basin streams, however, are related to urbanization. Comprehensive watershed management will require maintaining and managing these uses, but the biggest challenge, by far, will be to preserve and enhance streams in urban areas.

The effects of urbanization cannot be reduced to pollutants per acre, or even to increases in acre-feet of runoff, but rather are engendered by a myriad of changes to drainage patterns, changes that accelerate the movement of runoff into streams, alter the patterns of erosion and deposition within the streambanks, and alter the flow of water, sediment, and nutrients between streams and riparian areas.

Although municipalities' General Plans coordinate the spatial arrangement of land uses, they generally do not incorporate the relationship of land to drainage and to waterbodies. There is a conceptual gap between the tools of urban planning—tools developed to coordinate traffic circulation, and to balance jobs with housing—and the needs of the watershed planner. Although most municipalities have adopted preservation of water resources as a goal of their comprehensive plan and have the authority to undertake a variety of initiatives, they lack a methodology for developing and implementing measures to protect and enhance watersheds at the appropriate watershed-wide scale.

To develop such a methodology, it is necessary to examine the spatial patterns of urban development, including the social causes and ecological consequences of those patterns. As the primer, *Landscape Ecology Principles in Landscape Architecture and Land Use Planning*, states:

> Spatial pattern matters. It is no longer appropriate to plan based on totals or averages of prices, jobs, wages, parkland, bicycle paths, logging area, waterflows, and so forth. Rather, the arrangement of land uses and habitats is critical to planning, conservation, design, management and policy (Dramstad et al. 1996).

4.1.2 Spatial Patterns of Urbanization

To understand the relationship between urban land uses and the streams that drain them, we must first review the characteristics and spatial relationships of the land uses themselves. As is documented in Section 4.2, the predominant characteristic of land uses in the Basin is the continuous swath of urban development across the valley and into the lower foothills of the Basin. Viewed in the context of land use change over the past 150 years, the pattern has been characterized as "sprawl."[1]

The report of the President's Council on Sustainable Development, Task Force on Sustainable Communities, defines "sprawl" as:

> …low-density development that spreads out from the edges of cities and towns. It is poorly planned, and often situated without regard to the overall design of a community or a region. It often results in types of development—such as rambling, cookie-cutter subdivisions and strip malls—that perpetuate homogeneity, make inefficient use of land, and rely almost exclusively on automobiles for transportation (President's Council on Sustainable Development 1997).

In an April 12, 1999 report, the conservation organization American Rivers paints an alarming portrait of how land use change is affecting rivers across the U.S.: "…sprawl is one of the fastest growing, most ominous threats to our nation's rivers. Sprawl wreaks havoc on both the quality of water in a river and on the amount of water flowing between the banks (American Rivers Press Release 1999)."

The Sierra Club's October 1998 report, "Dark Side of the American Dream" describes the origins of the problem this way:

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[1] A pictorial and video representation of urbanization sprawling across the Bay Area can be viewed at http://geo.arc.nasa.gov/sge/william/urban.html.

> Since the end of World War II, the American Dream has been defined as a house in the suburbs. Sparked by a series of federal and state government policies, including home-buying subsidies provided by the GI Bill, massive roadbuilding projects and community planning designed around the car, Americans abandoned the cities for greener pastures in suburbia.
>
> The consequences of decades of unplanned, rapid growth and poor land-use management are evident all across America: increased traffic congestion, longer commutes, increased dependence on fossil fuels, crowded schools, worsening air and water pollution, lost open space and wetlands, increased flooding, destroyed wildlife habitat, higher taxes and dying city centers (Sierra Club 1999).

Over the past year, despite the protests of the Heritage Foundation (Cox 1999), “sprawl” has become the focal point for an intensifying national debate on land use changes, how they affect society, and how they affect the environment—in particular, how these changes affect watersheds.

4.1.3 A Short History of Ideas About Cities and Nature

Economic and population growth (spurred by private investment and government defense spending) caused the Basin’s rapid post-war urbanization. But policies—and ideas behind those policies—account for the spatial arrangement of urban land uses. Where did those ideas come from? As population and economic activity continue to grow, can different ideas about cities help bring about land use patterns that support society and nature alike?

The decrying of sprawl links general unease over rampant environmental destruction with unease over social divisions and loss of quality of life. The urban designer Peter Calthorpe conveys the sensibility that for city dwellers, community and ecology are necessarily connected:

> Communities historically were embedded in nature—it helped set both the unique identity of each place and the physical limits of the community. Local climate, plants, vistas, harbors, and ridgelands once defined the special qualities of every memorable place. Now smog, pavement, toxic soil, receding ecologies, and polluted water contribute to the destruction of neighborhood and home in the largest sense (Calthorpe 1993)….

How did sprawl get started? Calthorpe’s end-of-the-twentieth-century reaction to the problems of suburban development was presaged, a century ago, by the reaction of planners and academics to the overcrowded living conditions, poverty and unhealthful conditions of 19th century cities.

Indeed, the very conception of this Watershed Characteristics Report might be seen as a reflection, nearly a century later, of Patrick Geddes’ idea of a regional plan (for Edinburgh, Scotland), as described in Lewis Mumford’s *The Story of Utopias* (Mumford 1963):

> The aim of the Regional Survey is to take a geographic region and explore it in every aspect. It differs from the social survey with which we are acquainted in America in that

> it is not chiefly a survey of evils; it is, rather, a survey of the existing conditions in all their aspects; and it emphasizes to a much greater extent than the social survey the natural characteristics of the environment, as they are discovered by the geologist, the zoologist, the ecologist—in addition to the development of natural and human conditions in the historic past, as presented by the anthropologist, the archaeologist, and the historian. In short, the regional survey attempts a local synthesis of all the specialist 'knowledges.'

Geddes' purpose was to create a rational basis for planning future development that would avoid the environmental and social pitfalls of industrial-age cities.

Attempts to "design away" the problems of urban life begin with the Englishman Ebenezer Howard, who proposed, in 1898, to halt the growth of London and repopulate the countryside with a new kind of "Garden City" where the city poor might once again live close to nature. (Jane Jacobs describes this conception as a kind of "model company town, with profit-sharing" [Jacobs 1961]).

Le Corbusier expanded this modernist vision with his 1920s "Radiant City," which incorporated then-new building technology. He wrote: "[S]upposing we are entering the city by way of the Great Park. Our fast car takes the special elevated motor track between the majestic skyscrapers: as we approach nearer, there is seen the repetition against the sky of the 24 skyscrapers; to our left and right on the outskirts of each particular area are the municipal and administrative buildings; and enclosing the space are the museums and university buildings. The whole city is a Park."

Lewis Mumford said the "City in the Park" idea "misconceived the nature and functions of both city and park…. a suburban conception. By its very isolation of functions that should be closely connected to every other aspect of city life… it can be detached from the organic structure of the city and planted anywhere…. The City in a Park has now taken a more acceptable, commercially attractive form, and has become a City in Parking Lot (Mumford 1986)." Here Jane Jacobs agreed with Mumford, saying that Le Corbusier's technocratic approach attempted to "sort and sift out of the whole certain simple uses, and to arrange each of these in relative self-containment" (Jacobs 1961).

These ideal cities (examples include Howard's Welwyn Garden City, Le Corbusier's Contemporary City, and Frank Lloyd Wright's Broadacre City) expressed not only an ideal form of urban design, but also a design for a social utopia. They were rarely built, but as Jacobs notes, they greatly influenced city planning and legislation affecting housing and housing finance.

The utopian vision of suburbia was posed as a solution to the social ills of the day, but was also rooted in intellectual city dwellers' idealization of nature. Roderick Nash notes in his 1973 book, *Wilderness and the American Mind*: "Appreciation of wilderness began in the cities. The literary gentleman wielding a pen, not the pioneer with his axe, made the first gestures of resistance against the strong currents of antipathy [toward the wilderness]" (Nash 1982). Mumford notes:

"This impulse to have closer contact with the rural scene was fed by the literature of the Romantic movement, from Rousseau on to Thoreau; but it did not originate there…. The rich families of Florence, Rome and Venice in the fifteenth and sixteenth centuries [built] country villas…. What marks the modern age is that both the impulse and the means of achieving it have become universal" (Mumford 1986).

By 1962, when Jane Jacobs wrote *The Death and Life of Great American Cities*, the unintended consequences of utopian city planning—particularly the separation of land uses and the incorporation of natural areas into the urban realm—were all too apparent. She noted: "There are dangers in sentimentalizing nature. Most sentimental ideas imply, at bottom, a deep if unacknowledged disrespect. It is no accident that we Americans, probably the world's champion sentimentalizers about nature, are at one and the same time probably the world's most voracious and disrespectful destroyers of the wild and rural countryside."

Heedless of warnings by Jacobs and others, the utopian ideology of suburbia has governed post-World War II land development throughout the San Francisco Bay Area (the Bay Area). As Calthorpe notes:

> Every piece of land in the USA is controlled by codes and planning documents that evolved after WWII. These controls have been largely founded on modernist principles—segregation of uses, circulation systems focused on the car, and a loss of public orientation for buildings and gathering places. With the exception of a few urban centers, every city, county and town has a set of zoning ordinances, planning codes, street standards and perhaps a comprehensive plan that binds the area to a future of sprawl-like development (Calthorpe 1993).

4.1.4 Economy, Equity, Environment

The engineering of a modernist landscape has been implemented despite the additional public and private costs compared to more dense, integrated urban development. Tina Axelrad's 1998 synthesis of the national literature on the costs of urban sprawl notes that: "Generally, patterns of sprawl characterized by large-lot, single-family developments far from the "core" of a metropolitan area, will result in greater public capital and operating costs for local roads, schools, and utility infrastructure" (Axelrad 1998).

Urban Ecology, a Bay Area organization dedicated to "promoting urban environments that are ecologically, socially and economically healthy," has noted the "hidden costs" associated with sprawl in the Bay Area. Pacific Gas and Electric's rate structure spreads the additional costs for gas and electricity distribution in 1 DU/2 to 5 acres areas to urban, as well as suburban, ratepayers. City dwellers' tax dollars end up subsidizing new roads and utility systems, instead of going toward transit systems and urban services they need (Urban Ecology 1996).

Another cost of sprawl is the high rate of pedestrian injury and death. Of all Bay Area counties, Santa Clara has the second-lowest proportion of its population walking to work (2.1 percent);

however, it had a relatively high incidence (44.7/100,000 population) of pedestrian injuries and fatalities (Bay Area Transportation and Land Use Coalition 1999).

The tendency toward sprawl is exacerbated, in California, by the effects of Proposition 13. For example, Santa Clara County voters passed an extension of a half-cent sales tax increase (Proposition A, 1992) to provide $3.5 billion for light rail expansion. The measure was struck down, however, by the California Supreme Court, which rules that the sales tax extension would require a two-thirds majority.

To make up for the shift of taxing power away from municipalities and toward the state, municipalities have been pressed to approve commercial development, because it produces higher tax revenues than does housing, and demands less outlay for public services. This forces cities to vie with each other for commercial projects, undercutting their ability to negotiate mitigation measures for development.

Social attitudes and effects, including “economic polarization,” are making it difficult to control sprawl. In a May 1998 report prepared for the Urban Habitat Program (a nonprofit organization founded in 1989 to “develop multicultural urban environmental leadership for sustainable communities in the San Francisco Bay Area”) Myron Orfield warns:

> There is a dangerous social and economic polarization occurring in the San Francisco Bay Area…. First, poverty and social and economic need has concentrated and is deepening in central city neighborhoods and in older, inner suburbs…. This concentration destabilizes schools and neighborhoods, is associated with increases in crime, and results in the flight of middle-class families and businesses. As social needs accelerate in the central cities, inner suburbs, and many outlying communities, the property tax base supporting local services erodes. Second, in a related pattern, growing middle-income communities are beginning to experience increases in their poverty and crime rates, and could well become tomorrow’s troubled suburban places…. Third, upper-income residentially exclusive suburban places are capturing the largest share of regional infrastructure spending, economic growth and jobs. As the property tax base expands in high property-wealth areas and their housing markets remain exclusive, these areas…become both socially and politically isolated from regional responsibilities.
>
> Overlaying this socioeconomic polarization is an environmental nightmare. As the wave of socioeconomic decline rolls outward from the central cities and older, inner-ring suburbs, tides of middle-class homeowners sweep into fringe communities. Growing communities, facing tremendous service and infrastructure needs, offer development incentives and zone in ways that allow them to capture the most tax base. In so doing, they lock the region into 1 DU/2 to 5 acres development patterns that are fiscally irresponsible, foster automobile dependency, contaminate groundwater, and needlessly destroy tens of thousands of acres of forest and farmland….

> At (literally) either end of regional polarization are two seemingly unrelated but actually quite interconnected negative impacts: the concentration of poverty in the region's core, and environmental degradation on the region's fringe (Orfield 1998).

Although Bay Area concentrations of poverty are most pronounced in Oakland and San Francisco, there is reason to be concerned about the connection between economic polarization and environmental degradation in the Basin. San Jose had no "extreme" poverty census tracts in 1980 or in 1990; however, the number of tracts characterized as "transitional"— where between 20 and 40 percent of the population lives below the federal poverty line ($1,111/month for a family of three in 1998 (U.S. Department of Agriculture 1998), a measure that is generally assumed to grossly underestimate actual poverty (Schwarz 1998))—increased from 11 to 15.

4.1.5 Effects of Urbanization on Santa Clara Basin Watersheds

A number of studies have investigated, or are investigating, physical and biological parameters of Basin streams, but the overall condition of aquatic ecosystems has not been systematically assessed. A detailed assessment of conditions in three Basin watersheds will be reported in Volume 2 of the Watershed Management Plan (Watershed Assessment Report). It is possible, however, based on a knowledge of watershed structure and function, and examination of land use patterns—to identify generalized effects of land use on Basin streams.

Bay Area landscapes have been progressively altered, over 150 years, by mining, forestry, ranching, agriculture, and urbanization. Chapter 7.1 includes descriptions of the Basin's presettlement flora and fauna and changes due to development.

Because we are accustomed to the current conditions of creeks, we are most likely to notice when "normal" conditions change. Visible trash and pollutants, bank washouts, increased turbidity, and fish kills are immediate and obvious effects of land use; however, these visible changes are usually symptomatic of larger, more serious changes affecting hydrology, flow regime, and riparian vegetation.

Urbanized areas extend over the valley floor to an elevation of 600 to 800 feet. Above this level, moderately sloped areas are mostly rangeland, and steep-sloped areas are forested. Within the urbanized area, small patches of natural area and park dot an otherwise continuous swath of residential, industrial and commercial development. Continuous bands of riparian vegetation along creeks, which typify less disturbed areas in the region, exist in some urbanized watersheds; in others, they have been reduced to a few disconnected lengths or eliminated entirely (see Sections 7.1 and 7.2).

From a watershed perspective, the primary effects of sprawl development are the segregation of land uses, low density, and dependency on automobiles for transportation. The vast, uniform swath of houses and workplaces disrupts watershed function principally by altering the characteristics of its drainage. The principles of landscape ecology tell us that the disturbance from the natural landscape pattern—most notably the narrowing and linear discontinuity of streamside corridors—will have specific effects on the functioning of watersheds.

Land uses change the characteristics of a watershed when, individually or in combination, they alter its structure or impair key ecological functions. These changes are best understood by how they affect ecosystem structure, processes, and functions (Federal Interagency Stream Restoration Working Group 1998). Wesche describes the chain of events as follows: changes in land use lead to changes in geomorphology and hydrology, to changes in stream hydraulics, sediment transport and storage, and on to changes in the functions of stream habitat (Wesche 1985).

The following discussion is organized under these topics:

- Urbanization and Imperviousness
- Geomorphic Changes and Disconnection of Streams from Floodplains
- Riparian Areas
- Pollutants

4.1.6 Urbanization and Imperviousness

Various studies have simply correlated biological changes with urbanization or other land use change, without elucidating causal mechanisms.

Karr (Karr and Chu 1997) uses simple graphs to illustrate that biological metrics (benthic index of biological integrity, taxa richness) decline with increasing "human influence." The latter quantity is characterized by percent impervious area or (even more simply) by subjective characterizations of intensity of use (after Patterson 1996). Pitt and Bozeman (1982) were unable to conclude that urban runoff pollutants impair beneficial uses of Coyote Creek, but did find significant differences in fish and benthic macroinvertebrate assemblages (decreased diversity and biomass) in urban locations.

May et al. (1997a) use percent total impervious area to represent "urbanization" of streams in the Puget Sound (Washington) region, and correlate other quantifiable measures related to habitat quality (road density, 2-year storm/baseflow discharge ratio, riparian buffer width, and quantity of large woody debris). The authors show that road density is strongly correlated to percent total impervious area, and could even be used as a substitute measure for imperviousness.

Schueler (1994) demonstrates the relationship between increased impervious cover and increases in peak flow and total volume of runoff. Schueler concludes that the hydrologic changes cause degradation of habitat structure, water quality, and biodiversity of aquatic systems at relatively low levels of imperviousness (10 to 20 percent of total drainage area).

Tom Richman, in his design guidance manual prepared for the Bay Area Stormwater Management Agencies Association (BASMAA 1999), summarizes the environmental consequences of impervious land coverage:

- Rainwater is prevented from infiltrating the soil and recharging groundwater. This reduces base streamflows.

- More rainwater runs off, and runs off more quickly, increasing flow volumes, accelerating erosion in natural channels, and reducing habitat. Flooding and channel destabilization may lead to channelization of the stream, with further loss of beneficial uses.

- As runoff moves over large impervious areas, it collects and concentrates pollutants.

- Impervious surfaces retain and reflect heat, causing increases in ambient air and water temperatures (BASMAA 1999).

Increased imperviousness has little effect on flows during “extreme” events (such as the extensive flooding in the Santa Clara Valley 1952-1953). During these events, rainfall saturates even natural soils, rendering them effectively impervious. Hollis (1975) shows that urbanization can increase smaller frequent floods by up to 10 times, while extreme events barely increase at all. Mineart and Ha (1999) showed that flooding in Coyote Creek has not increased with urbanization, largely due to management of flows at Anderson Dam; however, there may have been an increase in the tendency to flood in specific urban catchments within the watershed.

Related to imperviousness is the increase in drainage density, which is defined as the length of drainage conduit (pipe, ditch, or stream) divided by the drainage area (Graf 1977). Drainage density encourages rapid runoff, exacerbating the effects of imperviousness, but also represents physical alteration of smaller tributary streams.

The studies by Schueler (1994), May et al. (1997a), and others show that imperviousness is correlated to an increase in peak and volume of flow (particularly during smaller storms and in smaller streams) and that imperviousness is also correlated to reduced habitat quality, as measured by biological indices. To understand the causal relationships, however, it is necessary to examine the relationship between imperviousness and stream geomorphology.

4.1.6.1 Changes to Geomorphology and Disconnection from Floodplains

The most significant and characteristic impacts of land use to Santa Clara Valley streams are (1) the destabilization of streambeds and banks, which is caused by imperviousness, increased drainage density, and changes to sediment inputs; (2) agricultural and urban encroachment on riparian corridors; (3) gravel quarry operations; and (4) the disconnection of streams from floodplains, caused by erosive downcutting of streambeds and by construction of channels and levees.

Imperviousness associated with urban development magnifies the peak flow and total runoff during the 1.5- to 2-year flood event—the size of flood that most strongly influences stream characteristics. The major “work” by a perennial stream in moving sediment, and thereby determining its form, is accomplished by floods which occur, on average, at 1- to 2-year intervals (Leopold et al. 1995). Consistently, this frequency corresponds to the flood of near bankfull depth, i.e., the discharge when water just begins to leave the channel and spread onto the floodplain.

Ann Riley summarizes the scientific consensus on the geomorphic parameters of streams in equilibrium with their channel:

- Depth of flow is proportional to discharge. Depths increase with increasing discharges, but not as much as width.
- Channel width is proportional to both water discharge and sediment discharge.
- Channel shape (width/depth) is directly related to sediment discharge.
- Channel gradient flattens with an increase in discharge and increases with a decrease in discharge.
- Channel slope is proportional to both sediment discharge and sediment grain size.
- Sinuosity (or degree of meandering) is proportional to valley slope.
- Meander wavelengths tend to maintain a constant relationship with channel width. Increased discharges tend to increase meander wavelength and channel width (Riley 1998).

To understand the geomorphological relationship between watershed disturbance and stream health, Dave Rosgen advocates a stepwise analysis of stream geomorphology (channel slope, shape and patterns), followed by a detailed morphological description (width/depth, sinuosity, channel slope, channel materials). According to Rosgen, these steps are required before proceeding to develop a description of stream condition as it relates to "stream potential," defined as the best condition achievable for a stream's morphological characteristics. The degree of departure from potential is then assessed by comparing the subject stream to criteria based on streams of similar geomorphic type (Rosgen 1996).

The geomorphology of the Santa Clara Valley—a gently sloping plain underlain by alluvial gravels interspersed with clays—was created by the "work" of streams carrying sediment down from the hillsides. The relatively flat alluvial plain was created (and in geologic time, is being recreated) by streams moving back and forth over the valley floor.

In addition to reconstructing and maintaining the characteristic channel morphology and substrate, periodic flooding is essential to some riparian plants (e.g., willows and cottonwoods) and replenishes floodplains with sediments and nutrients. The flooding yields a "pulsed" increase in habitat, which is essential for invertebrate communities, amphibians, reptiles, and fish spawning. Flooding also replenishes shallow groundwater, extending streamflows longer into the summer (Federal Interagency Stream Restoration Working Group 1998).

4.1.6.2 Riparian Areas

“Riparian” may be simply defined as “streamside.” Ann Riley summarizes the functions of riparian vegetation in supporting fish habitat:

- Tree roots and other growth bind the streambank soil and resist erosion. This produces deeper channels with banks that are undercut but held together with exposed root systems. These undercut banks, with overhanging vegetation, provide important escape cover for fish.
- Riparian vegetation moderates water temperatures.
- Most of a stream’s biological energy comes from plant detritus.
- Woody debris that falls in the stream creates habitat in backwater pools and provides storage for sediment that would otherwise be released into spawning areas.
- Riparian vegetation slows flood velocities and helps deposit and store sediment on the floodplains, rather than in the stream channel.
- A well-vegetated channel helps store water during the rainy season; subsequent release in the dry season helps maintain base flows (Riley 1998).

In addition, riparian vegetation helps to moderate stream temperatures, which in turn moderates fluctuations in dissolved oxygen concentrations and the toxicity of pollutants.

As is noted in the *Riparian Corridor Policy Study* (City of San Jose 1994):

> … land uses, coupled with the accompanying need for flood protection have, over time, altered the natural features of the City’s landscape, including the amount and condition of its riparian resources. Creeks and rivers that historically supported relatively wide corridors of natural vegetation over their floodplains now support narrow bands of vegetation within their banks or have been modified for flood protection and water supply purposes.

Similar conditions exist throughout the urbanized areas within the Basin.

4.1.6.3 Pollutants

Santa Clara Basin streams receive no discharges from industries or municipal wastewater. Industrial discharges are routed to municipal sanitary sewers and then to one of three regional municipal wastewater treatment plants. These plants discharge to tidal sloughs or to San Francisco Bay (the Bay). Runoff from urban and rural areas and open space contributes pollutants to Basin streams. Many toxicants are associated with the particulate matter in urban runoff; this particulate matter is deposited in stream sediments (Pitt et al. 1995; Schueler 1987; Pitt and Bozeman 1982).

From 1989 to 1996, Bay Area stormwater agencies regularly sampled urban runoff flows during storm events. The samples were analyzed to determine the concentrations of potentially toxic chemical constituents. A 1996 summary of this monitoring, prepared for the BASMAA, concluded that concentrations of metals in runoff from urban areas are generally lower than the U.S. Environmental Protection Agency's dissolved water quality criteria for the protection of freshwater aquatic life.

Concentrations of total cadmium, copper, lead, nickel and zinc were sometimes higher than Regional Water Quality Control Board (Regional Board) freshwater objectives. Concentrations of total mercury were generally higher than objectives; however, these standards are designed to prevent accumulation of mercury in fish tissues. The duration of stormflows is much shorter than this period for which objectives are designed. The stormwater agencies conducted additional studies to determine whether the presence of these metals caused the runoff to be toxic to stream organisms. Toxicity, when found, was generally attributable to nonpolar organics, rather than particulates or dissolved metal ions (BASMAA 1996, pg. 7-1). Sampling and laboratory bioassays conducted in 1988-1992, however, indicated that dissolved metals caused runoff from the Walsh Avenue catchment, an industrial area in the City of Santa Clara, to be acutely toxic to the water flea *(Ceriodaphnia dubia)* under laboratory conditions. Runoff from the catchment had elevated concentrations of zinc, copper, and lead.

The results of chemical monitoring of runoff suggest that metals in urban runoff can potentially cause toxicity to stream organisms; however, actual toxic effects are probably rare because of instream dilution, sorption, and speciation (BASMAA 1996). In addition, there is evidence that organophosphate pesticides (e.g., Diazinon) occur at concentrations toxic to *Ceriodaphnia dubia*; however, laboratory toxicity results have not been correlated to instream impacts (Katznelson and Mumley 1997).

Although urban land uses as a whole result in increased pollutant concentrations in runoff, the distinction among residential, commercial, and industrial land uses is statistically insignificant when compared with other sources of variability. In general, average pollutant concentrations in runoff do not vary significantly from one place to another within an urbanized watershed (Schueler 1987; Chandler 1994). Pollutant concentrations do increase when impervious cover is greater than 40 percent to 50 percent of the drainage area (Konnan 1999); however, runoff volume is the single most important variable for predicting pollutant loads (Charbeneau and Barrett 1998). A recent study in the Basin found that localized sources (e.g., fugitive emissions from electroplating operations) may elevate concentrations of copper and nickel in runoff from specific industrial sites. The study confirmed, however, that as a whole, different types of urban land uses do not produce significantly different concentrations of copper and nickel in runoff (Soller and Gallo 1998). This suggests that control of imperviousness and total quantity of runoff may be the most meaningful strategy for reducing urban runoff pollutant loads to the Bay.

Efforts to reduce pollutant concentrations in the Bay have focused on the total load of pollutants coming from the watershed and their long-term effects on biota. By contrast, the most significant pollutant effects on aquatic life in streams may be acute response to transitory phenomena. Anecdotal evidence links first-of-season rainstorms with low dissolved oxygen and fish kills in the Basin's urban creeks (Stevenson 1999). Throughout the year, illegal dumping incidents can cause severe, localized effects in creeks.

4.1.6.4 Summary: Effects of Urbanization

In summary, the beneficial uses of creeks, including those in the Basin, are sustained by:

- A characteristic surface water hydrology, including a bankfull discharge caused by the 1.5- to 2-year flood, with less-frequent floods causing periodic overbanking and extension onto the floodplain
- The sinuosity of the creeks, and movement within their floodplain, which creates and sustains a characteristic stream channel structure and variety of habitat types
- Groundwater inflows to some creek reaches, which determine the extent and annual duration of flow within the channels
- Characteristic extent and types of streamside vegetation

Alterations to creek hydrology, the disconnection of creeks from floodplains, and the loss of riparian vegetation have affected the ability of Basin streams to support healthy aquatic ecosystems. The evidence is mixed on whether pollutants from urban runoff have chronic effects on aquatic life. The long-term fate and effects of urban runoff pollutants in creeks depend on the transport of water and sediment between creek and floodplain, and movement of water and sediment down the stream corridor. Pulses of organic litter and illegally dumped materials can have localized, acute effects.

In the Basin, the spatial pattern of urbanization—a continuous swath of urbanized area across the valley floor—is key to the overall effects of land use on the watershed. That is, the degradation of Basin waterbodies is not so much due to the intensity of land use as it is that land uses are arranged without regard to the natural structure and functions of stream corridors.

4.1.7 Opportunities to Change Land Use and Development Patterns

4.1.7.1 "Smart Growth"

"Smart Growth" has been prescribed as the solution to sprawl. The Urban Land Institute defines smart growth this way:

> "Growth is inevitable, growth is necessary, but how growth is accommodated can be good or bad. In setting the framework for land development and redevelopment, we must

> focus on practices that are environmentally sound, economically vital, and that encourage livable communities—in other words, smart growth" (Pawlukiewicz, undated).

The concept of smart growth is considered new and distinctive (i.e., distinguished from earlier concepts such as "Green Development" [U.S. Environmental Protection Agency 1996]) in that it seeks to identify a common ground where developers, environmentalists, public officials, citizens, and financiers all can find ways to accommodate growth that is acceptable to each entity. Many public officials, citizens, and environmental groups have figured out that the way to get good projects built in the places that make fiscal and environmental sense is to do everything possible to make them economically successful. Projects that are the most sensitive to the environment and to community values should be given the best opportunity to succeed and should not be subject to costly delays and conditions.

On April 26, 1999, the California Senate adopted Senate Resolution 12 (Solis) relative to the use of "Smart Growth" approaches to land use and development.

The resolution indicates that more than 300 California organizations have called upon California officials to follow "Smart Growth" principles in addressing California's future growth and development, including all of the following:

1. Planning for the future, by making government more responsive, effective, and accountable through reforming the system of land use planning and public finance.

2. Promoting prosperous and livable communities, by making existing communities vital and healthy places for all residents to live, work, obtain an education, and raise a family.

3. Providing better housing and transportation opportunities, by developing efficient transportation alternatives and a range of housing choices affordable to all residents without jeopardizing farmland, open space, and wildlife habitat.

4. Conserving green space and the natural environment, by focusing new development in areas planned for growth while protecting air and water quality and providing green space for recreation, water recharge, and wildlife.

5. Protecting California's agricultural and forestlands, by shielding California's farm, range, and forest lands from sprawl and the pressure to convert farmland to development.

This resolution encourages the development of "Smart Growth" approaches to land use and development as an effective way to ensure California's economic prosperity, social equity, and environmental quality (Legislative Analyst 1999).

In the San Francisco Bay Region, the Bay Area Alliance for Sustainable Development—which includes economic development interests, environmental groups, advocates for social equity, and elected officials—envisions:

> …a Bay Area where the natural environment is vibrant, healthy and safe, where the economy is robust and globally competitive, and where all citizens have equitable opportunities to share in the benefits of a quality environment and a prosperous economy.…
>
> The Bay Area Alliance will work with others to identify and protect high-priority lands. We will seek resources to develop a regionwide plan and map showing which lands should be considered for preservation and which should be considered for development, consistent with sustainability criteria. These criteria should include compact, efficient development patterns that use land efficiently, match jobs with housing, link homes, jobs and services, and reduce dependence on motor vehicles. We will work to obtain funds for land protection and management, through acquisition and other means, to protect watersheds and preserve open space, agriculture, and natural resources. We will work with local and regional park and open space agencies, environmental organizations, and local governments to identify priority areas." (Bay Area Alliance for Sustainable Development 1998).

"Smart Growth" incorporates the protection of open space and natural resources, more efficient use of land, and acceptance of more dense development (through an agenda of urban livability and equity). Design of dense, livable multiuse urban spaces ("new urbanism") is a key component of "Smart Growth."

"Smart Growth" is consistent with many of the growth-management policies already adopted in Palo Alto, San Jose and other Basin municipalities. These policies are described in Chapter 6.4. Two current projects within the Basin exemplify the "new urbanism" approach to design and the "Smart Growth" approach to land use policy.

The City of San Jose is currently implementing the "Jackson-Taylor Revitalization Strategy" in a previously industrial area. The project's designer, Peter Calthorpe, describes this vision:

> This project represents a ubiquitous urban opportunity—to transform old rail-oriented industrial zones into mixed-use neighborhoods with excellent transit service…. Decaying industrial sites would redevelop adding density and diversity to a semisuburban section of town. Much of San Jose is marked by an odd combination of an urban street system and a low-rise, 1 DU/2 to 5 acres building fabric.… San Jose has done much to urbanize its downtown through intelligent planning, redevelopment, and a new light rail system. This project would extend this largely successful effort by beginning to create a series of urban nodes radiating from the central city.

> The plan provides for a gradual transition of a 75-acre area directly north of downtown from low-intensity industrial and residential uses to a mix of retail, office, and medium and high-density housing (Calthorpe 1993).

The second project is the Crossings Transit-Oriented Neighborhood Project in Mountain View, which is transforming a 1960s auto-oriented strip mall into a vibrant pedestrian-oriented community. Located adjacent to a new CalTrain commuter station, The Crossings provides a range of housing and retail opportunities, with single-family homes, townhouses, rowhouses, and apartments all located within a short walk of shopping and transit. An interconnected network of tree-lined streets and pedestrian paths knit this new mixed-use neighborhood together. Streets connect to an existing grocery store, allowing residents to walk directly to the store without crossing arterial streets. Community parks and open spaces are distributed throughout the 18-acre site (Calthorpe Associates 1999). Construction on the first phase of the project is nearly complete; 97 single-family homes and 30 townhouses have been completed or are under construction. For Phase II, TPG Development has proposed 240 more units consisting of 5 single-family homes, 132 apartments and 103 row houses. The City of Mountain View is currently reviewing the Phase II proposal (City of Mountain View 1999).

4.1.7.2 Changing Land Use Patterns to Preserve and Enhance the Watershed

The Federal Interagency Stream Restoration Working Group (1998) (after Schueler 1996a) recommends the following "key tools" for restoring urban streams:

1. Partially restore the predevelopment hydrological regime (e.g., by constructing upstream stormwater detention ponds).

2. Reduce urban pollutant pulses.

3. Stabilize channel morphology (e.g., bank stabilization using bioengineering methods).

4. Restore instream habitat structure that has been "blown out" by erosive floods (e.g., with log checkdams, wing deflectors, or boulder clusters along the stream channel).

5. Reestablish riparian cover.

6. Protect critical stream substrates and reduce clogging by fine sediment deposits (often, the energy of stormwater inflows can be used to create "cleaner" substrates).

7. Allow for recolonization of the stream community (e.g., by removing downstream fish barriers).

As the Working Group notes, "The best results are usually obtained when the following tools are applied together." (Federal Interagency Stream Restoration Working Group 1998).

Some of these tools (#4, #7) require no changes in land use pattern. Some reduction of urban pollutants (#2) is being implemented by municipal urban runoff pollution prevention programs (e.g., elimination of illicit discharges, inspection of industries, cleaning of stormdrains). However, most of the "tools"—most significantly, restoration of the hydrologic regime—would require restoring the landscape pattern that links creeks to floodplains in more or less continuous streamside corridors. Stormwater detention ponds, where appropriate and effective, would need to be located within or adjacent to these corridors. Therefore, preserving and enhancing the watershed will require changes to the spatial structure of land use in the Basin, from one continuous swath of urbanized land to a more fine-grained mosaic characterized by more intensely urbanized areas that are interstitial to broad, continuous stream corridors. Floodplains should be reconnected to streams, where feasible, and development within the floodplain should be designed to accommodate flooding.

Changes to land use patterns may take many decades to significantly improve watershed function; however, advocates of watershed preservation and enhancement should be encouraged by current efforts, already under way, to radically alter the urban fabric to enhance economic sustainability and improve the quality of life. In most cases, the land use pattern changes required to meet these objectives dovetail, rather than conflict, with the changes needed to enhance the watershed. There should be opportunities to apply the methods of landscape ecology to integrate "Smart Growth"- inspired development and redevelopment initiatives with restoration of crucial links between creeks and floodplains.

Richard Register (1987) uses a series of seven maps to illustrate his vision of a Bay Area city transformed, over 40 to 125 years, from a continuous urban swath to patches of intensely developed centers surrounded by agricultural and natural areas. Register's vision is that, even with a 50 percent increase in population, urbanized area would decrease 35 percent (Register 1987).

Implementation of changes in the Basin's land use patterns should not be tied to a utopian vision, however. Consistent with the "Smart Growth" idea, change must be implemented through consensus and practical extension of existing land use policies and initiatives.

4.1.7.3 Linking Development/Redevelopment to Watershed Enhancement

The Watershed Management Initiative's (WMI's) Land Use Subgroup developed a generalized approach to implementing land use changes that favor watershed enhancement (Santa Clara Basin Watershed Management Initiative 1999). As illustrated on Figure 4-1, land use planners must find ways to translate the "overall objectives" (e.g., goals and mission statements adopted by the WMI, the Bay Area Alliance for Sustainable Development, the California Legislature, and others) to specific municipal actions (i.e., public capital improvements and conditions of approval for private projects).

As is also illustrated on Figure 4-1, the Land Use Subgroup's approach is different than earlier efforts to mitigate the effects of new development on watersheds. In general, those early efforts focused on implementing design features or devices at specific sites without due regard to the characteristics of the surrounding watershed or the placement of the site within the watershed.

The key to changing the effects of land use on watersheds is to express watershed objectives spatially. A future land use pattern—one that protects and enhances the watershed—must be mapped.

The mapping would need to be at a geographic scale that is appropriate to the planning level. The Basin scale—i.e., the WMI's Watershed Management Plan—could map the general spatial objectives for land use change within the major stream and river corridors. Municipalities could consider these objectives for incorporation into their General Plans. The Basin-scale Watershed Management Plan could become the framework for local plans that map, in more detail, the spatial objectives appropriate to protect and enhance subwatersheds. These local plans could be incorporated into Specific Area Plans that would integrate the watershed objectives with social and economic considerations at the neighborhood level. Subwatershed-level Specific Area Plans could then be the basis for reviewing the watershed impacts of specific development projects—and for defining appropriate mitigations for those projects. This would enable municipal planners to address watershed impacts proactively. The mapping should also incorporate a time scale that is appropriate to the changes envisioned (probably measured in decades).

4.1.8 Methods for Reducing Impacts from Developed Sites

4.1.8.1 Site Design Considerations

Control and treatment of runoff requires considerable land area to store water long enough to settle or to infiltrate into the soil. The Metropolitan Washington Council of Governments (Schueler 1987) provided a comprehensive manual for designing "structural" best management practices. The Council updated the manual in 1992 (Schueler et al. 1992). Many of the same structural techniques were incorporated into the *California Storm Water Best Management Practices Handbooks* (California Stormwater Quality Task Force 1993). In 1994, staff from the San Francisco Bay Regional Water Quality Control Board provided guidance for implementing these techniques (Regional Board 1994).

Because runoff cannot be effectively controlled or treated in a small space, emphasis has shifted to site design elements that limit imperviousness and that disperse and infiltrate runoff, rather than collecting and treating it.

Imperviousness has been proposed as an indicator for the extent of urbanization (Schueler 1994). Proposed methods for controlling imperviousness tend to mix urban planning and design objectives (e.g., control of sprawl, and a more pedestrian-oriented urban environment) with site planning and design methods. The *Impervious Surface Reduction Study* (City of Olympia Public Works Department 1995) listed 19 recommendations, including policies to limit sprawl and cluster development, and provide public transit. Methods for reducing imperviousness of developed sites include narrower streets and alleys and the use of pervious paving (City of Olympia Public Works Department 1995).

Start at the Source, a design guidance manual prepared by BASMAA, promotes "new urbanist" or "neotraditional" neighborhood design as a means of reducing imperviousness (BASMAA 1999). This includes detailed designs for narrower streets and driveways and methods for reducing parking demand. The manual advocates "using drainage as a design element" by integrating open drainage into landscapes, rather than piping runoff offsite. Most of the manual, however, is devoted to site designs and landscape details, with "case studies" showing how these can be applied to typical sites where residential and commercial development are planned. Some design details for street and parking lots are provided, as are details for the use of porous paving materials and for some infiltration devices, such as swales and detention basins.

The Low Impact Development Design Manual, prepared by Prince Georges County, Maryland (Prince Georges County Department of Environmental Resources 1997), emphasizes the use of hydrologic analysis, and setting of hydrologic objectives, as a precursor to site planning. *The Consensus Agreement On Model Development Principles To Protect Our Streams, Lakes, and Wetlands* codifies many of these principles and represents consensus reached by a group of planners, architects, engineers, and environmental advocates convened by the Center for Watershed Protection (1998a). Steps to implementing the principles are described in *Better Site Design: A Handbook for Changing Development Rules in Your Community* (Center for Watershed Protection 1998b). Wendy Edde, in a study for the San Mateo Stormwater Pollution Prevention Program (1999), describes methods and incentives used in Santa Monica, San Rafael, and Menlo Park, California, Olympia, Washington, and Charlotte, North Carolina, to reduce impervious surfaces for new developed and redeveloped sites.

Effective urban watershed management will require that site design standards mature beyond "do what you can, where you can" toward explicit consideration of site location and drainage to streams. Imperviousness may be of little account in one watershed location (e.g., in a low-lying district where drainage is pumped over a levee to a tidal slough), but critically important in another (e.g., in a medium-density area with moderate slopes and an intact riparian corridor).

Chapter 6.7.4 compares and contrasts some of the Basin municipalities' existing watershed protection policies. For the SCVURPPP, Pacific Municipal Consultants (1998) prepared a catalog of Basin municipalities' General Plan and Development-related policies, including riparian protection, open space preservation, imperviousness, and policies regarding automobile dependence and transportation use.

Insert Figure 4-1 (front)

Figure 4-1 (back)

4.1.8.2 Reducing Impacts from Existing Land Uses

As described in its *1997 Urban Runoff Management Plan*, the SCVURPPP assists municipalities within the portion of Santa Clara County that drains to the South Bay, and the Santa Clara Valley Water District (Water District), to implement measures to prevent urban runoff pollutants from entering the stormdrain system.

Each municipality implements a comprehensive program to eliminate illegal discharges to stormdrains and to control pollutants in runoff from urban activities. The municipalities' efforts include response to spills and illegal dumping incidents, cleaning and maintenance of stormdrains, inspections of commercial and industrial facilities, inspections of construction sites, and public education and outreach. The municipalities also take steps to eliminate sources of pollutants related to their own capital improvements, and to ongoing maintenance of streets and public areas.

The SCVURPPP's and municipalities' extensive participation in the Land Use Subgroup is part of a joint effort to develop planning policies and development approval procedures that will protect and enhance the beneficial uses of streams, wetlands, and the South Bay most effectively. The Program and municipalities also participate in other aspects of the WMI.

4.1.9 Summary

The national angst over sprawl is often expressed as loss of community and sense of place and immersion in an ugly, environmentally degraded landscape. The origins of sprawl lie in utopian attempts to segregate land uses and develop ideal forms for the city based on romanticized views of nature and society. Despite the warnings of iconoclasts like Jane Jacobs, post-WWII land use and economic policies encouraged and subsidized suburban development. Economic polarization became reflected in urban geography, resulting in disempowered, high-poverty central cities and expansion of 1 DU/2 to 5 acres, high-cost, environmentally unsound development into ecologically sensitive areas. According to Orfield's analysis, this tendency threatens to accelerate unless actions are taken to reverse the trend.

Land uses in the Basin are characterized by a continuous swath of urban development. The primary watershed effects of this development are an increase in imperviousness, increased frequency of flooding, destabilized stream geomorphology, disconnection of streams from floodplains, and loss of riparian corridors. By comparison, toxic pollutants, although a concern, probably have less significant effects on the biological functions of streams. In general, pollutant loading is not a function of specific urban land use, but is related to imperviousness and total volume of runoff.

The California Senate and the Bay Area Alliance for Sustainable Development have adopted a policy of "Smart Growth," which endorses compact efficient development patterns and protection of watersheds and natural areas. Projects typifying "Smart Growth" and "New Urbanism" designs are being built in the Basin.

Enhancement of streams within the urbanized portion of the Basin will require partial restoration of the predevelopment hydrologic regime, including reconnection of streams with floodplains (where feasible) and restoration of riparian cover. This would require changes to the spatial structure of land use in the Basin, from one continuous swath of urbanized land to a more fine-grained mosaic characterized by more intensely urbanized areas that are interstitial to broad, continuous stream corridors.

The Watershed Management Plan should incorporate maps showing spatial objectives for land use changes. In this way, continuing development and redevelopment, as it occurs in the "Smart Growth" context, can contribute toward new spatial patterns that help protect and enhance the watershed.

Implementation of spatial objectives for land use change can best be accomplished through consensus and practical extension of existing land use policies and initiatives. Within newly developed and redeveloped areas, "low-impact" site design techniques, where appropriate, can best be implemented in the context of hydrologic objectives determined for the specific location within a subwatershed. Similarly, the municipalities' comprehensive urban runoff pollution prevention programs will be most effective when they are targeted to subwatershed-scale objectives.

Patterns of Land Use

The analysis of land use data presented in this chapter was completed prior to the provisional revision of the Baylands boundary. Information in the text, tables, and figures for the Baylands and Arroyo la Laguna watersheds do not reflect the boundary revisions. The previous boundaries on which the analysis was based are shown on Figure 4-12. The provisional revisions moved the Baylands found in the portion of the Basin that is in Alameda County from the Arroyo la Laguna watershed to the Baylands area.

4.2.1 Introduction

The purpose of this chapter is to describe the distribution of existing and projected land uses in the Basin. Land uses can greatly influence ecosystem structure and function; thus, understanding patterns of land use in the Basin is an important aspect of the Assessment. While topography and climate influence the distribution of natural communities, and to an extent, the pattern of urbanization, land use patterns in the Basin are most influenced by human activities. The information in this chapter includes discussion of how both natural and human factors influence the distribution of land use in the Basin.

4.2.2 Methods

Patterns of existing land use and projected development were analyzed at four spatial scales: the Basin, its watersheds and subwatersheds, and municipal jurisdictions (Figures 4-2 and 4-3). Before characterizing the spatial distribution of land uses, appropriate data for land use and hydrologic features were identified. Factors considered are discussed below and included data completeness, accuracy, and precision. Values included in tables were either rounded to integers or to a single decimal.

4.2.2.1 Existing Land Use

Two land use data sets exist for the Basin: the 1995 data developed by the Association of Bay Area Governments (ABAG 1996), and data maintained by the Santa Clara County Assessor's Office. The ABAG land use data set was used for this analysis because it was the most accurate (all data current as of 1995), and its spatial resolution (1 hectare) was a suitable scale for analysis. ABAG's digital land use data set was established in 1985, based on the land use classification system established by the U.S. Geological Survey (ABAG 1996). ABAG updates this data set every 5 years, identifying land use changes by photointerpreting large-scale (1:3,000) aerial photography, and mapping groundtruthed data on the 1:24,000 base map. Lands that are protected by either public agencies, property easements, or private land trusts were identified using a data set (Bayareap) developed by the GreenInfo Network (GreenInfo Network 1998).

A complete description of how the ABAG 1995 land use data were classified for this analysis is included in Appendix 4A, Table 4A-1. Once classified, land use data were processed in a geographic information system (GIS). Spatial overlays between land use, protected lands, and hydrologic unit data (see next section for definitions) resulted in estimates of existing land uses for the Basin (Table 4-1, Figure 4-3), its watersheds (Tables 4-2 through 4-4, Figures 4-4 through 4-8), and its subwatersheds (Table 4-5, Figure 4-9).

4.2.2.2 Hydrologic Units

Watershed boundaries were delineated following the definition prescribed by Work Group C in a technical memorandum dated December 3, 1998: a hydrologic unit that drains to tidal waters of the Bay. In addition to the 13 watersheds so defined for the Basin, the tidally influenced area draining to the South Bay, referred to as the Baylands (Work Group C 1998), is also included in this analysis. Subwatersheds were defined by stream order (Strahler 1957). Figure 4-3 portrays Basin, watershed, and subwatershed boundaries, and Appendix 4B describes the process of identifying source data and spatial analyses used to define these respective boundaries. Subwatersheds were used as units of analysis because watershed management plans developed at the subwatershed scale have been most successful (Schueler 1996b), and the greatest success at correlating percent impervious area to environmental indicators of riparian corridors has been at this scale (Schueler 1995a).

4.2.2.3 Jurisdictions

The percentage of land uses within Santa Clara County municipalities was described previously by the SCVURPPP (1997). Their calculations are presented in Table 4-6, and trends are discussed below.

4.2.2.4 Projected Development

Projected development was analyzed using data (Projections ‘98) that ABAG developed by surveying local government land use policies (including general plans, zoning, urban growth boundaries, and other policies specific to land development) to determine the amount of land available for development between 1995 and 2020 (ABAG 1998). Unlike the existing land use data, which have a fine spatial resolution and numerous land use categories, the Projections ’98 data were generated at a coarser spatial resolution (U.S. Census tracts[2]) and for fewer land use categories (residential and industrial/commercial only). Projections ‘98 includes the acreage of each Census tract expected to be developed, and the acreage projected to be available for development for each 5-year period starting from 1995. The available acreage category includes vacant and redevelopable land, but excludes parks, open space, agriculture, vacation homes, and rural residential housing (less than 1 dwelling unit [DU]/10 acres). Using these data, it was possible to calculate (1) the percent of Census tract and watershed acreage projected to be developed; and (2) the increase in the percent of each watershed projected to be developed for both categories of land use (Table 4-7, Figures 4-10 through 4-12). The process used to analyze the Projections ’98 data is included in Appendix 4B. Watersheds with the greatest percentage of either residential or industrial/commercial development, or residential and industrial/commercial development were chosen by identifying those for which the percent watershed area, for the respective development classes, exceeded the median value for all watersheds.

4.2.3 Results

4.2.3.1 Existing Land Use

Existing land use is described at four spatial scales: for three hydrologic units–the basin, watersheds, and subwatersheds–and for municipalities. To understand subsequent sections, the following terms are defined: residential development is presented in terms of density, or DU/acre, and is grouped into three categories: 1 DU/2 to 5 acres, 1 to 3 DU/acre, and 4+ DU/acre.

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[2] Units used by the U.S. Government to survey demographics. Census tracts are small, relatively permanent statistical subdivisions of a county that are designed to be homogeneous with respect to population characteristics, economic status, and living conditions. Census tracts do not cross county boundaries. The spatial size of census tracts varies widely depending on the density of settlement. Census tract boundaries are delineated with the intention of being maintained over a long time to enable statistical comparisons between censuses.

Table 4-1
Descriptive Statistics for the Percent of Existing Land Uses in Santa Clara Basin Watersheds

Existing Land Uses	Percent Land Uses in Basin	Percent Land Uses in Watersheds		
		Mean	Median	Standard Deviation
Residential, 4+ DU/acre	21.5	29.7	32.1	18.0
Residential, 1 to 3 DU/acre	1.8	1.1	5.8	7.7
Residential, 1 DU/2 to 5 acres	0.1	0.6	0.7	0.6
Res. Subtotal[1]	*23.4*	*30.2*	*36.0*	*18.4*
Commercial	3.1	4.5	4.7	3.1
Public, Quasi-Public	2.5	3.1	5.7	7.3
Industry - Heavy	2.9	3.5	5.6	6.7
Industry - Light	1.3	1.9	2.9	2.7
Transportation, Communication	1.0	1.1	1.2	0.5
Utilities	0.2	0.2	0.9	1.2
Land Fills	0.0	0.7	0.7	0.5
Mines, Quarries	0.2	0.3	1.2	1.7
Ind/Com. Subtotal[1]	*11.2*	*16.6*	*19.6*	*15.3*
Agriculture	2.4	1.8	2.6	2.6
Forest	0.9	34.7	26.6	18.9
Rangeland	3.9	7.0	11.6	12.0
Urban Recreation	33.8	2.0	3.6	4.0
Vacant, Undeveloped	19.6	0.9	1.0	0.6
Wetlands	4.4	25.4	25.9	25.8
Subtotal	*65.0*	*46.0*	*44.1*	*25.3*
Bays, Estuaries	0.0	na	na	na
Freshwater	0.4	0.4	0.6	0.5

[1] Subtotals reflect land uses included in project development (Table 4-7) and may be compared.

Table 4-2
Insert Excel table

Table 4-3

Table 4-4
Percent Area Protected by Public Agencies, Property Easements, or Private Land Trusts for Watersheds in the Santa Clara Basin[1]

Watersheds	Area (ac)	Protected Area (ac)	Percent Area (ac) Protected
Adobe	7,242	2,473	34.2
Arroyo la Laguna	47,636	14,392	30.2
Baylands	20,965	6,584	31.4
Calabazas	13,366	653	4.9
Coyote	205,145	58,031	28.3
Guadalupe	108,912	30,682	28.2
Matadero/Barron	10,864	620	5.7
Lower Penitencia	18,279	1,606	8.8
Permanente	11,096	2,180	19.7
San Francisquito	27,417	8,798	32.1
San Tomas	28,681	3,998	13.9
Stevens	18,686	6,619	35.4
Sunnyvale East	4,556	118	2.6
Sunnyvale West	4,857	285	5.9

[1] Analysis was completed prior to the provisional revision of the Baylands boundary. Therefore, values depicted for the Baylands and the Arroyo la Laguna watershed do not reflect the revised boundary.

Table 4-5
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
Adobe	3	Adobe	Agriculture	19.8
		Adobe	Commercial	415.0
		Adobe	Forest	2,629.5
		Adobe	Freshwater	1.3
		Adobe	Heavy Industrial	146.0
		Adobe	Residential, 4+ DU/acre	2,689.0
		Adobe	Residential, 1 DU/2 to 5 acres	0.4
		Adobe	Residential, 1 to 3 DU/acre	678.8
		Adobe	Public Quasi-Public	231.5
		Adobe	Rangeland	194.0
		Adobe	Transportation, Communication	64.4
		Adobe	Urban Recreation	57.6
		Adobe	Vacant Undeveloped	115.0
Arroyo la Laguna	4	Arroyo la Laguna	Agriculture	3,757.7
		Arroyo la Laguna	Bays and Estuaries	647.4
		Arroyo la Laguna	Commercial	2,126.5
		Arroyo la Laguna	Forest	929.5
		Arroyo la Laguna	Freshwater	17.6
		Arroyo la Laguna	Heavy Industrial	2,380.1
		Arroyo la Laguna	Residential, 4+ DU/acre	11,280.5
		Arroyo la Laguna	Light Industrial	1,817.1
		Arroyo la Laguna	Residential, 1 DU/2 to 5 acres	75.7
		Arroyo la Laguna	Mines, Quarries, Gravel Pits	162.7
		Arroyo la Laguna	Public/Quasi-Public	930.9
		Arroyo la Laguna	Rangeland	9,324.1
		Arroyo la Laguna	Transportation, Communication	613.7
		Arroyo la Laguna	Urban Recreation	652.5
		Arroyo la Laguna	Utilities	32.1
		Arroyo la Laguna	Vacant/Undeveloped	792.5
		Arroyo la Laguna	Wetlands	12,095.2
Baylands	4	Baylands	Agriculture	1,013.6
		Baylands	Bays and Estuaries	147.1
		Baylands	Commercial	847.2
		Baylands	Freshwater	64.2
		Baylands	Heavy Industrial	1,014.6
		Baylands	Residential, 4+ DU/acre	1,990.7
		Baylands	Light Industrial	59.8
		Baylands	Residential, 1 to 3 DU/acre	7.4
		Baylands	Public/Quasi-Public	322.7
		Baylands	Rangeland	341.3

Table 4-5 (continued)
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
		Baylands	Sanitary Landfills	5.9
		Baylands	Transportation, Communication	261.2
		Baylands	Urban Recreation	2,946.1
		Baylands	Utilities	828.2
		Baylands	Vacant/Undeveloped	131.2
		Baylands	Wetlands	10,558.5
Calabazas	3	Calabazas	Agriculture	44.6
		Calabazas	Commercial	1,169.9
		Calabazas	Forest	1,181.1
		Calabazas	Heavy Industrial	1,883.3
		Calabazas	Residential, 4+ DU/acre	6,985.7
		Calabazas	Residential, 1 DU/2 to 5 acres	152.3
		Calabazas	Residential, 1 to 3 DU/acre	145.3
		Calabazas	Public/Quasi-Public	655.8
		Calabazas	Rangeland	694.7
		Calabazas	Transportation, Communication	223.3
		Calabazas	Urban Recreation	165.6
		Calabazas	Vacant/Undeveloped	64.3
Coyote	2	Coyote-A16	Agriculture	476.1
		Coyote-A16	Forest	4,369.1
		Coyote-A16	Rangeland	1,500.9
	2	Coyote-A3	Forest	293.2
		Coyote-A3	Freshwater	0.6
		Coyote-A3	Rangeland	2,643.1
	2	Coyote-A4	Forest	404.0
		Coyote-A4	Rangeland	1,757.9
	2	Coyote-A9	Forest	2,095.1
	2	Coyote-B1	Forest	2,022.1
		Coyote-B1	Freshwater	4.5
		Coyote-B1	Rangeland	438.5
	2	Las Animas-1	Agriculture	64.0
		Las Animas-1	Forest	1,558.8
		Las Animas-1	Residential, 4+ DU/acre	106.3
		Las Animas-1	Rangeland	558.5
	2	Upper Thompson	Forest	1,111.7
		Upper Thompson	Residential, 4+ DU/acre	27.3
		Upper Thompson	Rangeland	1,652.5
	3	Arroyo Aguague-1	Forest	2,878.2
		Arroyo Aguague-1	Rangeland	597.7
		Arroyo Aguague-2	Forest	1,502.2
		Arroyo Aguague-2	Freshwater	7.0

Table 4-5 (continued)
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
		Arroyo Aguague-2	Rangeland	512.9
	3	Coyote-A1	Forest	1,505.0
		Coyote-A1	Rangeland	2,466.9
	3	Coyote-A11	Forest	1,994.4
	3	Coyote-A12	Forest	1,789.1
	3	Coyote-A13	Forest	2,387.8
		Coyote-A13	Rangeland	323.5
	3	Coyote-A14	Forest	6,208.5
		Coyote-A14	Rangeland	967.9
	3	Coyote-A2	Forest	91.6
		Coyote-A2	Rangeland	2,837.8
	3	Coyote-C23	Forest	2,433.9
		Coyote-C23	Rangeland	212.5
	3	Las Animas-2	Agriculture	1.6
		Las Animas-2	Commercial	39.6
		Las Animas-2	Forest	1,933.2
		Las Animas-2	Residential, 4+ DU/acre	34.6
		Las Animas-2	Public/Quasi-Public	202.7
		Las Animas-2	Rangeland	2,187.0
		Las Animas-2	Vacant/Undeveloped	7.4
	3	Lower Thompson	Agriculture	1,871.4
		Lower Thompson	Commercial	916.2
		Lower Thompson	Forest	1,814.8
		Lower Thompson	Heavy Industrial	44.5
		Lower Thompson	Residential, 4+ DU/acre	10,051.4
		Lower Thompson	Light Industrial	195.9
		Lower Thompson	Residential, 1 to 3 DU/acre	1.4
		Lower Thompson	Public/Quasi-Public	846.6
		Lower Thompson	Rangeland	7,377.7
		Lower Thompson	Transportation, Communication	410.6
		Lower Thompson	Urban Recreation	759.2
		Lower Thompson	Utilities	12.4
		Lower Thompson	Vacant/Undeveloped	460.3
	3	Packwood	Forest	6,071.5
		Packwood	Rangeland	755.4
	3	San Felipe-1	Forest	4,319.2
		San Felipe-1	Freshwater	32.6
		San Felipe-1	Rangeland	1,170.4
	3	San Felipe-2	Forest	2,039.4
		San Felipe-2	Rangeland	644.0
	3	San Felipe-4	Forest	2,183.3
		San Felipe-4	Rangeland	335.1

Table 4-5 (continued)
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
	3	San Felipe-5	Forest	2,966.6
		San Felipe-5	Rangeland	300.4
	3	Upper Penitencia-1	Forest	3,165.5
		Upper Penitencia-1	Freshwater	24.7
		Upper Penitencia-1	Residential, 4+ DU/acre	1.6
		Upper Penitencia-1	Rangeland	645.1
	3	Upper Silver	Residential, 4+ DU/acre	119.9
		Upper Silver	Mines, Quarries, Gravel Pits	5.3
		Upper Silver	Rangeland	2,870.1
		Upper Silver	Transportation, Communication	4.9
		Upper Silver	Urban Recreation	1.9
		Upper Silver	Vacant/Undeveloped	437.6
	3	Willow Springs	Agriculture	4,091.1
		Willow Springs	Commercial	59.5
		Willow Springs	Forest	1,425.3
		Willow Springs	Heavy Industrial	2.5
		Willow Springs	Residential, 4+ DU/acre	181.5
		Willow Springs	Public/Quasi-Public	71.8
		Willow Springs	Rangeland	3,296.8
		Willow Springs	Transportation, Communication	5.5
		Willow Springs	Urban Recreation	27.2
		Willow Springs	Vacant/Undeveloped	21.9
	4	Coyote A2a	Forest	9,375.6
		Coyote A2a	Freshwater	0.0
		Coyote A2a	Rangeland	5,652.5
	4	Coyote-A8	Forest	8,472.9
		Coyote-A8	Rangeland	3,971.8
	4	San Felipe-3	Agriculture	868.8
		San Felipe-3	Forest	8,861.0
		San Felipe-3	Freshwater	22.3
		San Felipe-3	Rangeland	2,001.3
	4	Upper Penitencia-2	Agriculture	164.9
		Upper Penitencia-2	Commercial	89.7
		Upper Penitencia-2	Forest	2,464.2
		Upper Penitencia-2	Heavy Industrial	74.5
		Upper Penitencia-2	Residential, 4+ DU/acre	1,247.3
		Upper Penitencia-2	Light Industrial	62.6
		Upper Penitencia-2	Residential, 1 to 3 DU/acre	53.0
		Upper Penitencia-2	Public/Quasi-Public	37.9
		Upper Penitencia-2	Rangeland	1,888.2
		Upper Penitencia-2	Transportation, Communication	26.6
		Upper Penitencia-2	Urban Recreation	21.9

Table 4-5 (continued)
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
		Upper Penitencia-2	Vacant/Undeveloped	39.3
	5	Coyote Mainstem	Agriculture	4,100.7
		Coyote Mainstem	Commercial	1,049.0
		Coyote Mainstem	Forest	14,689.2
		Coyote Mainstem	Freshwater	628.3
		Coyote Mainstem	Heavy Industrial	1,434.9
		Coyote Mainstem	Residential, 4+ DU/acre	5,880.8
		Coyote Mainstem	Light Industrial	737.5
		Coyote Mainstem	Mines, Quarries, Gravel Pits	140.2
		Coyote Mainstem	Public/Quasi-Public	626.3
		Coyote Mainstem	Rangeland	11,532.4
		Coyote Mainstem	Transportation, Communication	509.0
		Coyote Mainstem	Urban Recreation	1,346.0
		Coyote Mainstem	Utilities	58.0
		Coyote Mainstem	Vacant/Undeveloped	758.4
Guadalupe	2	Canoas	Agriculture	397.6
		Canoas	Commercial	283.4
		Canoas	Residential, 4+ DU/acre	2,349.8
		Canoas	Light Industrial	11.6
		Canoas	Mines, Quarries, Gravel Pits	2.8
		Canoas	Public/Quasi-Public	141.3
		Canoas	Rangeland	187.0
		Canoas	Transportation, Communication	170.0
		Canoas	Urban Recreation	38.7
		Canoas	Vacant/Undeveloped	164.5
	2	McAbee	Commercial	46.4
		McAbee	Forest	818.7
		McAbee	Residential, 4+ DU/acre	1,081.8
		McAbee	Public/Quasi-Public	17.3
		McAbee	Rangeland	19.9
		McAbee	Urban Recreation	92.6
	2	Ross	Agriculture	131.1
		Ross	Commercial	308.4
		Ross	Forest	804.6
		Ross	Residential, 4+ DU/acre	4,513.4
		Ross	Light Industrial	0.9
		Ross	Residential, 1 to 3 DU/acre	54.6
		Ross	Public/Quasi-Public	256.9
		Ross	Rangeland	34.5
		Ross	Transportation, Communication	21.9
		Ross	Urban Recreation	119.4
		Ross	Vacant/Undeveloped	57.8

Table 4-5 (continued)
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
	2	Santa Teresa	Agriculture	412.7
		Santa Teresa	Commercial	562.3
		Santa Teresa	Forest	223.2
		Santa Teresa	Heavy Industrial	225.0
		Santa Teresa	Residential, 4+ DU/acre	3,810.2
		Santa Teresa	Light Industrial	275.3
		Santa Teresa	Residential, 1 to 3 DU/acre	12.9
		Santa Teresa	Public/Quasi-Public	331.3
		Santa Teresa	Rangeland	1,792.8
		Santa Teresa	Transportation, Communication	82.4
		Santa Teresa	Urban Recreation	262.1
		Santa Teresa	Vacant/Undeveloped	161.6
	3	Calero	Agriculture	565.9
		Calero	Commercial	18.6
		Calero	Forest	2,661.3
		Calero	Freshwater	17.3
		Calero	Residential, 4+ DU/acre	402.2
		Calero	Light Industrial	19.8
		Calero	Residential, 1 to 3 DU/acre	160.2
		Calero	Rangeland	4,166.0
		Calero	Vacant/Undeveloped	35.9
	3	Upper Guadalupe	Agriculture	74.2
		Upper Guadalupe	Commercial	63.6
		Upper Guadalupe	Forest	7,471.7
		Upper Guadalupe	Freshwater	5.1
		Upper Guadalupe	Residential, 4+ DU/acre	723.3
		Upper Guadalupe	Light Industrial	0.5
		Upper Guadalupe	Residential, 1 to 3 DU/acre	12.3
		Upper Guadalupe	Public/Quasi-Public	11.6
		Upper Guadalupe	Rangeland	907.3
		Upper Guadalupe	Urban Recreation	185.8
		Upper Guadalupe	Vacant/Undeveloped	34.2
	4	Alamitos	Agriculture	477.5
		Alamitos	Commercial	1,023.2
		Alamitos	Forest	8,847.5
		Alamitos	Freshwater	91.3
		Alamitos	Heavy Industrial	93.3
		Alamitos	Residential, 4+ DU/acre	7,621.5
		Alamitos	Light Industrial	460.5
		Alamitos	Mines, Quarries, Gravel Pits	7.4
		Alamitos	Public/Quasi-Public	480.8
		Alamitos	Rangeland	2,939.1

Table 4-5 (continued)
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
		Alamitos	Transportation, Communication	219.9
		Alamitos	Urban Recreation	198.0
		Alamitos	Utilities	7.4
		Alamitos	Vacant/Undeveloped	144.8
	4	Los Gatos	Agriculture	224.5
		Los Gatos	Commercial	1,147.4
		Los Gatos	Forest	16,980.7
		Los Gatos	Freshwater	285.0
		Los Gatos	Heavy Industrial	251.8
		Los Gatos	Residential, 4+ DU/acre	7,585.1
		Los Gatos	Light Industrial	306.2
		Los Gatos	Mines, Quarries, Gravel Pits	17.3
		Los Gatos	Public/Quasi-Public	492.9
		Los Gatos	Rangeland	6,805.4
		Los Gatos	Transportation, Communication	404.2
		Los Gatos	Urban Recreation	300.6
		Los Gatos	Utilities	4.9
		Los Gatos	Vacant/Undeveloped	453.9
	5	Lower Guadalupe	Agriculture	836.8
		Lower Guadalupe	Commercial	1,433.7
		Lower Guadalupe	Heavy Industrial	2,827.6
		Lower Guadalupe	Residential, 4+ DU/acre	3,901.0
		Lower Guadalupe	Light Industrial	973.9
		Lower Guadalupe	Public/Quasi-Public	1,044.3
		Lower Guadalupe	Rangeland	7.4
		Lower Guadalupe	Transportation, Communication	801.3
		Lower Guadalupe	Urban Recreation	1,085.1
		Lower Guadalupe	Utilities	2.5
		Lower Guadalupe	Vacant/Undeveloped	310.8
Lower Penitencia	4	Lower Penitencia	Agriculture	509.1
		Lower Penitencia	Commercial	516.3
		Lower Penitencia	Forest	207.7
		Lower Penitencia	Heavy Industrial	498.6
		Lower Penitencia	Residential, 4+ DU/acre	5,478.2
		Lower Penitencia	Light Industrial	1,386.1
		Lower Penitencia	Mines, Quarries, Gravel Pits	61.8
		Lower Penitencia	Residential, 1 to 3 DU/acre	138.4
		Lower Penitencia	Public/Quasi-Public	538.6
		Lower Penitencia	Rangeland	7,071.0
		Lower Penitencia	Transportation, Communication	465.5
		Lower Penitencia	Urban Recreation	966.3
		Lower Penitencia	Utilities	0.5
		Lower Penitencia	Vacant/Undeveloped	441.1

Table 4-5 (continued) Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
Matadero/Barron	1	Barron	Commercial	87.1
		Barron	Forest	1.2
		Barron	Heavy Industrial	36.2
		Barron	Residential, 4+ DU/acre	555.4
		Barron	Residential, 1 to 3 DU/acre	911.8
		Barron	Public/Quasi-Public	186.3
		Barron	Rangeland	28.4
		Barron	Urban Recreation	118.7
		Barron	Vacant/Undeveloped	5.0
	3	Matadero	Commercial	462.4
		Matadero	Forest	791.0
		Matadero	Freshwater	1.2
		Matadero	Heavy Industrial	55.1
		Matadero	Residential, 4+ DU/acre	4,285.4
		Matadero	Residential, 1 to 3 DU/acre	818.6
		Matadero	Public/Quasi-Public	1,249.3
		Matadero	Rangeland	734.8
		Matadero	Transportation, Communication	107.8
		Matadero	Urban Recreation	236.9
		Matadero	Utilities	0.8
		Matadero	Vacant/Undeveloped	190.4
Permanente	3	Permanente	Commercial	181.0
		Permanente	Forest	3,888.4
		Permanente	Heavy Industrial	94.6
		Permanente	Residential, 4+ DU/acre	4,794.9
		Permanente	Light Industrial	168.1
		Permanente	Residential, 1 DU/2 to 5 acres	155.4
		Permanente	Mines, Quarries, Gravel Pits	529.3
		Permanente	Residential, 1 to 3 DU/acre	190.2
		Permanente	Public/Quasi-Public	406.3
		Permanente	Rangeland	305.3
		Permanente	Transportation, Communication	77.8
		Permanente	Urban Recreation	225.0
		Permanente	Vacant/Undeveloped	80.1
San Francisquito	1	Alambique	Agriculture	4.9
		Alambique	Forest	1,157.1
		Alambique	Freshwater	1.3
		Alambique	Residential, 1 DU/2 to 5 acres	8.2
		Alambique	Residential, 1 to 3 DU/acre	239.8
		Alambique	Rangeland	134.3
		Alambique	Wetlands	16.1
	3	Alpine	Agriculture	30.0
		Alpine	Commercial	22.4

Table 4-5 (continued)
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
		Alpine	Forest	2,451.1
		Alpine	Freshwater	14.3
		Alpine	Residential, 4+ DU/acre	90.0
		Alpine	Residential, 1 to 3 DU/acre	1,215.0
		Alpine	Public/Quasi-Public	32.1
		Alpine	Rangeland	1,123.2
		Alpine	Urban Recreation	22.8
		Alpine	Wetlands	17.8
	3	Bozzo	Agriculture	96.5
		Bozzo	Commercial	17.3
		Bozzo	Forest	1,193.2
		Bozzo	Freshwater	21.0
		Bozzo	Residential, 4+ DU/acre	22.9
		Bozzo	Residential, 1 DU/2 to 5 acres	4.9
		Bozzo	Residential, 1 to 3 DU/acre	866.1
		Bozzo	Public/Quasi-Public	9.9
		Bozzo	Rangeland	443.8
		Bozzo	Urban Recreation	56.9
		Bozzo	Wetlands	67.5
	3	Los Trancos	Agriculture	41.4
		Los Trancos	Commercial	43.3
		Los Trancos	Forest	1,747.3
		Los Trancos	Freshwater	20.8
		Los Trancos	Residential, 4+ DU/acre	127.9
		Los Trancos	Residential, 1 to 3 DU/acre	1,421.4
		Los Trancos	Rangeland	1,051.5
		Los Trancos	Transportation, Communication	53.2
		Los Trancos	Urban Recreation	11.9
		Los Trancos	Vacant/Undeveloped	306.1
	3	West Union	Agriculture	128.6
		West Union	Commercial	1.3
		West Union	Forest	4,677.1
		West Union	Freshwater	14.8
		West Union	Residential, 1 DU/2 to 5 acres	11.6
		West Union	Residential, 1 to 3 DU/acre	2,157.5
		West Union	Public/Quasi-Public	16.0
		West Union	Rangeland	376.7
		West Union	Transportation, Communication	45.1
		West Union	Urban Recreation	7.4
		West Union	Vacant/Undeveloped	42.0
	4	San Francisquito	Agriculture	188.3
		San Francisquito	Commercial	410.5
		San Francisquito	Forest	1,041.2

Table 4-5 (continued)
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
		San Francisquito	Heavy Industrial	18.3
		San Francisquito	Residential, 4+ DU/acre	1,786.4
		San Francisquito	Residential, 1 to 3 DU/acre	174.8
		San Francisquito	Public/Quasi-Public	648.8
		San Francisquito	Rangeland	970.3
		San Francisquito	Transportation, Communication	118.1
		San Francisquito	Urban Recreation	316.7
		San Francisquito	Utilities	2.5
		San Francisquito	Vacant/Undeveloped	57.7
San Tomas	4	San Tomas-Aquino	Commercial	990.4
		San Tomas-Aquino	Forest	1,366.5
		San Tomas-Aquino	Heavy Industrial	27.8
		San Tomas-Aquino	Residential, 4+ DU/acre	10,301.6
		San Tomas-Aquino	Residential, 1 DU/2 to 5 acres	158.2
		San Tomas-Aquino	Residential, 1 to 3 DU/acre	15.7
		San Tomas-Aquino	Public/Quasi-Public	744.6
		San Tomas-Aquino	Transportation, Communication	189.4
		San Tomas-Aquino	Urban Recreation	265.5
		San Tomas-Aquino	Utilities	39.6
		San Tomas-Aquino	Vacant/Undeveloped	172.7
	4	Saratoga	Agriculture	8.3
		Saratoga	Commercial	793.7
		Saratoga	Forest	5,444.7
		Saratoga	Freshwater	14.5
		Saratoga	Heavy Industrial	1,679.7
		Saratoga	Residential, 4+ DU/acre	4,965.1
		Saratoga	Residential, 1 DU/2 to 5 acres	1.0
		Saratoga	Residential, 1 to 3 DU/acre	14.0
		Saratoga	Public/Quasi-Public	789.7
		Saratoga	Rangeland	229.5
		Saratoga	Transportation, Communication	125.7
		Saratoga	Urban Recreation	253.0
		Saratoga	Vacant/Undeveloped	88.9
Stevens Creek	3	Stevens Creek	Agriculture	92.2
		Stevens Creek	Commercial	393.0
		Stevens Creek	Forest	9,195.4
		Stevens Creek	Freshwater	182.9
		Stevens Creek	Heavy Industrial	732.3
		Stevens Creek	Residential, 4+ DU/acre	4,473.7
		Stevens Creek	Mines, Quarries, Gravel Pits	61.6
		Stevens Creek	Residential, 1 to 3 DU/acre	102.0
		Stevens Creek	Public/Quasi-Public	202.0
		Stevens Creek	Rangeland	2,332.6

Table 4-5 (concluded)
Acreage of Existing (1995) Land Uses in Subwatersheds in the Santa Clara Basin[1, 2]

Watershed	Stream Order	Subwatershed	Land Use	Acreage
		Stevens Creek	Transportation, Communication	180.4
		Stevens Creek	Urban Recreation	565.7
		Stevens Creek	Utilities	121.2
		Stevens Creek	Vacant/Undeveloped	44.3
Sunnyvale East	1	Sunnyvale East	Commercial	586.1
		Sunnyvale East	Heavy Industrial	419.4
		Sunnyvale East	Residential, 4+ DU/acre	2,975.3
		Sunnyvale East	Public/Quasi-Public	355.6
		Sunnyvale East	Transportation, Communication	82.7
		Sunnyvale East	Urban Recreation	117.8
		Sunnyvale East	Utilities	4.9
		Sunnyvale East	Vacant/Undeveloped	14.8
Sunnyvale West	1	Sunnyvale West	Agriculture	76.6
		Sunnyvale West	Commercial	245.7
		Sunnyvale West	Heavy Industrial	1,199.6
		Sunnyvale West	Residential, 4+ DU/acre	1,016.0
		Sunnyvale West	Light Industrial	235.8
		Sunnyvale West	Public/Quasi-Public	1,377.7
		Sunnyvale West	Rangeland	0.1
		Sunnyvale West	Sanitary Landfills	33.7
		Sunnyvale West	Transportation, Communication	57.9
		Sunnyvale West	Urban Recreation	526.0
		Sunnyvale West	Utilities	16.5
		Sunnyvale West	Vacant/Undeveloped	71.5

[1] Numbers associated with subwatershed names correspond to the naming convention applied by the Water District and uniquely identify subwatersheds with similar prefixes.

[2] Analysis was completed prior to the provisional revision of the Baylands boundary. Therefore, values depicted for the Baylands and the Arroyo la Laguna watershed do not reflect the revised boundary.

Insert Table 4-6

Table 4-7

Santa Clara Basin

There are several trends in the spatial distribution of existing land uses in the Basin, influenced both by natural factors such as elevation and precipitation, and by human activities. A distinct transition in land use occurs at about 600 to 800 feet above sea level: areas above this elevation threshold (upper elevation zone) are largely populated by forests and rangelands, whereas areas below this elevation threshold (lower elevation zone) are dominated by an urbanized landscape (Figure 4-4). Several patterns exist within the upper and lower elevation zones.

Upper Zone. Forest communities[3] occur predominantly on steeper slopes, while rangeland communities occupy moderately sloped areas. In the western basin hills, forest communities occupy approximately 2 to 10 times more area than rangeland communities. Conversely, in the eastern basin hills, rangeland communities commonly occupy 10 to 40 times more area than forest communities. At high elevations in the eastern hills, however, this trend reverses, and forest occupies a third more area than rangeland.

Lower Zone. The majority of the Basin floor is occupied by residential communities developed at a density of 4+ DU/acre. The relatively small amount of 1 to 3 DU/acre housing in the Basin occurs in its northwest corner (e.g., San Francisquito, Matadero/Barron, Adobe, and Permanente watersheds). The even smaller amount of 1 DU/2 to 5 acres housing in the Basin occurs in its southwest portion (e.g., Calabazas, San Tomas, and Permanente watersheds). Commercial land uses are distributed throughout the Basin floor but are concentrated along state and county highways. Public and quasi-public land uses are also distributed across the Basin floor, and are more evenly dispersed than commercial land uses. Industrial areas are clustered near the Bay and along major transportation corridors, including rail and interstate highways. The only exception is State Highway 85, which was recently constructed and runs primarily through residential areas. Agricultural land uses occur either near the Baylands or on the urban fringe, mainly on the east side of the Basin.

Percent of each land use in the Basin, and descriptive statistics on land uses in Basin watersheds, are found in Table 4-1.

Watersheds

Basin watersheds are categorized here using a two-tiered approach: first on the basis of the influence of topography and climate; and second by the relative proportion and distribution of land uses. What follows are narratives describing the distribution of land uses in each watershed, presented first by topographic/climatic category (west side, east side, and valley floor), and subsequently by the relative proportion of land uses within each topographic/ecological category. A description of land use patterns in the Baylands is also included to more completely describe land use patterns in the Basin. The following watershed narratives support Figures 4-3 through 4-7 and Tables 4-2 through 4-4.
Figure 4-2 (front)

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[3] The term “communities” as used here refers to biological, not human communities.

Figure 4-2 (front)

Figure 4-2 (back)

Figure 4-3 (front)

Figure 4-3 (back)

Figure 4-4 (front)

Figure 4-4 (back)

Figure 4-5 (front)

Figure 4-5 (back)

Figure 4-6 (front)

Figure 4-6 (back)

Figure 4-7 (front)

Figure 4-7 (back)

Figure 4-8 (front)

Figure 4-8 (back)

Figure 4-9 (front)

Figure 4-9 (back)

Figure 4-10 (front)

Figure 4-10 (back)

Figure 4-11 (front)

Figure 4-11 (back)

Figure 4-12 (front)

Figure 4-12 (back)

West Side (see Figure 4-5 for an example). The west-side watersheds have the following characteristics: headwaters originate in the Santa Cruz Mountains; the upper and lower elevation zones are represented; the upper watershed is primarily nonurbanized and has a high ratio of forest to grassland; the lower watershed is urbanized; and watershed morphology is typically long and slender.

West-side watersheds with a very high proportion of natural areas (50 to 60 percent), a moderate proportion of residential (25 to 30 percent), and low proportion of industrial/commercial development (5 to 15 percent) consist of the following:

Stevens Creek. The majority of the area draining to Stevens Creek watershed in its upper elevation zone is undeveloped (forest or rangeland) and permeable. Notably, this watershed has the highest percentage of area legally protected; thus, about half of the headwaters to Stevens Creek drain protected area, and the remaining headwaters drain primarily forested area. The composition and distribution of land uses in the lower elevation zone is typical of west-side watersheds: the predominant land use is residential, 4+ DU/acre; commercial and public/quasi-public developments are interspersed; and contiguous commercial development is also prevalent along State Highway 82. Industrial development occurs in the downstream area of the watershed and is concentrated near U.S. Highway 101. The land use pattern in the lower elevation zone of Stevens Creek watershed differs from most west-side watersheds by having fewer areas of vacant/undeveloped land and a greater proportion of urban recreation areas.

San Francisquito Creek. The majority of the upper elevation zone in San Francisquito watershed is also undeveloped, primarily existing as forest and rangeland. Permeable, protected land drains to all headwaters of Los Trancos Creek. Most of Corte Madera and West Union Creeks headwaters drain protected or forested areas. In a number of respects, the distribution of land uses in San Francisquito watershed is atypical for west-side watersheds. San Francisquito watershed has a greater proportion of 1 to 3 DU/acre housing than any other watersheds in the Basin, and exhibits a more heterogeneous mix of land uses throughout. The pattern of land use in the upper elevation zone is unusual due to the presence of residential development, consisting of 1 to 3 DU/acre with pockets of 1 DU/2 to 5 acres rather than 4+ DU/acre (as seen in San Tomas, Guadalupe, and Lower Penitencia watersheds). The transition from the upper to the lower elevation zone is unique because land uses shift from primarily natural conditions to moderate, rather than 4+ DU/acre, residential development. Moreover, unlike most other watersheds in the Basin, large contiguous sections of natural areas (forest and rangeland), as well as agriculture, exist in the lower elevation zone. In the lower elevation zone, the diversity and distribution of land uses is greater than other watersheds. The land use pattern typical of most west-side watersheds in the lower elevation zone (predominantly residential, 4+ DU/acre with public/quasi-public and commercial development interspersed) only manifests below 200 feet elevation (downstream of the Hetch Hetchy Aqueduct) whereas most other watersheds exhibit this pattern immediately below the transition zone. Moreover, even in this low position in the watershed, forests and urban recreation areas exist. Stanford University owns 35 percent of the watershed.

Guadalupe River. Like other west-side watersheds, the majority of the upper elevation zone in Guadalupe River watershed is undeveloped (forest and rangeland), however, a greater-than-typical proportion of this area (three-quarters) is legally protected. Thus, virtually all headwaters to Guadalupe River drain from permeable, protected areas. Over three-quarters of the headwaters to Los Gatos Creek drain from such areas, as do about one-half of the headwaters to Alamitos Creek. Unlike other watersheds, numerous pockets of 4+ DU/acre residential development and areas of vacant/undeveloped land also exist in the upper elevation zone. The pattern of land uses in the lower elevation zone is typical of west-side watersheds (see description under Stevens Creek watershed). Exceptional to this watershed is the presence of agriculture in the lower elevation zone (both at its upper and lower extents), and the presence of forest and rangeland. Although a low proportion of this watershed exists as vacant/undeveloped land, a large, contiguous area of vacant/undeveloped land exists in the lower watershed, downstream of U.S. Highway 101. The Guadalupe River watershed is transected by most of the large transportation corridors in the Basin, and an unusually large transportation/communication development exists. One effect of the broad transportation network is a more distributed pattern of industrial uses throughout the lower elevation zone than typically exists in watersheds in the Basin.

West-side watersheds containing a high proportion of natural areas (approximately 40 percent) and residential development (approximately 45 percent) and a moderately low proportion of industrial/commercial development (10 to 15 percent) consist of the following:

Adobe Creek. About 40 percent of the area draining to Adobe Creek watershed is undeveloped, existing primarily as forest in the upper elevation zone, and draining virtually all of Adobe Creek's headwaters. The area in the lower elevation zone is almost exclusively 4+ DU/acre residential development. Near the northern edge of the watershed, southwest of Interstate 280, pockets of vacant/undeveloped land exist and public land use occurs. Immediately north of Interstate 280 the residential land use becomes 1 to 3 DU/acre, and numerous smaller areas under public land use are interspersed. Commercial land use is clustered along U.S. Highway 101. What little industrial development exists in this watershed is located on lands draining to the extreme downstream reaches of Adobe Creek.

Permanente Creek. Similar to Adobe Creek watershed, about 40 percent of the area draining to Permanente Creek is undeveloped, and primarily forested in the upper elevation zone (Figure 4-5) About half of the creek-miles in the upper elevation zone drain are protected, permeable areas. In contrast to the Adobe Creek watershed, both mine/quarry/gravel and light industrial land uses protrude into the forested upper zone of the Permanente Creek watershed. A greater diversity and broader distribution of land uses exist in the lower zone on the southwest side of Interstate 280 than for Adobe Creek watershed. Residential development of 4+ DU/acre occupies the central area, but on the northern edge, pockets of vacant/undeveloped land and residential development of 1 DU/2 to 5 acres exist. Near the southern edge, a mosaic of urban recreation, vacant/undeveloped, public and commercial development, and small blocks of rangeland exist.

West-side watersheds containing a moderate proportion of natural areas (approximately 25 percent); high proportion of residential development (approximately 55 percent) and a moderate proportion of industrial/commercial development (approximately 20 percent) consist of the following:

San Tomas Aquino Creek. Although only a moderate proportion of San Tomas watershed in the upper elevation zone remains undeveloped as forest and rangeland, about two-thirds of these areas are legally protected. The majority of Saratoga Creek's headwaters drain from such protected areas, as do several headwater streams of San Tomas Aquino Creek. The San Tomas watershed is unusual because vacant/undeveloped, commercial, and moderate- and 4+ DU/acre residential development also exist in the upper elevation zone. The lower elevation zone in San Tomas watershed is typical of west-side watersheds (see description for Stevens Creek watershed). Unusual features of this watershed include the presence of the largest contiguous area of 1 DU/2 to 5 acres housing in the Basin, and a distinct land use pattern in the lower watershed (area draining north and south of U.S. Highway 101): virtually all of this area exists as industrial development, with a smaller proportion (than typical for west-side watersheds) of commercial, public/quasi-public, transportation/communication, residential development of 4+ DU/acre, and urban recreation areas. This composition and distribution of land uses is more typical of the valley-floor watersheds.

West-side watershed containing minimal upper elevation zone, a low proportion of natural areas (approximately 15 percent), a very high proportion of residential development (55 to 60 percent), and a moderate proportion of industrial/commercial development (20 to 30 percent) consist of the following:

Matadero/Barron Creeks. Unlike Adobe and Permanente watersheds, the upstream extent of the Matadero/Barron watershed coincides with the transition between upper and lower elevation zones; thus, extremely little area exists in the upper elevation zone. The majority of the area draining to the headwaters of Matadero and Barron Creeks is developed for residential use at either 4+ DU/acre or 1 to 3 DU/acre; only a small proportion of the area draining to the headwaters is undeveloped as either forest or rangeland, or relatively nonurbanized (urban recreation, and vacant/undeveloped land uses). This watershed has the second highest percentage of 1 to 3 DU/acre residential development of watersheds in the Basin. Both the diversity and distribution of land uses present in this watershed are greater than for most other watersheds; forest, grassland, and 1 to 3 DU/acre residential areas extend to the valley floor, up to and beyond where the flood control bypass channels cross the watershed. Areas draining the lower reaches of Matadero and Barron Creeks (less than 200 feet elevation, and north of the Hetch Hetchy Aqueduct) are primarily 4+ DU/acre residential, with very little (less 1 percent) industrial development. An unusual aspect of this watershed is the large proportion of the lower watershed occupied by contiguous public/quasi-public development.

Calabazas Creek. The upper elevation zone of the Calabazas Creek watershed is small compared to other west-side watersheds, but is mostly undeveloped, existing as forest or rangeland (one-quarter of which is legally protected), or as vacant/undeveloped land. Thus, the upper reaches of

Calabazas Creek, and some of its headwaters, drain from permeable, undeveloped areas. A minimal amount of residential development at both 1 DU/2 to 5 acres and 1 to 3 DU/acre exists in the upper elevation zone, but unique to this watershed is the presence of several areas of heavy industry in this zone. The majority of the lower elevation zone is occupied residential development at 4+ DU/acre, with public/quasi-public, commercial, and some urban recreation and agricultural areas interspersed. Two large, contiguous areas of heavy industry are located near Interstate 280 and U.S. Highway 101.

Valley Floor (see Figure 4-6 for an example watershed). The Valley Floor has the following characteristics: headwaters originate in the Santa Cruz Mountains; watershed is confined to the lower elevation zone (Basin floor); few natural areas exist; there is a very high proportion of industrial and commercial development (30 to 65 percent); and there is a moderate to very high proportion of residential development (20 to 65 percent):

Valley floor watersheds with a high ratio of industrial/commercial to residential development (3:1) consist of:

<u>Sunnyvale West</u>. Although lacking both forest and rangeland, Sunnyvale West watershed has a very high percentage of urban recreation area (second only to the Baylands watershed), of which approximately one-quarter is legally protected. Such permeable areas, however, are located at the downstream end of the watershed, and thus do not buffer the upper reaches of the channels in this watershed from urbanized areas. The Sunnyvale West watershed is unique in having a greater proportion developed as industrial and commercial land uses than any other Basin watershed. The land use pattern in the upper-third of this watershed is similar to that described for the lower elevation zone of the west-side watersheds (see Stevens Creek watershed description); however, the pattern in the lower two-thirds of the watershed is distinct: industrial and public/quasi-public development cover over three-quarters of the area. The remaining area is mostly occupied by urban recreation, agriculture, and vacant/undeveloped lands.

Valley floor watersheds with a high ratio of residential to industrial/commercial development (2:1) consist of:

<u>Sunnyvale East</u>. The pattern of land use in the Sunnyvale East watershed closely resembles that described for the lower elevation zone of the west-side watersheds (see Stevens Creek watershed description); however, a greater proportion of this watershed is developed as commercial, public/quasi-public, and industrial land uses than the west-side watersheds (Figure 4-6). Virtually none of the land draining to either Calabazas Creek or lower tributaries initiating in Sunnyvale East watershed exists as permeable, undeveloped land use.

East Side (see Figure 4-7 for an example). The East Side has the following characteristics: headwaters originate in the Diablo Range; both the upper and lower elevation zones are represented; the upper watershed is nonurbanized and has a high ratio of rangeland to forest; the lower watershed is urbanized; and watershed morphology is broader than west-side watershed morphology.

East-side watersheds with a moderate to high proportion of natural areas (approximately 20 – 40 percent) in upper elevation zone and in which a transition between nonurbanized and urbanized land uses occurs at lower elevation (200 to 400 feet) consist of:

<u>Lower Penitencia Creek</u>. About 50 percent of the Lower Penitencia watershed exists as permeable land uses (40 percent rangeland; 10 percent urban recreation, forest, and agriculture), but less than a quarter of this total area is legally protected (Figure 4-7). Headwater streams for Calera Creek drain this protected area, as do some upper reaches of Arroyo de los Coches Creek; however, none of Berryessa Creek tributaries drain protected areas. Land use patterns in Lower Penitencia's upper elevation zone are typical of east-side watersheds: small pockets of residential development and vacant/undeveloped land, and agriculture amidst undeveloped area with a high ratio of rangeland to forest. Unique for east-side watersheds is the presence of two small mine/quarry/gravel areas in Lower Penitencia's upper elevation zone. The majority of the lower elevation zone is occupied by residential development at 4+ DU/acre. Interspersed are pockets of commercial and public/quasi-public development, and vacant/undeveloped areas. Lower Penitencia watershed is bisected by one major transportation corridor (Interstate 880), near which most of the industrial development lies as both scattered and large contiguous areas, and an area of transportation/communication development exists. Urban recreation areas are associated with the lower reaches of Lower Penitencia, Berryessa, and Calera Creeks. The headwaters of Lower Penitencia Creek, located in the lower elevation zone, drain from agricultural areas.

<u>Arroyo la Laguna</u>. A lower percentage of the Arroyo la Laguna watershed's upper elevation zone exists as permeable land use as compared to that for the Lower Penitencia watershed. Since about one-third of the lower elevation zone exists as wetlands (legally protected), however, a higher percentage of Arroyo la Laguna watersheds is undeveloped. The headwaters for Agua Caliente and Mission Creeks drain from protected, forested areas. Arroyo la Laguna's upper elevation zone has a similar land use pattern to Lower Penitencia's, except that a greater proportion of the residential development is at 1 DU/2 to 5 acres, and a greater proportion of this zone is forested. Land use patterns in the lower elevation zone are also similar to those in Lower Penitencia, mainly differing by having a prevalence of large, contiguous agricultural areas, fewer large areas of rangeland, an area developed for mine/quarry/gravel development, and a large expanse of wetlands by the Bay. Notably, Arroyo la Laguna watershed has the largest percentage of area under agricultural cultivation.

East-side watersheds with a very high proportion of natural areas (approximately 80 percent) in the upper watershed consist of:

<u>Coyote Creek</u>. Despite the relatively vast size of the Coyote Creek watershed, and the huge proportion of undeveloped land in its upper elevation zone, the composition and distribution of land uses are similar to those of other east-side watersheds. The upper elevation zone is comprised mainly of rangeland and forest (about one-third legally protected), but the rangeland-to-forest ratio is lower than for other east-side watersheds. The upper reaches of Arroyo

Aguague, San Felipe, Little Coyote, Middle Fork Coyote, Soda Springs, Grizzly, and numerous unnamed creeks drain from such protected, permeable areas, as do the mid-reaches of Upper Penitencia Creek. Urbanized land use is confined to the downstream region of the lower elevation zone, and to several small areas in the lower elevation zone near the mainstream of Coyote Creek. Within the matrix of residential development at 4+ DU/acre, public/quasi-public and commercial development are interspersed (the latter clustered along major surface streets), and industrial development exists near major transportation corridors, particularly concentrated in the narrow downstream neck of the watershed. Agricultural and vacant/undeveloped lands exist on the up-slope urban fringes, as well as in the narrow downstream neck. Though proportionately less area is agriculturally cultivated than Lower Penitencia watershed, the total area is much greater, and Coyote contains the largest contiguous agricultural areas in the Basin. The frequent interspersion of urban recreation areas, and their presence along much of lower Coyote Creek, is unusual for the east-side, but is also observed in the Guadalupe River watershed.

Baylands. The Baylands is a unique area in the Basin because it drains from both the Santa Cruz Mountains and the Diablo Range, contains relatively little development, is mostly at or near sea level, and is over 50 percent wetlands (about one-third of which is legally protected). Approximately 75 percent of its area is permeable and undeveloped, and includes (in addition to wetlands), the greatest percentage of urban recreation and agricultural land uses of any watershed in the Basin (Table 4-3). The predominant developed land use in the Baylands is residential at 4+ DU/acre followed by approximately equal area devoted to development for industrial, commercial and utility enterprises. The Baylands periphery is surrounded, rather than bisected, by major transportation corridors including U.S. Highway 101, Interstate 880, and State Highway 237.

Subwatersheds

In this section, land use patterns for subwatersheds within the Basin are presented pictorially for one watershed (Figure 4-9) and in tabular format for all watersheds (Table 4-5). Due to the number of subwatersheds (58) in the Basin, an in-depth, narrative description of the composition and distribution of land uses within subwatersheds is not provided here. Analysis of land use at the subwatershed scale, however, will be important for subsequent WMI tasks that (1) evaluate effects of land uses on riparian corridor features and (2) develop watershed management plans.

Jurisdictions

Jurisdictions included in the Basin are listed and illustrated on Figure 4-2 and in Table 4-6. Most municipalities in the Basin are more than 90 percent built out. Exceptions are Milpitas, San Jose, and unincorporated areas in the county. The following land use patterns are observed for municipalities:

- Residential is the majority land use in west-side communities and in San Jose.

- Commercial land use is less than 12 percent in all communities.
- Industrial land use is greatest (17 to 21 percent) in Milpitas, Sunnyvale, Mountain View, and Santa Clara.
- Public/Institutional land use is greatest in Palo Alto (26 percent); other municipalities range between 0 to 13 percent.
- Parks/Open Space land use is greatest in Palo Alto and Los Gatos.
- Vacant/Agriculture land use is greatest in unincorporated areas of Santa Clara County (73 percent), and is relatively high in Milpitas and Saratoga (20 to 26 percent).
- The percentage of municipal area developed as roadways is greatest in Campbell, Mountain View, Santa Clara, Cupertino, and Los Altos (17 to 21 percent).

4.2.3.2 Distribution of Projected Land Uses by Watersheds (1995 – 2020)

The following section presents projected land use patterns (Table 4-7, Figures 4-10 through 4-12) for the Basin from 1995 to 2020. The year 1995 was used as the baseline for analysis due to the organization of both existing and projected data (ABAG 1996, 1998). The format of the Projections '98 land use data (ABAG 1998) also defined the finest spatial resolution (U.S. Census tract) and land use categories (residential and industrial/commercial) presented here. Land use patterns are depicted both by U.S. Census tracts to provide information on projected development patterns within watersheds, and by watersheds to provide projected development summaries at the scale of the assessment (e.g., watersheds).

To best understand the results presented below, particularly the estimates of percent buildout (Figure 4-12), it is critical to understand the "available acreage" category included in the Projections '98 data. Thus, in addition to being presented in Appendix 4B, it is reiterated here. The available acreage category includes vacant and redevelopable land, but excludes parks, open space, agriculture, vacation homes, and rural residential housing (less than 1 DU/10 ac). This definition influences how one interprets the information provided for percent watershed area projected as developed, and for percent watershed area available for further development, post-2020. For example, by 2020, the large Census tract in the upper Guadalupe watershed is projected to have no industrial/commercial development, and to have 1 to 33 percent residential development (Figures 4-11 and 4-10, respectively). At that time, this area will be considered built out, because despite the presence of undeveloped land, land use policies indicate that no further land will be available for development after 2020 (Figure 4-12).

Watersheds

Trends in projected residential and industrial/commercial development are presented below using the following categories: watersheds with the greatest percentage of area developed as residential and/or industrial/commercial land uses; watersheds with the greatest *increase* in the percent of their watershed developed between 1995 and 2020 for residential and/or industrial/commercial land uses; and watersheds with the greatest percent buildout by 2020 (buildout reflects percent watershed development according to zoning for respective development types). Assignment to these categories was determined by identifying which watersheds equaled or exceeded the median values calculated for all watersheds. These trends are supported by Table 4-7 and Figures 4-10 through 4-12.

Greatest percent watershed developed for residential and/or industrial/commercial land uses by 2020:

- *Both residential and industrial development*: Calabazas, Matadero/Barron, San Tomas, and Sunnyvale East
- *Residential development only*: Adobe, Permanente, and San Francisquito
- *Industrial development only*: Arroyo la Laguna, Baylands, Lower Penitencia, and Sunnyvale West

Greatest increase in percent watershed developed since 1995:

- *Both residential and industrial development*: Arroyo la Laguna, Lower Penitencia, and Sunnyvale East
- *Residential development only*: Adobe, Coyote, Matadero/Barron, and San Francisquito
- *Industrial development only*: Baylands, Calabazas, San Tomas, and Sunnyvale West

Greatest percent watershed buildout by 2020:

- *Both residential and industrial development*: Calabazas, Matadero/Barron, Permanente, and San Tomas
- *Residential development only*: Adobe, Guadalupe, and Stevens
- *Industrial development only*: Lower Penitencia, San Francisquito, and Sunnyvale West

The above trends in projected development indicate that, in the next two decades, the northeast section of the Basin (Arroyo la Laguna and Lower Penitencia watersheds) will experience the greatest amount of growth for both residential and industrial/commercial land uses. The northwest corner of the Basin, and much of the eastern Basin, will also experience considerable residential development. Industrial/commercial development will continue to dominate in the valley floor, increasing most in the Baylands and lower portions of watersheds located in south and central areas on the west side of the Basin. By the year 2020, most watersheds will be 90 to 95 percent built out, placing a greater requirement on redevelopment activity. San Francisquito and the watersheds on the east side of the Basin will provide the greatest available acreage for new development.

Subwatersheds

The level of effort required to present projected land use patterns for subwatersheds within the Basin such data in pictoral and/or tabular format is beyond the scope of this analysis and will be most relevant once the WMI is ready to prepare the Watershed Assessment Report.

4.2.4 Recommendations for Further Analysis

Two analyses of land use data are recommended for the Watershed Assessment Report and subsequent watershed management plans, as described below.

4.2.4.1 Estimate Percent Impervious Cover for Subwatersheds

Land uses characteristic of urbanization, including residential, commercial, and industrial development, typically increase the amount of impervious surface in watersheds and alter stream morphology, hydrology, and ecology, as well as water quality (Schueler 1995a). At the subwatershed scale, imperviousness can be correlated most successfully to environmental indicators (including fish and macroinvertebrate populations and streambed and bank features) in riparian corridors and addressed most successfully by management plans (Schueler 1995a, 1996b). Section 4.3 describes the percent impervious cover in Basin watersheds and enables the WMI to link impacts of land use patterns to riparian corridor health. For the Watershed Assessment Report and subsequent watershed management plans, however, it would be useful to analyze the percent impervious cover at the scale of subwatersheds.

4.2.4.2 Analyze Land Uses Within Riparian Corridors and Floodplains

Certain land uses and any impervious areas within riparian corridors and floodplains may have greater impacts on stream ecology and function than land uses outside of these hydrologic units (Tufford et al. 1998; Lammert and Allan 1999). Section 4.4 describes the distribution of land uses and additional features of interest within riparian corridors. For the Watershed Assessment Report and subsequent watershed management plans, it would be useful to examine spatial and temporal trends in the distribution of land uses within riparian corridors, and to correlate these changes with the respective conditions of the biological and physical stream resources.

Analysis of Imperviousness in Santa Clara Basin Watersheds

4.3.1 Introduction

Urbanization of watersheds contributes to changes in basin hydrology, channel morphology, and physiochemical water quality. Cumulatively, these changes impact instream habitat structure and associated biological communities. Quantifying the relationship between urbanization and metrics of aquatic ecosystem health is essential to successfully managing these resources. A common measure of urbanization is the percentage of watershed area covered by impervious surfaces (Arnold and Gibbons 1996). Impervious surfaces are those that prevent or inhibit rainfall infiltration to ground cover and groundwater, and include roads, sidewalks, roof tops, or parking lots. Soil infiltration capacity may also be reduced by accumulated salts associated with runoff, and by compaction associated with development activities that can render even landscaped, pervious areas somewhat impervious (Booth and Jackson 1997). As development increases, so typically does the percentage of watershed area covered by impervious surfaces (referred to as imperviousness).

Imperviousness has been identified as a useful environmental indicator for community-level and watershed planning because it is (1) cost-effective[4], (2) easily quantified, (3) well understood by a variety of professionals, and (4) provides an estimate of cumulative water resource impacts that can be linked to land use planning practices (Arnold and Gibbons 1996; Claytor and Brown 1996; May et al. 1997b; Center for Watershed Protection 1998c).

Imperviousness has most often been estimated using variations on two techniques: (1) direct measurement from remotely sensed data or from topographic maps; and (2) estimation from data including land use, zoning, road area or density, or population. Combining techniques and/or several data sources can improve the overall estimate of imperviousness, particularly when accuracies[5] of data sets vary; for example, the estimate of impervious area directly connected to stormdrain systems could be improved by combining high accuracy road area data with lower accuracy land use data. Choosing a technique or combination thereof depends on the accuracy required to address the questions being asked, and on available budget. The relative benefits of each are summarized below (Table 4-8).

4.3.2 Methods

Watershed imperviousness was estimated (Table 4-9) based on the 1995 land use data (ABAG 1996) and used to describe the distribution of land use throughout Basin watersheds (Section 4.1). As discussed in Section 4.1, the accuracy and spatial resolution of the ABAG land use data were suitable for analyzing the distribution of land uses within Basin watersheds; they were also suitable for estimating watershed imperviousness.[6]

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[4] Estimating percent imperviousness is cost-effective because data requirements are simple compared to other common techniques such as hydrologic modeling.

[5] Accuracy refers to precision of location, spatial resolution, and currency of data.

[6] At least one study (Couch 1997) found that imperviousness was not a good correlate of biological health (fish community assemblages) because it was not an accurate enough estimate. They resorted to estimating imperviousness from infrared satellite data.

Table 4-8
Techniques Used to Estimate Imperviousness

Technique	Effort/ Resources	Accuracy	Utility for Future Forecasting	Utility to Address Better Site Design	When to Use
Direct Measure					• GIS system in place • Large budget • Very accurate measure is needed • On a limited basis as a foundation for other techniques
Estimate From Data:					
Land Use					• Moderate budget • Moderate accuracy is needed
Zoning					• Rough estimate is sufficient • If more accurate land use data are unavailable
Road Area					• To estimate impervious area directly connected to stormdrain system • Combine with other data to estimate entire impervious area
Road Density					• Rough estimate is sufficient • In urban areas, if road area data are unavailable.
Population					• Rough estimate is sufficient: only appropriate for watershed scale

Adapted from Center for Watershed Protection 1998c.

Legend:

Best: Most accurate; least effort; can be used to forecast future impervious cover; can address better site design techniques.
Moderate
Worst

Table 4-9
Percentage of Santa Clara Basin Watershed Imperviousness Estimated from 1995 Land Use Data[1]

Watersheds	Land Uses	Impervious Acres	Percentage of Watershed Imperviousness
Adobe	Residential, 4+ DU/acre	2,178.3	30.1
	Commercial	398.4	5.5
	Residential, 1 to 3 DU/acre	285.1	3.9
	Public/Quasi-Public	145.4	2.0
	Heavy Industrial	132.9	1.8
	Transportation, Communication	57.8	0.8
	Forest	26.3	0.4
	Urban Recreation	12.1	0.2
	Agriculture	0.4	< 0.05
	Vacant/Undeveloped	1.2	< 0.05
	Rangeland	1.9	< 0.05
Arroyo la Laguna	Residential, 4+ DU/acre	9,137.2	19.2
	Heavy Industrial	2,166.0	4.6
	Commercial	1,953.2	4.1
	Light Industrial	1,653.6	3.5
	Public/Quasi-Public	759.4	1.6
	Transportation, Communication	552.2	1.2
	Urban Recreation	121.7	0.3
	Rangeland	93.2	0.2
	Agriculture	75.2	0.2
	Wetlands	60.4	0.1
	Utilities	27.4	0.1
	Forest	9.3	< 0.05
	Residential, 1 DU/2 to 5 acres	5.3	< 0.05
	Mines, Quarries, Gravel Pits	3.3	< 0.05
	Vacant/ Undeveloped	7.5	< 0.05
Baylands	Residential, 4+ DU/acre	1,612.5	7.9
	Heavy Industrial	923.2	4.5
	Commercial	808.1	3.9
	Urban Recreation	692.8	3.4
	Utilities	582.9	2.8
	Public / Quasi-Public	254.4	1.2
	Transportation, Communication	214.4	1.0
	Light Industrial	54.3	0.3
	Wetlands	52.6	0.3
	Agriculture	20.3	0.1
	Residential, 1 to 3 DU/acre	3.1	< 0.05
	Rangeland	3.4	< 0.05
	Sanitary Landfills	0.1	< 0.05
	Vacant/Undeveloped	1.3	< 0.05

Table 4-9 (continued)
Percentage of Santa Clara Basin Watershed Imperviousness Estimated from 1995 Land Use Data[1]

Watersheds	Land Uses	Impervious Acres	Percentage of Watershed Imperviousness
Calabazas	Residential, 4+ DU/acre	5,658.4	42.3
	Heavy Industrial	1,713.7	12.8
	Commercial	1,123.0	8.4
	Public / Quasi-Public	497.9	3.7
	Transportation, Communication	201.1	1.5
	Residential, 1 to 3 DU/acre	61.0	0.5
	Urban Recreation	28.5	0.2
	Forest	11.8	0.1
	Residential, 1 DU/2 to 5 acres	10.6	0.1
	Rangeland	7.0	0.1
	Vacant/Undeveloped	0.6	< 0.05
	Agriculture	0.9	< 0.05
Coyote	Residential, 4+ DU/acre	14,297.0	7.0
	Commercial	2,059.6	1.0
	Public / Quasi-Public	1,446.3	0.7
	Heavy Industrial	1,416.2	0.7
	Light Industrial	906.5	0.4
	Transportation, Communication	831.1	0.4
	Rangeland	610.9	0.3
	Urban Recreation	441.1	0.2
	Forest	373.0	0.2
	Agriculture	232.8	0.1
	Utilities	58.6	< 0.05
	Residential, 1 to 3 DU/acre	22.8	< 0.05
	Vacant/Undeveloped	16.9	< 0.05
	Mines, Quarries, Gravel Pits	2.9	< 0.05
Guadalupe	Residential, 4+ DU/acre	25,910.3	23.8
	Commercial	4,676.9	4.3
	Heavy Industrial	3,091.5	2.8
	Public / Quasi-Public	2,168.7	2.0
	Light Industrial	1,864.5	1.7
	Transportation, Communication	1,539.5	1.4
	Forest	378.0	0.4
	Urban Recreation	362.5	0.3
	Rangeland	168.5	0.2
	Residential, 1 to 3 DU/acre	100.7	0.1
	Agriculture	62.5	0.1
	Utilities	12.2	< 0.05
	Vacant/Undeveloped	13.3	< 0.05

Table 4-9 (continued)
Percentage of Santa Clara Basin Watershed Imperviousness Estimated from 1995 Land Use Data[1]

Watersheds	Land Uses	Impervious Acres	Percentage of Watershed Imperviousness
	Mines, Quarries, Gravel Pits	0.6	< 0.05
Matadero/Barron	Residential, 4+ DU/acre	3,920.7	36.1
	Public / Quasi-Public	1,106.2	10.2
	Residential, 1 to 3 DU/acre	726.8	6.7
	Commercial	518.0	4.8
	Transportation, Communication	97.4	0.9
	Heavy Industrial	83.1	0.8
.	Urban Recreation	77.7	0.7
	Forest	7.9	0.1
	Rangeland	7.6	0.1
	Utilities	0.8	< 0.05
	Vacant/Undeveloped	1.9	< 0.05
Lower Penitencia	Residential, 4+ DU/acre	4,437.2	24.3
	Light Industrial	1,261.4	6.9
	Commercial	495.5	2.7
	Heavy Industrial	453.7	2.5
	Public / Quasi-Public	444.5	2.4
	Transportation, Communication	424.0	2.3
	Urban Recreation	169.2	0.9
	Rangeland	70.7	0.4
	Residential, 1 to 3 DU/acre	58.2	0.3
	Agriculture	10.2	0.1
	Forest	2.1	< 0.05
	Mines, Quarries, Gravel Pits	1.2	< 0.05
	Utilities	0.4	< 0.05
	Vacant/Undeveloped	4.3	< 0.05
Permanente	Residential, 4+ DU/acre	3,884.0	35.0
	Public / Quasi-Public	329.8	3.0
	Commercial	173.8	1.6
	Light Industrial	153.0	1.4
	Heavy Industrial	86.6	0.8
	Residential, 1 to 3 DU/acre	79.9	0.7
	Transportation, Communication	69.9	0.6
	Forest	38.9	0.4
	Urban Recreation	33.2	0.3
	Residential, 1 DU/2 to 5 acres	10.9	0.1
	Mines, Quarries, Gravel Pits	10.6	0.1
	Rangeland	3.0	< 0.05
	Vacant/Undeveloped	0.8	< 0.05

Table 4-9 (continued)
Percentage of Santa Clara Basin Watershed Imperviousness Estimated from 1995 Land Use Data[1]

Watersheds	Land Uses	Impervious Acres	Percentage of Watershed Imperviousness
San Francisquito	Residential, 1 to 3 DU/acre	2,551.3	9.3
	Residential, 4+ DU/acre	1,642.1	6.0
	Public / Quasi-Public	531.8	1.9
	Commercial	470.9	1.7
	Transportation, Communication	195.1	0.7
	Forest	122.6	0.5
	Rangeland	86.5	0.3
	Urban Recreation	65.0	0.2
	Heavy Industrial	16.7	0.1
	Agriculture	12.2	< 0.05
	Residential, 1 DU/2 to 5 acres	1.7	< 0.05
	Utilities	1.2	< 0.05
	Vacant/Undeveloped	4.0	< 0.05
	Wetlands	0.5	< 0.05
San Tomas	Residential, 4+ DU/acre	12,365.8	43.1
	Commercial	1,627.4	5.7
	Heavy Industrial	1,554.2	5.4
	Public / Quasi-Public	1,187.8	4.1
	Transportation, Communication	283.7	1.0
	Urban Recreation	105.5	0.4
	Forest	68.1	0.2
	Utilities	27.7	0.1
	Residential, 1 DU/2 to 5 acres	11.2	0.0
	Residential, 1 to 3 DU/acre	12.5	0.0
	Rangeland	2.3	0.0
	Freshwater	0.0	0.0
	Agriculture	0.2	< 0.05
	Vacant/Undeveloped	2.6	< 0.05
Stevens	Residential, 4+ DU/acre	3,623.4	19.4
	Heavy Industrial	666.1	3.6
	Commercial	371.3	2.0
	Public / Quasi-Public	167.1	0.9
	Transportation, Communication	162.7	0.9
	Urban Recreation	96.6	0.5
	Forest	92.0	0.5
	Utilities	85.4	0.5
	Residential, 1 to 3 DU/acre	42.8	0.2
	Rangeland	23.3	0.1
	Agriculture	1.8	< 0.05
	Mines, Quarries, Gravel Pits	1.2	< 0.05

Table 4-9 (concluded)
Percentage of Santa Clara Basin Watershed Imperviousness Estimated from 1995 Land Use Data[1]

Watersheds	Land Uses	Impervious Acres	Percentage of Watershed Imperviousness
	Vacant/Undeveloped	0.4	< 0.05
Sunnyvale East	Residential, 4+ DU/acre	2,410.3	52.9
	Commercial	559.0	12.3
	Heavy Industrial	381.7	8.4
	Public / Quasi-Public	294.4	6.5
	Transportation, Communication	74.4	1.6
	Urban Recreation	23.5	0.5
	Utilities	3.5	0.1
	Vacant/Undeveloped	0.1	< 0.05
Sunnyvale West	Heavy Industrial	1,091.7	22.5
	Public / Quasi-Public	1,028.2	21.2
	Residential, 4+ DU/acre	823.1	17.0
	Commercial	236.0	4.9
	Light Industrial	214.6	4.4
	Urban Recreation	58.4	1.2
	Transportation, Communication	52.1	1.1
	Utilities	11.7	0.2
	Agriculture	1.5	< 0.05
	Sanitary Landfills	0.7	< 0.05
	Vacant/Undeveloped	0.7	< 0.05

[1] Analysis was completed prior to the provisional revision of the Baylands boundary. Therefore, values depicted for the Baylands and the Arroyo la Laguna watershed do not reflect the revised boundary.

Coefficients of imperviousness were identified for the ABAG land use data based on previous studies[7] (Bredehorst 1981; EOA 1999). Most imperviousness coefficients were drawn from Bredehorst (1981), who studied a statistically representative random sample of land use classes within the Los Angeles Flood Control District's jurisdiction (Appendix 4A, Table 4A-1). These coefficients were rounded to two significant digits for this analysis, per personal communication with District staff[8]. For land use classes that were not sampled by Bredehorst, we used coefficients developed by Eisenberg, Olivieri, and Associates (EOA 1999) to estimate imperviousness (Appendix 4A, Table 4A-1). Some coefficients from both studies were truthed in a GIS by overlaying land use data on orthophotographs and digitizing impervious areas on the computer screen for up to 5 polygons for selected land uses (Appendix 4A, Table 4A-1).

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[7] A literature search was conducted to identify studies that (1) had the most accurate imperviousness estimates (based on their methods and data sources), and (2) were conducted in regions with similar climate and land use patterns.

[8] Iraj Nasseri, Chief Hydrologist, Los Angeles Flood Control District.

Once entered into a lookup table (Dbase format), imperviousness coefficients were linked to the land use GIS coverage. The imperviousness of land uses was estimated by multiplying land use acreages by imperviousness coefficients. Estimates of impervious watershed acreages were generated by intersecting existing[9] land uses with watersheds in a GIS (Table 4-9). The percentage of each watershed's area estimated to be impervious (Table 4-10) was calculated subsequently. Projected imperviousness for Basin watersheds (Table 4-10) was estimated by taking the difference between existing and projected land use acreages for each watershed (using the results of analyses described in Section 4.1); assigning coefficients of imperviousness to the projected land use classes (residential, 0.86; industrial/commercial, 0.91); and multiplying the coefficients by the differences between existing and projected land use acreages.

4.3.3 Results

Percent watershed imperviousness estimated for each watershed is listed for both existing and projected land uses (Table 4-9). Existing percent watershed imperviousness appears to correlate with the relative percent watershed developed. Table 4-9 illustrates that Coyote Creek watershed had the least impervious landscape (11.1 percent), and the least percent acreage existing as either residential (8.6 percent) or industrial/commercial (3.7 percent) land uses, and the greatest percent acreage existing as relatively undeveloped land uses (87.1 percent). Conversely, Sunnyvale East watershed had the most impervious landscape (82.2 percent), and the greatest percent residential (65.3 percent), the second greatest percent industrial/commercial (31.8 percent) land uses, and the least percent acreage existing as relatively undeveloped land uses (2.9 percent).

The projected increase in the percentage of watershed imperviousness (1995 – 2020) ranged from 0.03 percent to 6.9 percent (Table 4-9). Watersheds estimated to experience the greatest increase in impervious area were Arroyo la Laguna (6.9 percent), San Francisquito (5.3 percent), and Lower Penitencia (4.6 percent) (Table 4-9).

The relative contributions of individual existing land uses to the percentage of watershed imperviousness are described in Table 4-10. In most watersheds, residential land uses at 4+ DU/acre contributed the most to watershed imperviousness. Either industrial (mostly heavy), commercial, or public/quasi-public land uses typically contributed the next most to the percentage of watershed imperviousness. The Sunnyvale West watershed was an exception, in which heavy industry most contributed to watershed imperviousness.

Estimates of watershed imperviousness are sorted in descending order of relative contribution by land use in Table 4-9 (ABAG 1996 – see Section 4.2 for a description of this data source and analysis). Impervious acres and percentages were rounded to single digits; thus, percentages less than 0.05 are reported in this single value class. For total watershed imperviousness see Table 4-10.

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[9] Existing as of 1995, based on ABAG land use data (1996). See Section 4.1 for complete description of how existing land use was analyzed.

Insert Table 4-10

Watersheds are sorted in ascending order by existing percent imperviousness. Also shown are total watershed acreages, number of existing[10] and projected[11] watershed acres estimated to be impervious, existing and projected percentage of watersheds estimated to be impervious, the difference between existing and projected watershed imperviousness and the percentage of watersheds occupied by grouped, land use categories[12]. Data sources included existing land use (ABAG 1996), projected land use (ABAG 1998), and coefficients of imperviousness (Bredehorst 1981; EOA 1999).

4.3.4 Discussion

4.3.4.1 The Importance of Scale

Imperviousness has been identified as a useful quantitative measure for evaluating effects of urbanization and land use planning practices on the health of aquatic ecosystems. This measurement has become popular because it provides a single, quantifiable measure that is easily understood by planners, engineers, landscape architects, scientists, local officials, and citizens (Schueler 1995a). It is important, however, to apply this measurement at appropriate spatial scales. Past studies have found that estimates of imperviousness best correlate with ecological indicators[13] at a subwatershed scale, typically those delineated at a third-order scale; for example, the area draining to the point where two second-order[14] streams merge (Center for Watershed Protection 1998c) (Figure 4-13).

The Basin's watersheds range from first to sixth order based on 1:24,000 scale mapping[15]. Several Basin watersheds are third order or smaller, and thus are suitable sizes for applying imperviousness statistics (Table 4-11). Others require delineation of subwatersheds to at least a third-order level. Because this tool is only appropriately applied to hydrologic units that are at most third-order in size, the analysis presented in this section is useful for general description and for regional planning, but is not appropriate as a basis for detailed subwatershed assessment or planning[16]. To assess the relationship between imperviousness and the aquatic ecosystem health, the WMI will need to estimate imperviousness for third-order (or smaller) subwatersheds within

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[10] Existing references the year 1995, used as a baseline date based on the currency of the ABAG land use data (1996).

[11] Time frame for projections is 1995 – 2020. See Section 4.1 for a complete description of how projected land use data (Projections '98) was analyzed.

[12] The grouped land use categories correspond to subtotals calculated for Table 4.3, Percent of Santa Clara Basin Watersheds as Existing (1995) Land Uses presented in Section 4.1 of Chapter 4. Note: the percentages in the Agriculture/Open category represent a combination of the surface water and the less developed land use categories.

[13] Including instream habitat structure, riparian buffer integrity, biological integrity of macroinvertebrate and fish communities.

[14] Strahler (1957).

[15] Note that the scale of data used to assign stream/drainage order influences the size of the hydrologic unit: larger scale mapping will include a greater number of streams than smaller scale mapping, thus hydrologic units mapped from larger scale data will be smaller than those mapped from smaller scale data.

[16] An initial assessment of subwatershed order was done to complete the analyses for this chapter, however, the source data available at the time analysis was initiated was not entirely suitable for this exercise: the data set used was developed by the Water District in 1985; their subwatershed boundaries were delineated to coincide with streamflow gage locations and features that influence streamflow, such as bridges. This method of delineation differs from one based on stream order.

the selected representative watersheds. Such analysis will require developing a creek data set with stream order as an attribute[17] and using it as a basis for delineating subwatershed boundaries.

Table 4-11
Drainage Order for Basin Watersheds[1]

Watersheds	Area (mi^2)	Drainage Order
Guadalupe	170	6
Coyote	321	5
San Tomas	45	5
Arroyo la Laguna	74	4
Baylands	33	4
Lower Penitencia	29	4
San Francisquito	43	4
Matadero/Barron	17	3
Adobe	11	3
Permanente	17	3
Calabazas	21	3
Stevens	29	3
Sunnyvale West	8	1
Sunnyvale East	7	1

[1] Sorted in descending order. Watershed area rounded to whole numbers.

4.3.4.2 The Importance of the Spatial Distribution of Land Uses

The percentage of watershed imperviousness is a metric that summarizes a complex mosaic of land uses. When interpreting imperviousness, it is essential to consider the spatial distribution of land uses within hydrologic units. The following examples illustrate this point.

As described in Section 4.2, the typical coarse-scale pattern of land use distribution in most Basin watersheds consists of steep uplands in relatively natural states that transition to urbanized lowlands adjacent to and on the valley floor. In general, the lower portions of these watersheds contain the majority of the impervious area, whereas the upper portions are relatively pervious. This pattern suggests that stream reaches in the upper watershed areas would be impacted less by impervious areas than streams in the lower watershed areas. This pattern, however, may not always be similarly interpreted for impacts to organisms. Anadromous fish, for example, may be affected by the conditions of lower reaches, which they must navigate to access their spawning and feeding habitat in upper reaches.

Figure 4-13 (front)

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[17] No existing stream data set includes stream order as an attribute. Thus, it is recommended that the WMI fund a task to attribute a creek data set, of suitable scale, and delineate subwatershed boundaries based on it.

Figure 4-13 (back)

Lammert and Allan (1999) explored the relationship between land use and several ecological indicators (instream habitat structure, an index of biological integrity for fish, and two multimetric indices for macroinvertebrates) at three scales of measurement (subcatchments, 250-meter-wide riparian corridor, and a 100-meter-wide riparian corridor). They found that land use measured within riparian corridors better predicted aquatic biotic condition than land use measured within subcatchments. Local habitat variables, however, best explained the variability observed in fish and macroinvertebrate communities (Lammert and Allan 1999). Thus, for the watershed assessments, the WMI may want to consider (1) identifying patterns of land use within riparian corridors at a finer spatial resolution than exists in the ABAG land use data, and (2) identifying and obtaining data pertaining to local aquatic habitat variables.

4.3.4.3 Correlating Imperviousness with Ecological Indicators

Numerous studies have identified relationships between drainage basin imperviousness and the health of receiving waterbodies (May et al. 1997a, b; Arnold and Gibbons 1996; Schueler 1994). Schueler (1995a) summarized a large body of research that related imperviousness to changes in the hydrology, habitat structure, water quality, and biodiversity of aquatic ecosystems. He found that these studies reported occurrence of stream degradation at similar levels of imperviousness. Based on this finding, Schueler (1995a, 1996b; Center for Watershed Protection 1998c) developed a model for classifying urban stream quality (Table 4-12) and for setting restoration and management objectives.

While Schueler's work demonstrates an approach that could be applied when assessing and planning for the Basin's subwatersheds, May et al. (1997a) found that physical, chemical, and biological characteristics of streams change with increasing urbanization in a continuous manner rather than according to thresholds. Because the studies Schueler reviewed occurred in dissimilar, humid ecoregions distant from the Bay Area, the classification thresholds he describes may not apply well to the Basin's streams. Comparing imperviousness to aquatic characteristics in a continuous manner is a useful mechanism for evaluating the classification thresholds and determining which may be appropriate for Basin streams. The WMI's watershed assessments could examine the correlation between percent imperviousness and biological stream characteristics for Basin streams, and determine whether classification thresholds can be well-defined and how they compare to those described by Schueler (1995a, 1996b; Center for Watershed Protection 1998c).

Instream infrastructure associated with flood control and water supply, and extractive activities such as aggregate mining, can have a large impact on aquatic resources (Williams and Wolman 1984; Lignon et al. 1995), yet such activities are not directly measured by percent imperviousness. Thus, correlating only percent imperviousness with physical, biological, and chemical stream characteristics may not sufficiently measure nor characterize human-associated impacts on aquatic resources.

Table 4-12
Model for Classifying Urban Streams and for Establishing Watershed Management Performance Criteria Based on Percent Subwatershed Imperviousness [1, 2]

Urban Stream Classification	**Sensitive: 0-10% Imperviousness**	**Impacted: 11-25% Imperviousness**	**Nonsupporting: > 25% Imperviousness**	**Restorable: ≤ 11% Imperviousness**
Indicators:				
Channel Stability	Stable	Unstable	Highly Unstable	See previous two columns
Water Quality	Good-Excellent	Fair-Good	Fair-Poor	"
Habitat Quality	Good-Excellent	Fair-Good	Fair-Poor	"
Stream Biodiversity	Good-Excellent	Fair-Good	Poor	"
Performance Criteria:				
Goal	Maintain predevelopment biodiversity	Limit degradation of stream habitat and quality	Minimize downstream pollutant loads	Restore stream biodiversity to impacted or sensitive levels
Land Use	Watershed and site impervious cover limits	Upper limit on subwatershed imperviousness	No watershed cap; redevelopment encouraged	Limited watershed redevelopment with full BMPs, some infill
BMPs	Maintain predevelopment hydrology and recharge	Emphasize pollutant removal and channel protection	Maximize removal of pollutants	Subwatershed restoration with stormwater retrofit ponds and wetland creation
Buffers	Wide riparian buffers to protect sensitive areas	Variable width riparian buffers	Greenway for recreation and flood protection	Acquisition or easements on stream corridors, riparian reforestation
Monitoring	Biological Indicators	Biological and physical indicators	Water quality trends and loads	Biological indicators, citizen monitoring

[1] Adapted from Schueler 1995a, 1996b; Center for Watershed Protection 1998c.
[2] Restorable streams are identified after inventorying all subwatersheds (Schueler 1996b).

4.3.4.4 Measuring Imperviousness

The methods used here to measure imperviousness could be modified to provide more accurate estimates applicable to hydrologic units smaller than watersheds; for example, equal to or less than 3rd order. For example, it would be useful to combine data describing actual road areas with the land use data employed for this analysis. The importance of the road-component of imperviousness is widely noted (Schueler 1994; Arnold and Gibbons 1996); roads are directly connected to stormdrain systems, and thus runoff contributed from their impervious area is quickly and completely transported. The ABAG data include few transportation routes due to the 2.5-acre spatial resolution of the data.

Several current projects within the Basin are estimating imperviousness using variations of the techniques presented above, and may provide methodologies and additional data that are useful for the WMI's assessments and watershed plans. The Stormwater Environmental Indicator Pilot Demonstration project is combining several data sources to estimate imperviousness for the Coyote Creek watershed. The Water District and the City of Mountain View are collaborating to estimate imperviousness by directly measuring from remotely sensed imagery.

Analysis of Land Use, Other Special Features in Riparian Corridors

4.4.1 Introduction

4.4.1.1 Riparian Corridor Definition

The term "riparian corridor" was developed to convey the importance of both aquatic and terrestrial resources that are ecologically linked to river systems. While no standard definition of a riparian corridor exists, one broadly accepted includes "banks and other adjacent terrestrial (as opposed to aquatic) environs of fresh waterbodies, watercourses, estuaries, and surface-emergent aquifers (springs, seeps, oases), whose transported freshwaters provide soil moisture sufficiently in excess of that otherwise available through local precipitation to potentially support growth of mesic vegetation" (Warner and Hendrix 1984). In some cases a riparian corridor is defined to include only area within the bank-to-bank stream channel (City of San Jose 1994).

Because no standard riparian corridor definition exists, municipalities have used one or more of the following approaches to identify riparian corridor boundaries: using physical attributes, including vegetation, stream morphology, or hydrology; assigning arbitrary widths; or mapping (City of San Jose 1994). The *Riparian Corridor Policy Study* (City of San Jose 1994) defined riparian corridors to include:

> "…any defined stream channels including the area up to the bankfull flow line, as well as all riparian (streamside) vegetation in contiguous adjacent uplands. Characteristic woody riparian vegetation species could include (but are not limited to): willow, *Salix* sp.; alder, *Alnus* sp.; box elder, *Acer negundo*; Fremont cottonwood, *Populus fremontii*; bigleaf maple, *Acer macrophyllum*; western sycamore, *Platanus racemosa*; and oaks, *Quercus* sp. Stream channels include all perennial and intermittent streams shown as a solid or dashed blue line on USGS topographic maps, and ephemeral streams or arroyos with well-defined channels and some evidence of scour or deposition."

4.4.1.2 Importance of Riparian Corridors

Riparian corridors provide a variety of ecosystem services that are important both for wildlife and for human societies; specifically, they:

- Provide food and habitat for aquatic and some terrestrial organisms
- Preserve water quality by filtering sediment from runoff before it enters surface waterbodies
- Protect streambanks from erosion
- Provide a storage area for floodwaters
- Preserve open space and aesthetic surroundings

4.4.1.3 Potential Conflicts

Preservation of riparian corridors often competes with other land uses, especially in growing urban areas. To address potentially incompatible land use development patterns in riparian corridors, many Basin municipalities have established riparian corridor policies that recommend either numeric or nonnumeric development setbacks. Numeric setbacks range from narrower, 100 feet from creek center beds, to wider, 100 feet from the edge of riparian vegetation or the top of streambank, whichever is wider. Nonnumeric setbacks include language that describes the establishment of buffers from adjacent land uses to protect natural creekside areas.

The size of riparian buffer needed to protect the ecological and functional integrity of stream systems is difficult to establish (Schueler 1995b). The minimum buffer width suitable for these purposes may be determined from the associated beneficial uses and from the quality of the existing riparian vegetation (Castelle et al. 1994). Increases in the percentage of watershed imperviousness (see Section 4.3) are often accompanied by proportionate increases in riparian buffer encroachment, contributing to the nonfunctional condition of riparian corridors (Castelle et al. 1994).

Maintaining the longitudinal connectivity of riparian corridors is at least as important as maintaining a riparian buffer width; however, it is often overlooked in riparian corridor policies. Riparian corridors in highly urbanized areas are often fragmented, particularly by road crossings, which disrupt habitat and introduce disturbances and pollutants to stream systems.

4.4.2 Methods

4.4.2.1 Riparian Corridor Mapping

For this analysis, the City of San Jose’s definition of riparian corridors was used. Where riparian vegetation data existed for streamside areas within the Basin, it was used to define riparian corridors; where riparian vegetation data was absent, riparian corridors were defined by a distance of 100 feet on either side of the creek centerline, or top of bank where available. This distance was chosen because most municipalities in the Basin have policies or ordinances requiring at least 100-foot setbacks from riparian vegetation or the top of streambanks Multiple creek data sets were compiled to provide comprehensive coverage of creeks throughout the entire Basin. The following lists the data used and the analyses conducted to develop a comprehensive data set of riparian corridors in the Basin:

Riparian Vegetation Communities

Riparian vegetation communities were mapped separately by the Habitat Restoration Group for areas within the City of San Jose for the City of San Jose's Planning Department, and unincorporated areas of Santa Clara County for the Water District. Vegetation mapping[18] was based on aerial photography from 1984 and 1990 for the City of San Jose, and from 1990 for the Water District. Different vegetation community classifications were used for these studies (Water District 1996, 1998).

Creeks Within Santa Clara Valley Water District Jurisdiction

The Water District maintains a GIS data set (Eircrks) that includes most creeks within their jurisdiction. They also maintain a large database (Waterways Management Model, or WWMM) that describes all channel modifications they have undertaken, and is associated with the creeks GIS data set. An attribute within the WWMM, width at the top of streambanks, was used to define the top of streambank edge. For areas lacking riparian vegetation data but included in the WWMM, riparian corridor areas were defined as those extending 100 feet beyond the top of streambank edges.

Canals and Reservoirs Within Santa Clara Valley Water District Jurisdiction

In addition to their creeks data set, the Water District maintains two other data sets that describe surface waterbodies: canals, and reservoirs. Where vegetation mapping was unavailable for these surface waterbodies, riparian corridor areas were defined as those extending 100 feet beyond the perimeter of canals and reservoirs.

Creeks in the Alameda and San Mateo County Portions of the Santa Clara Basin that were Outside Santa Clara Valley Water District Jurisdiction

Riparian corridors within the Basin and beyond the jurisdiction of the Water District were defined using a creeks data set (Reach File 3) compiled by the California Department of Fish and Game in cooperation with the California Rivers Assessment (CDFG 1999). For these creeks, riparian corridors were defined as those areas extending 100 feet beyond the creek centerlines.

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[18] Riparian vegetation was originally mapped on vellum and subsequently digitized and developed into GIS data by Thomas Reid and Associates. None of the airphotos were orthocorrected prior to human interpretation, and none of the mapped vegetation data has been ground truthed. Due to manual digitizing tolerance and media stretching, there is unquantified positional error in the data.

4.4.2.2 Identifying Land Uses in Riparian Corridors

Land uses within riparian corridors were identified by overlaying the compiled riparian corridor data set with the existing land use data (ABAG 1996) as described in Section 4.2. The number and percentage of land use acreages within riparian corridors were summarized by watershed (Table 4-13).

Defining and Identifying Special Features in Riparian Corridors

Special features within riparian corridors were defined as:

- Structures established to manage aquatic resources: dams, gages, channel modifications, and fish passage structures
- Fixed-location activities established to exploit aquatic resources: instream quarry operations

Data describing the special features were compiled from the following sources: Water District World Wide Web site[19] (dams, Table 4-14; gages, Table 4-15); Water District Waterways Management Model (channel modifications, Table 4-16); and personal communication with Water District staff (fish passage structures[20], Table 4-17; instream gravel quarry operations[21], Table 4-18). The number of linear creek feet in each watershed for each channel type was calculated by using a GIS to identify which watersheds creeks belonged to, and summing by creek and by watershed, the length of creek occupied by each channel type.

4.4.3 Results

4.4.3.1 Existing Land Use within Riparian Corridors

The percentage of watersheds occupied by riparian areas ranged from about 3.5 percent (Sunnyvale East) to 72.5 percent (Baylands), and the median was 7.7 percent (Table 4-13). The percentage of riparian corridor in the Baylands was much greater than all other Basin watersheds due to the abundance of marshlands. Although these are predominantly saltwater marshlands, they were included in this analysis because Warner and Hendrix’s definition (1984) includes estuaries. The percentage of riparian corridor in the Arroyo la Laguna watershed was also noticeably higher than other Basin watersheds because its watershed boundary currently includes a portion of the Baylands[22].

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[19] www.Water District.dst.ca.us

[20] David Salsbery, Fisheries Biologist, Water District

[21] Ken Reiller, Associate Civil Engineer, Water District

[22] Bayland areas within the Arroyo la Laguna watershed boundary will be removed as part of a project funded by the Santa Clara Urban Runoff Pollution Prevention Program. Figure 4-3 shows the revised boundary.

Table 4-13
Acreage and Percentage of Land Uses Within Riparian Corridors[1]

Watershed	Land Use	Acres	Percentage of Riparian Corridor	Percentage of Watershed
Adobe	Forest	241	39.18	3.32
	Residential, 4+ DU/acre	183	29.79	2.53
	Residential, 1 to 3 DU/acre	116	18.92	1.60
	Public/Quasi-Public	34	5.46	0.46
	Heavy Industrial	12	2.01	0.17
	Vacant/Undeveloped	11	1.81	0.15
	Urban Recreation	6	1.04	0.09
	Transportation, Communication	4	0.70	0.06
	Commercial	3	0.55	0.05
	Agriculture	2	0.40	0.03
	Rangeland	1	0.15	0.01
	Total	***614***	***100.00***	***8.48***
Arroyo la Laguna	Wetlands	3,520	57.77	7.39
	Residential, 4+ DU/acre	736	12.07	1.54
	Rangeland	561	9.21	1.18
	Bays and Estuaries	339	5.57	0.71
	Agriculture	175	2.87	0.37
	Light Industrial	132	2.17	0.28
	Commercial	116	1.90	0.24
	Heavy Industrial	116	1.90	0.24
	Urban Recreation	89	1.46	0.19
	Forest	87	1.42	0.18
	Vacant/Undeveloped	81	1.33	0.17
	Public/Quasi-Public	59	0.98	0.12
	Transportation, Communication	54	0.88	0.11
	Mines, Quarries, Gravel Pits	21	0.35	0.04
	Fresh Water	5	0.08	0.01
	Utilities	3	0.05	0.01
	Total	***6,093***	***100.00***	***12.79***
Baylands[2]	Wetlands	9,910	66.60	48.25
	Urban Recreation	2,654	17.84	12.92
	Utilities	803	5.40	3.91
	Heavy Industrial	362	2.43	1.76
	Commercial	293	1.97	1.43
	Rangeland	216	1.45	1.05
	Bays and Estuaries	136	0.92	0.66
	Residential, 4+ DU/acre	128	0.86	0.62

Table 4-13
Acreage and Percentage of Land Uses Within Riparian Corridors[1]

Watershed	Land Use	Acres	Percentage of Riparian Corridor	Percentage of Watershed
	Agriculture	112	0.75	0.55
	Transportation, Communication	90	0.60	0.44
	Vacant/Undeveloped	79	0.53	0.39
	Light Industrial	40	0.27	0.19
	Sanitary Landfills	6	0.04	0.03
	Fresh Water	2	0.02	0.01
	Total	***4,970***	***100.00***	***24.20***
Calabazas	Residential, 4+ DU/acre	435	55.98	3.25
	Commercial	123	15.86	0.92
	Heavy Industrial	103	13.26	0.77
	Forest	41	5.25	0.31
	Public/Quasi-Public	28	3.64	0.21
	Urban Recreation	13	1.64	0.10
	Rangeland	12	1.53	0.09
	Transportation, Communication	10	1.23	0.07
	Vacant/Undeveloped	8	0.97	0.06
	Residential, 1 DU/2 to 5 acres	5	0.61	0.04
	Agriculture	0	0.02	0.00
	Residential, 1 to 3 DU/acre	0	0.02	0.00
	Total	***777***	***100.00***	***5.81***
Coyote	Forest	8,263	49.13	4.03
	Rangeland	3,777	22.46	1.84
	Public/Quasi-Public	1,511	8.98	0.74
	Agriculture	1,086	6.46	0.53
	Residential, 4+ DU/acre	943	5.61	0.46
	Fresh Water	437	2.60	0.21
	Urban Recreation	242	1.44	0.12
	Vacant/Undeveloped	226	1.34	0.11
	Commercial	106	0.63	0.05
	Transportation, Communication	93	0.56	0.05
	Heavy Industrial	74	0.44	0.04
	Light Industrial	31	0.18	0.01
	Utilities	16	0.10	0.01
	Residential, 1 to 3 DU/acre	12	0.07	0.01
	Mines, Quarries, Gravel Pits	2	0.01	0.00
	Total	***16,819***	***100.00***	***8.20***

Table 4-13
Acreage and Percentage of Land Uses Within Riparian Corridors[1]

Watershed	Land Use	Acres	Percentage of Riparian Corridor	Percentage of Watershed
Guadalupe	Forest	3,782	42.10	3.47
	Rangeland	1,545	17.20	1.42
	Residential, 4+ DU/acre	1,297	14.43	1.19
	Vacant/Undeveloped	994	11.07	0.91
	Commercial	516	5.74	0.47
	Agriculture	204	2.27	0.19
	Urban Recreation	194	2.16	0.18
	Fresh Water	126	1.40	0.12
	Transportation, Communication	112	1.24	0.10
	Heavy Industrial	74	0.83	0.07
	Light Industrial	70	0.78	0.06
	Public/Quasi-Public	49	0.55	0.05
	Residential, 1 to 3 DU/acre	16	0.18	0.01
	Utilities	4	0.04	0.00
	Mines, Quarries, Gravel Pits	1	0.01	0.00
	Total	***8,984***	***100.00***	***8.25***
Lower Penitencia	Rangeland	549	46.21	3.00
	Residential, 4+ DU/acre	321	26.99	1.75
	Light Industrial	104	8.79	0.57
	Forest	58	4.90	0.32
	Public/Quasi-Public	38	3.18	0.21
	Urban Recreation	35	2.95	0.19
	Commercial	30	2.51	0.16
	Heavy Industrial	16	1.32	0.09
	Vacant/Undeveloped	14	1.21	0.08
	Residential, 1 to 3 DU/acre	11	0.94	0.06
	Transportation, Communication	8	0.63	0.04
	Mines, Quarries, Gravel Pits	3	0.28	0.02
	Agriculture	1	0.08	0.01
	Total	***1,188***	***100.00***	***6.50***
Matadero/Barron	Residential, 4+ DU/acre	239	39.62	2.20
	Residential, 1 to 3 DU/acre	82	13.54	0.75
	Forest	71	11.80	0.65
	Public/Quasi-Public	60	9.95	0.55
	Rangeland	59	9.84	0.55
	Commercial	32	5.25	0.29

Table 4-13
Acreage and Percentage of Land Uses Within Riparian Corridors[1]

Watershed	Land Use	Acres	Percentage of Riparian Corridor	Percentage of Watershed
	Transportation, Communication	23	3.81	0.21
	Urban Recreation	16	2.60	0.14
	Heavy Industrial	14	2.31	0.13
	Vacant/Undeveloped	8	1.27	0.07
	Total	***602***	***100.00***	***5.54***
Permanente	Forest	473	57.26	4.26
	Residential, 4+ DU/acre	270	32.65	2.43
	Mines, Quarries, Gravel Pits	17	2.05	0.15
	Vacant/Undeveloped	14	1.70	0.13
	Residential, 1 to 3 DU/acre	11	1.32	0.10
	Light Industrial	9	1.08	0.08
	Commercial	8	0.92	0.07
	Public/Quasi-Public	5	0.66	0.05
	Heavy Industrial	5	0.65	0.05
	Transportation, Communication	5	0.63	0.05
	Rangeland	4	0.49	0.04
	Residential, 1 DU/2 to 5 acres	3	0.41	0.03
	Urban Recreation	1	0.18	0.01
	Total	***826***	***100.00***	***7.45***
San Francisquito	Forest	906	47.54	3.31
	Residential, 1 to 3 DU/acre	353	18.52	1.29
	Residential, 4+ DU/acre	208	10.93	0.76
	Rangeland	130	6.80	0.47
	Vacant/Undeveloped	75	3.96	0.28
	Agriculture	70	3.66	0.25
	Urban Recreation	50	2.64	0.18
	Wetlands	40	2.09	0.15
	Public/Quasi-Public	20	1.03	0.07
	Commercial	19	1.02	0.07
	Transportation, Communication	15	0.80	0.06
	Fresh Water	14	0.76	0.05
	Heavy Industrial	4	0.21	0.02
	Residential, 1 DU/2 to 5 acres	0	0.02	0.00
	Total	***1,906***	***100.00***	***6.95***
San Tomas	Residential, 4+ DU/acre	770	42.03	2.68
	Forest	745	40.65	2.60

Table 4-13
Acreage and Percentage of Land Uses Within Riparian Corridors[1]

Watershed	Land Use	Acres	Percentage of Riparian Corridor	Percentage of Watershed
	Commercial	111	6.07	0.39
	Public/Quasi-Public	76	4.17	0.27
	Heavy Industrial	56	3.04	0.19
	Urban Recreation	31	1.67	0.11
	Vacant/Undeveloped	21	1.14	0.07
	Rangeland	11	0.60	0.04
	Transportation, Communication	6	0.31	0.02
	Fresh Water	5	0.26	0.02
	Utilities	1	0.04	0.00
	Total	***1,832***	***100.00***	***6.39***
Stevens	Forest	1,168	64.36	6.25
	Residential, 4+ DU/acre	265	14.62	1.42
	Rangeland	158	8.72	0.85
	Urban Recreation	84	4.63	0.45
	Utilities	82	4.52	0.44
	Commercial	23	1.28	0.12
	Transportation, Communication	13	0.70	0.07
	Heavy Industrial	12	0.68	0.07
	Vacant/Undeveloped	5	0.28	0.03
	Public/Quasi-Public	2	0.12	0.01
	Residential, 1 to 3 DU/acre	1	0.07	0.01
	Mines, Quarries, Gravel Pits	0	0.00	0.00
	Agriculture	0	0.00	0.00
	Total	***1,815***	***100.00***	***9.71***
Sunnyvale East	Residential, 4+ DU/acre	106	65.31	2.33
	Heavy Industrial	26	15.84	0.57
	Commercial	13	7.86	0.28
	Public/Quasi-Public	9	5.42	0.19
	Urban Recreation	5	3.36	0.12
	Transportation, Communication	2	1.19	0.04
	Utilities	2	1.02	0.04
	Total	***163***	***100.00***	***3.57***
Sunnyvale West	Urban Recreation	159	40.90	3.28
	Public/Quasi-Public	102	26.29	2.11
	Heavy Industrial	61	15.60	1.25
	Sanitary Landfills	28	7.17	0.57

Table 4-13
Acreage and Percentage of Land Uses Within Riparian Corridors[1]

Watershed	Land Use	Acres	Percentage of Riparian Corridor	Percentage of Watershed
	Commercial	15	3.78	0.30
	Vacant/Undeveloped	12	2.98	0.24
	Utilities	8	1.99	0.16
	Agriculture	4	1.00	0.08
	Light Industrial	1	0.28	0.02
	Rangeland	0	0.02	0.00
	Total	***389***	***100.00***	***8.01***

[1] Analysis was completed prior to the provisional revision of the Baylands boundary. Therefore, values depicted for the Baylands and the Arroyo la Laguna watershed do not reflect the revised boundary.

[2] The percentage of riparian corridor in the Baylands is much greater than all other Basin watersheds due to the abundance of marshlands. Although these marshlands are predominately saltwater, they were included in this analysis because the definition given in *California Riparian Systems* (Warner and Hendrix 1984) includes estuaries. The percentage of riparian corridor in the Arroyo la Laguna watershed is also noticeably higher than in other Basin watersheds because its watershed boundary currently includes a portion of the Baylands.

Although the relative proportions of land uses varied within each watershed's riparian corridors, several patterns exist (Table 4-13):

- West-side watersheds that drain the upper elevation zone (see Section 4.2) of the Santa Cruz Mountains (San Francisquito, Adobe, Permanente, Stevens, San Tomas, and Guadalupe) had a high proportion (approximately 39 to 64 percent) of forested riparian corridors, occurring mostly in the upper watershed areas. The two west-side watersheds that minimally drain the upper elevation zone (Matadero/Barron and Calabazas), had a correspondingly lower proportion (5 to 12 percent) of forested riparian corridors.

- East-side watersheds that drain from the Diablo Range (Arroyo la Laguna, Lower Penitencia, and Coyote) had a high proportion (approximately 22 percent to 46 percent)[23] of rangeland, occurring mostly in upper watershed areas. Coyote was the only east-side watershed to have an even higher proportion of forested area (approximately 49 percent).

- For most west-side and east-side watersheds, 4+ DU/acre residential land use comprised the second greatest proportion of riparian corridors. Exceptions were: San Francisquito (3rd), Guadalupe (3rd), and Coyote (5th).

- The two west-side, valley floor watersheds (Sunnyvale East and Sunnyvale West) both had moderately high proportions (approximately 15 percent) of heavy industrial land use in their riparian corridor areas. While a very high proportion of 4+ DU/acre residential land use (approximately 65 percent) existed in Sunnyvale East's riparian corridors, Sunnyvale West had none. Instead, Sunnyvale West had a high proportion of urban recreation (approximately 41 percent) and public/quasi-public (approximately 27 percent) land uses.

- The Baylands' riparian corridors were mostly occupied by wetlands (approximately 67 percent) and by urban recreational (approximately 18 percent) land uses.

All of the percentages discussed here and presented in Table 4-13 are based on land use data of relatively coarse spatial resolution; for example, the minimal mapping unit for the ABAG (1996) land use data is 2.5 acres. Thus, for the most part, the stream channels are not represented in the ABAG data. The land use acreages within riparian corridors presented here are therefore approximations of true riparian acreages. Moreover, these statistics do not represent the spatial distribution of land uses within riparian corridors, which greatly influences how land uses may affect aquatic resources. Table 4-13 provides the acreage and percentage of canal uses within riparian corridors (sorted in descending order; rounded to whole numbers; summarized by

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[23] Due to known error in the Arroyo la Laguna watershed boundary, the relative percentages of land uses within riparian corridors was recalculated without considering wetland areas. The resulting proportion of rangeland in riparian corridors increased from 9.2 to 21.8 percent.

watershed; and calculated as the percentage of watershed area). Residential land uses definitions are 1 DU/2-5 acres, 1-3 DU/acre, and 4+ DU/acre.

4.4.3.2 Other Special Features within Riparian Corridors

Dams

The Water District operates 44 dams throughout the Basin. These dams were constructed for water conservation (8 reservoir dams), groundwater recharge through diversion and percolation (35 spreader dams), and irrigation[24] through diversion (1 dam) (Table 4-14). Reservoir dams privately owned and operated include two operated by Stanford University, and one operated by the San Jose Water Company (Table 4-14). Additional existing water rights diversions on Basin streams are listed in Table 4-15.

The presence of dams on streams, especially those formed in alluvial deposits, can change mean channel-bed elevation, channel width, bed-material sizes, vegetation, water discharges, and sediment loads (Williams and Wolman 1984). The frequency and magnitude of such downstream changes, however, will vary depending on the dam size, whether its presence is seasonal, and the length of its operation time. In a study of 21 dams constructed on alluvial rivers in semiarid western United States, Williams and Wolman (1984) found that in all cases, flood peaks were decreased by the dams, but that other post-dam, water-discharge characteristics varied among rivers. Such variation likely occurred because the dams in their study were built for different purposes and thus released flows within a large range of magnitude and duration (Williams and Wolman 1984). Dams are listed in Table 4-14 by watershed and by creek. Also listed are dam purpose (WC = water conservation, P = percolation, D = diversion); and for spreader dams (e.g., percolation and diversion), the type (where data were available[25]), operation status[26], and date the dam was last installed (na = not available). Spreader dam overflows are thirty inches in diameter, located on the upstream dam lip, 3.5 feet below the top. Unless otherwise indicated, dams listed are operated by the Water District.

Listed below in Table 4-15 are the Water Rights Permittees (except the Water District, since Table 4-14 lists their water diversion facilities), the watershed and creek from which water is diverted, the intended water use (D = Domestic; M = Municipal; I = Industrial), and the number of water rights diversions permitted on each creek.

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[24] Standish Dam was originally an earthen dam constructed for agricultural irrigation. As part of the mitigation for construction of the lower Coyote Creek flood control bypass project, the dam was reconstructed to additionally provide juvenile summer rearing habitat. However, through an agreement with the CDFG, the dam is not now in place and future reconstruction of the dam is subject to agency approval (see Section 7.2.2.10 for more information).

[25] Blank spreader dam type indicates no data available from the Water District World Wide Website.

[26] Water District spreader dams have not been installed since 1997; reinstallation/operation is subject to permit approval by the CDFG.

Table 4-14
Dams Operated in the Santa Clara Basin[1]

Watershed	Dam Sites	Dam Purpose	Spreader Dams			
			Type	Status	Number Active	Date Last Installed
COYOTE	**Coyote Creek**					
	Anderson Reservoir	WC				
	Coyote Reservoir	WC				
	Burnett Ave.	P		Active	1	Mar. 11, 1995
	2000' U/S Golf Course Entrance	P		Active	2	Sep. 28, 1993
	1500' D/S Golf Course Entrance	P		Active	3	Sep. 29, 1993
	2500' U/S Ford Rd.	P	Gravel	Active	4	Feb. 2, 1998
	1700' U/S Ford Rd.	P	Gravel	Active	5	Feb. 2, 1998
	900' U/S Ford Rd.	P	gravel	Active	6	Feb. 2, 1998
	Coyote Canal Diversion	D	Board	Active	7	Nov. 16, 1998
	Coyote Percolation Dam[2]	P	Steel	Active	8	Nov. 17, 1998
	50' U/S Tennant Ave.	P		Abandoned		
	Standish Dam	D	Steel	Active	9	1997
	Upper Penitencia Creek					
	Noble Ave. #1A	D	Board	Active	10	na
	Maybury Ave. #72	D	Steel	Active	11	Nov. 9, 1998
GUADALUPE	**Alamitos Creek**					
	Almaden Reservoir	WC				
	Alamitos Dam	D	Board	Active	12	Feb. 25, 1999
	Arroyo Calero Creek					
	Calero Reservoir	WC				
	Guadalupe Creek					
	Guadalupe Reservoir	WC				
	160' U/S Meridian	P		Active	13	Oct. 4, 1993
	1300' D/S Meridian	P		Active	14	Oct. 5, 1993
	2270' D/S Meridian	P		Active	15	Oct. 5, 1993
	500' U/S Almaden Expwy	P		Active	16	Oct. 6, 1993
	Masson Dam	D	Board	Active	17	Mar.12, 1999
	Guadalupe River					
	D/S Alamitos Crk. Confluence	P	Board	Active	18	Feb. 25, 1999
	1600' D/S Blossom Hill Rd.[2]	P		Active	19	Oct. 6, 1994
	900' U/S Branham Rd.[2]	P		Active	20	Oct. 6, 1994
	D/S Alamitos Crk. Confluence	P	Gravel	Abandoned		
	1800' D/S Branham Rd	P		Abandoned		
	100' U/S Capitol Expswy	P		Abandoned		
	Los Gatos Creek					
	Lake Elsman[3]	WC				

Table 4-14 (concluded)
Dams Operated in the Santa Clara Basin[1]

Watershed	Dam Sites	Dam Purpose	Spreader Dams			
			Type	Status	Number Active	Date Last Installed
	Lexington Reservoir	WC				
	Vasona Reservoir	WC				
	300' U/S Hamilton	P		Active	21	Oct. 3, 1994
	300' U/S Bascom Rd. [2]	P		Active	22	Sep. 30, 1994
	1500' U/S Leigh[2]	P		Active	23	Sep. 26, 1994
	100' D/S Leigh	P		Active	24	Oct. 9, 1993
	1100' U/S Meridian	P		Active	25	Oct. 9, 1993
	Kirk Dam	D	Steel	Active	26	na
SAN FRANCIS-QUITO	**Bear Gulch Creek**					
	Bear Gulch Reservoir Diversion[4]	WC				
	Corte Madera Creek					
	Searsville Lake[5]	WC				
	Los Trancos Creek					
	Felt Lake[5]	WC				
	San Francisquito Creek					
	Lake Lagunita	WC				
SAN TOMAS	**Saratoga Creek**					
	300' U/S Cox Ave.	P		Active	27	Sep. 29, 1994
	150' U/S Prospect Ave.	P		Active	28	Sep. 28, 1994
	3300' U/S Bollinger	P		Active	29	Sep. 27, 1994
	2900' U/S Bollinger	P		Active	30	Sep. 26, 1994
	2100' D/S Bollinger	P		Active	31	Oct. 7, 1993
	2600' D/S Bollinger	P		Active	32	Oct. 6, 1993
	1100' U/S Prospect Ave.	P		Abandoned		
	Smith Creek					
	Elam Ave.	P	Steel	Active	33	na
	San Tomas Aquino Rd.	P	Steel	Active	34	na
STEVENS	**Stevens Creek**					
	Stevens Creek Reservoir	WC				
	200' D/S Hwy. 280	P		Active	35	Oct. 1, 1992
	100' U/S Fremont	P		Active	36	Oct. 3, 1994
	1200' U/S Homestead Rd.	P		Proposed		
	1225' U/S Fremont	P		Proposed		
	U/S Stevens Crk. Blvd.	P	Board	Proposed		

Notes:
[1] Data posted to the Water District internet site are unedited, and should be considered preliminary.
[2] Indicates spreader dams with permanent riser overflows set one foot below the top of the dam.
[3] The dam at Lake Elsman is operated by the San Jose Water Company.
[4] The Bear Gulch Reservoir Diversion Dam is operated by the California Water Service Company.
[5] The dams on Felt Lake and Searsville Lake are operated by Stanford University.

Hydrologic Gages

Since 1983, the Water District has constructed a series of gages that measure real-time streamflow, reservoir levels, and precipitation volume. Currently, they operate 51 streamflow gages and 8 reservoir gages (Table 4-16, Figure 4-14), as well as 40 precipitation gages in the Basin (Appendix 4A, Table 4A-2). The Water District uses streamflow information for flood protection management, to monitor hydrologic conditions in support of maintenance and operations functions, and to make flow projections on larger watersheds. These data27 are accessible through the Water District World Wide Web site (www.scvwd.dst.ca.us), and may be useful for the WMI's watershed assessments. The U.S. Geological Survey also maintains four streamflow gages in the Basin: on San Francisquito Creek at the Standord University Campus, on the Guadalupe River in downtown San Jose, on Coyote Creek above State Highway 237 in Milpitas, and on Saratoga Creek in Saratoga.

Channel Modifications

As part of their flood protection and water supply programs, the Water District has modified the channel structure of some Basin streams. Stream channel modifications include creek bank and bottom stabilization, and construction of bypass channels, levees, floodwalls, and culverts. The Waterways Management Model maintained by the Water District describes the type and location of stream channel modifications (Table 4-17). The number of linear feet of modified stream channel is summarized by general and detailed channel type for Basin creeks in Appendix 4A, Table 4A-3.

Fish Ladders and Passage Structures

Fish ladders and passage structures enable adult fishes to migrate upstream through reaches where modifications, such as dams, are otherwise migratory obstacles. Fish ladders and passage structures exist on several Basin creeks, and are listed by watershed and creek in Table 4-18. Also listed are location, type (TBD indicates proposed passage structure type is to be determined), and status (A = active; I = inactive; P = proposed) of fish passage structures (personal communication, David Salsbery, Fisheries Biologist, Water District).

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[27] Installed since 1995 (original construction date unavailable).

Table 4-15
Water Rights Diversions[1]

Watershed	Creek	Use	Number
California Water Service Company			
San Francisquito	Bear Gulch Creek	M	2
Private Individual			
San Francisquito	Searsville Lake	D	1
	Unnamed (Tributary to Corte Madera Creek)	D	1
San Jose Water Company			
Guadalupe	Alamitos		
	Burton	M	1
	Beardsley	M	1
	Briggs	M	1
	Hendry's	M	1
	Hooker	M	1
	Los Gatos	D, M, I	2
	Los Gatos	M	1
	Moody	M	1
	Soda Springs	M	2
	Trout	M	1
San Tomas Aquino	Saratoga	D, M, I	1
	Saratoga	M	1
	Unnamed (trib to San Tomas Aquino Crk)	M	1
Santa Clara County Parks & Recreation Department			
Coyote	Unnamed (trib to Arroyo Aguague)	S	13
	Unnamed (trib to South Babb Crk)	S	1
	Unnamed (trib to Bodfish Crk)	S	1
	House Spring #1 (trib to Coyote Lake)	S	1
	House Spring #2 (trib to Coyote Lake)	S	1
	Unnamed (trib to San Felipe Crk)	S	22
	Unnamed (trib to Smith Crk)	S	2
Guadalupe	Alamitos	S	1
	Unnamed (trib to Alamitos Crk)	S	7
	Unnamed (trib to Canoas Crk)	S	1
	Unnamed (trib to Calero Reservoir)	S	7
	Unnamed (trib to Guadalupe Resvr)	S	1
	Unnamed (trib to Los Capitancillos Crk)	S	2
	Unnamed (trib to Guadalupe Crk)	S	
San Tomas Aquino	Sanborn Crk	S	2
	Todd Crk	S	2
Stanford University			
San Francisquito	Los Trancos Creek	D	2
	San Francisquito Creek	D	1
Unknown			
San Francisquito	West Union Creek	D	1

[1] Source: Water Rights Information Management System, State Water Resources Control Board, http://www.waterrights.ca.gov/program/wrims/default.htm.

Table 4-16
Hydrologic Gages Operated by the Santa Clara Valley Water District on Surface Waterbodies in the Santa Clara Basin

Watershed	Surface Waterbody	Number of Stream Gages
Adobe	Adobe Creek	1
Coyote	Coyote Creek	5
	Coyote Canal	2
	Fisher Creek	1
	Kirk Ditch	2
	Las Animas	1
	Overfelt Recarge Pond Diversion	1
	Thompson Creek	1
	Upper Penitencia Creek	2
	Anderson Reservoir	1
	Coyote Reservoir	1
Guadalupe	Almaden-Calero Canal	2
	Alamitos Creek	2
	Calero Creek	1
	Canoas Creek	1
	Capitancillos Recharge system	1
	Guadalupe Creek	2
	Golf Creek	1
	Guadalupe River	3
	Los Gatos Creek	3
	Ross Creek	2
	Almaden Reservoir	1
	Calero Reservoir	1
	Guadalupe Reservoir	1
	Lexington Reservoir	1
	Vasona Reservoir	1
Matadero/Barron	Barron Creek	1
	Barron Debris Basin	1
	Matadero Creek	1
Permanente	Permanente Creek	1
	Hale Creek	1
San Francisquito	San Francisquito Creek	1
San Tomas	Calabazas Creek	1
	San Tomas Creek	2
	Saratoga Creek	1
	Smith Creek	1
	Upper Page Ditch	2
	Wildcat Creek	1
Stevens	Stevens Creek	2
	Stevens Reservoir	1
Sunnyvale East	Sunnyvale East Channel	1
Total		59

Figure 4-14 (front)

Figure 4-14 (back)

Table 4-17
Channel Modifications Implemented by the Santa Clara Valley Water District

Detailed Channel Type	Generalized Channel Type	Channel Bottom	Hardscape
Earth Levees	Earth Levee	unfixed	soft
Excavated Earth	Earth Excavated	unfixed	soft
Widened Earth (one side)	none in analysis	unfixed	soft
Bypass Channel	Earth Excavated	unfixed	soft
Modified Floodplain	Natural Modified	unfixed	soft
Natural Unmodified	Natural Unmodified	unfixed	soft
Pipe Culvert	Concrete Channel	fixed	hard
Arch Culvert	Concrete Channel	fixed	hard
Box Culvert	Concrete Channel	fixed	hard
Bridge	Concrete Channel	fixed	hard
U-Frame Concrete	Concrete Channel	fixed	hard
Trapezoidal Concrete	Concrete Channel	fixed	hard
Concrete (bottom)	Excavated Earth	fixed	hard
Sack Concrete	Slope Concrete	unfixed	mixed
Articulated Concrete Blocks	Slope Rock	unfixed	mixed
Gabion (sides)	Slope Gabion	unfixed	mixed
Gabion (sides & bottom)	Concrete Channel	fixed	mixed
Rock Lined (sides)	Slope Rock	unfixed	mixed
Rock Lined (sides & bottom)	Concrete Channel	fixed	mixed
Floodwalls	Slope Concrete	unfixed	mixed

Source: Thomas Reid and Associates 1995.

Table 4-18
Number and Type of Fish Passage Structures Constructed or Proposed for Construction in Streams in the Santa Clara Basin

Watershed	Creek	Location	Type of Passage Structure	Status	Construction Date
Coyote	Coyote	Hwy 237	Washington Baffle	A	Since 1995[1]
		Ford Rd.	Flashboard Ladder	I	Since 1995[2]
		Ford Rd.	Flashboard Ladder	I	Since 1995[2]
		Ford Rd.	Flashboard Ladder	I	Since 1995[2]
	Upper Penitencia	Maybury Ave.	Flashboard Ladder	A	1997
		Noble Ave.	Flashboard Ladder	A	1999[3]
Guadalupe	Guadalupe River	Old Hillsdale Blvd.	Open-channel rock weir	A	1999
		Branham Ln.	Open-channel rock weir	A	1999
		Blossom Hill Rd.	Flashboard Ladder	A	1999
	Guadalupe Creek	Masson Dam	Open-channel rock weir	A	2000
	Los Trancos	Felt Lake Diversion Dam	Alaska steep-pass ladder w/ fish screen	A	1995
	San Francisquito Creek[4]	Lake Lagunita	Denil-style fishway	A	1978
Stevens	Stevens	Moffitt Blvd.	Denil Ladder	A	1950s
		Evelyn St.	Denil Ladder	A	1950s
		Central Ave.	TBD	P	2000
		Fremont Ave.	Denil Ladder	A	1950s

[1] Installed since 1995 (original construction date unavailable).
[2] Installed since 1995 (original construction date unavailable); inactive since 1997.
[3] Reconstructed 1999; installed since 1995 (original construction date unavailable).
[4] The San Francisquito Creek CRMP is currently working on an assessment of barriers to fish passage and is expected to recommend remedial steps.

Instream Quarries

Sand and gravel are common construction materials. The demand for such aggregate material has been high since the post World War II construction boom in California. Most sand and gravel are extracted from active river channels, and from alluvial deposits in adjacent floodplains (California State Lands Commission 1993).

Instream quarries have operated in Basin streams since the turn of the century (Table 4-19, Figure 4-15). Today, however, only one instream quarry may be active on Coyote Creek (Table 4-19). Extracting gravel from streambeds in excess of replenishment by upstream sources causes streambeds to lower (degrade) both upstream and downstream of the extraction area. Collins and Dunne (1990) have summarized the effects of bed degradation as follows:

- Undermine bridge supports, pipe lines, or other instream structures
- Impact aquatic habitat by changing channel morphology, changing channel substrate type, lowering the groundwater table, and subsequently destroying riparian vegetation
- Reduce flooding and flood heights, thereby reducing the supply of overbank sediments to floodplains
- Reduce size or height of bars, causing downstream bars to erode if they receive less bed material, and causing adjacent banks to erode more rapidly or to stabilize, depending on how much gravel is removed, the distribution of removal, and on channel geometry; especially rapid bed degradation induces bank collapse and erosion by increasing bank heights

4.4.4 Discussion

Relationships between patterns of land use and aquatic communities and instream habitat structure have been identified along gradients of urbanization (Limburg and Schmidt 1990; Richards and Host 1994; Lammert and Allan 1999). Lammert and Allan (1999) demonstrated how the scale of investigation influences the strength of such relationships. They found that land use immediate to tributaries (within 50 meters) correlated more closely with the health of biological communities and instream structure than land use measured within 125 meters or within entire subwatersheds.

As previously mentioned, the accuracy of the estimates of land use acreages and their distribution within riparian corridors could be improved by using higher accuracy data; for example finer spatial resolution for land use and creek data, and more complete creek attribute information. Finer resolution land use data would provide more precise estimates of land use acreages, notably for narrow linear features, such as streams and roads, that are underrepresented

Table 4-19
Status of Instream Quarries That Have Operated in the Santa Clara Basin

Watershed	Creek	Location	Status
Coyote	Coyote	Reach starting at Hellyer Avenue, extending approximately 2 miles downstream	Active[1] No current (1998) record[2]
	Coyote	From U.S. Highway 101 overpass north of Morgan Hill to Ford Road	Abandoned: unreclaimed[1]
	Los Alamitos	Near Coleman Avenue	Abandoned: quarry reclaimed as Lake Almaden[2]
	Los Gatos	Lark Avenue to State Highway 85	Reclaimed as mitigation for State Highway 85 construction[1]

[1] Personal communication, Ken Reiller, Associate Civil Engineer, Water District.
[2] Personal communication, Tim Kustic, California Department of Conservation, Office of Mine Reclamation.

in the ABAG (1996) data. A comprehensive creek coverage mapped at fine spatial resolution, and including creek attributes such as creek name, would also help accurately map riparian corridors throughout the Basin. The Water District is currently working on developing a coverage that will include all creeks within the Basin at a 1:500 scale. In addition, the Water District is funding work being done by the USGS and the San Francisco Estuary Institute to complete the 1:24,000 scale national hydrographic data set for the Basin in 2000. This data set will provide the names of creeks and other surface water features and their associated reach codes (RP-3).

In addition to analyzing patterns of land uses within watersheds and riparian corridors for the WMI's watershed assessments, it will be useful to consider potential impacts associated with instream flood control and water supply infrastructure (e.g., dams, modified channels, and fish ladders), and with near- or instream quarrying.

Figure 4-15 (front)

Figure 4-15 (back)

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A pictorial and video representation of urbanization sprawling across the Bay area can be viewed at http://geo.arc.nasa.gov/sge/william/urban.html.

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Appendix 4A
Supplemental Data

Table 4A-1
Coefficients of Imperviousness Estimated for the Association of Bay Area Governments Land Use Data (ABAG 1996)

Reclassified Land Use Category	Reclassified Land Use Code	ABAG Land Use Category	ABAG Land Use Code	Coefficient of Imperviousness	Source
Agriculture	20	Agricultural Land	2	0.02	B
	20	Cropland and Pasture	21	0.02	B
	20	Orchards & Horticulture	22	0.02	B
	20	Farmsteads & Other Agriculture	24	0.02	B
	20	Orchards or Groves	221	0.02	B
	20	Irrigated Cropland	2111	0.02	B
	20	Greenhouses & Floriculture	223	0.50	E
Bays and Estuaries	54	Bays and Estuaries	54	0.00	A
Commercial	121	Commercial Outdoor Rec.	122	0.66	B
	121	Mixed Residential/Commercial	16	0.91	B
	121	Urban and Built-Up	1	0.96	B
	121	Commercial and Services	12	0.96	B
	121	Retail and Wholesale	121	0.96	B
	121	Transitional	161	0.96	B
	121	Military Hospital	1254	0.96	B
Forest	42	Forest	42	0.01	E
	42	Mixed Forest	43	0.01	E
	42	Redwood and Douglas Fir	421	0.01	E
	42	Evergreen Mix	423	0.01	E
Fresh Water	50	Streams and Canals	51	0.00	A
	50	Lakes	52	0.00	A
	50	Freshwater	64	0.00	A
	50	Reservoirs	53	0.01	E
Heavy Industrial	132	Mixed Industrial/Commercial	15	0.91	B
	132	Light Industry	132	0.91	B
Light Industrial	131	Industrial	13	0.91	B
	131	Heavy Industrial	131	0.91	B

Table 4A-1 (continued)
Coefficients of Imperviousness Estimated for the Association of Bay Area Governments Land Use Data (ABAG 1996)

Reclassified Land Use Category	Reclassified Land Use Code	ABAG Land Use Category	ABAG Land Use Code	Coefficient of Imperviousness	Source
Mines, Quarries, Gravel Pits	75	Mines/Quarries/Gravel Pits	75	0.02	B
Public Quasi-Public	122	Colleges and Universities	1232	0.47	B
	122	Education	123	0.66	B
	122	Stadium (Education)	1233	0.66	B
	122	Stadium (Public)	1261	0.66	B
	122	Long-Term Care Facilities	1243	0.68	B
	122	State Mental Health Facilities	1248	0.68	B
	122	Military Installations	125	0.74	B
	122	Hospital Trauma Centers	1241	0.74	B
	122	Community Hospitals	1242	0.74	B
	122	Out-Patient Surgery Centers	1246	0.74	B
	122	Other Public Facilities	126	0.82	B
	122	Elementary/Secondary Schools	1231	0.82	B
	122	Churches and Synagogues	1262	0.82	B
	122	Fire Station	1263	0.82	B
	122	Police Station	1264	0.82	B
	122	County Government Center	1265	0.82	B
	122	Emergency Operations Center	1266	0.82	B
	122	Jails & Rehabilitation Centers	1267	0.82	B
	122	Convention Centers	1268	0.82	B
	122	Offices	128	0.91	B
	122	Research Centers	127	0.96	B
Rangeland	30	Herbaceous Rangeland	31	0.01	E
	30	Shrub & Brush Rangeland	32	0.01	E
	30	Mixed Rangeland	33	0.01	E
	30	Coastal Shrub	322	0.01	E
	30	Chaparral	321	0.01	E
Residential	113	4+ DU/acre	113	0.81	B
	113	Mobile Home Parks	114	0.81	B
	113	Military Residential	1251	0.81	B
Residential	111	1 DU/2 to 5 acres	111	0.07	B
Residential	112	1 to 3 DU/acre	112	0.42	B
	112	University Housing	1234	0.42	B
Sanitary Landfills	78	Sanitary Landfills	761	0.02	B

Table 4A-1 (concluded)
Coefficients of Imperviousness Estimated for the Association of Bay Area Governments Land Use Data (ABAG 1996)

Reclassified Land Use Category	Reclassified Land Use Code	ABAG Land Use Category	ABAG Land Use Code	Coefficient of Imperviousness	Source
Transportation, Communication	14	Commercial Airport - Other	1436	0.66	B
	14	Public Airfield	1437	0.66	B
	14	Highways and Interchanges	1411	0.90	E^2
	14	Park and Ride Lots	1413	0.90	E^2
	14	Truck/Bus Maintenance Yard	1414	0.90	B
	14	Rail Passenger Stations	1421	0.95	E
	14	Rail Yards	1422	0.95	E
	14	Commercial Airport Terminal	1431	0.96	B
	14	Commercial Airport Runway	1434	0.99	B
Urban Recreation	17	Transitional Areas	76	0.02	B
	17	Other Transitional	762	0.02	B
	17	Golf Courses (Extensive Rec.)	1711	0.03	B
	17	Other Urban & Built-up Land	17	0.20	E^1
	17	Parks	173	0.20	E^1
	17	Cemeteries	172	0.28	E^1
	17	Extensive Recreation	171	0.66	B
	17	Racetracks	1712	0.66	B
Utilities	19	Electricity - Other	1453	0.47	B
	19	Wastewater Treatment Plant	1461	0.70	E^2
	19	Wastewater Pumping Station	1462	0.70	E^2
	19	Wastewater Treatment-Filtration	1471	0.70	E^2
	19	Water Storage (covered)	1473	0.70	E^2
	19	Water Storage (open)	1474	0.70	E^2
	19	Electricity - Substation	1452	0.95	E
Vacant Undeveloped	18	Open Space - Urban	174	0.01	B
	18	Urban Vacant Land	175	0.01	B
Wetlands	60	Forested Wetlands	61	0.01	E
	60	Nonforested Wetlands	62	0.01	E
	60	Salt Evaporation Ponds	63	0.01	E

Note: ABAG land use data classes and codes, associated land use classes and codes as reclassified for the purpose of mapping and describing the distribution of land uses in the Basin (see Section 4.1.6), and a list of impervious coefficients derived from the following sources: Bredehorst (B) (1981); EOA (E) (1999) are included. For several surface water land uses, 0 percent imperviousness was assumed (A). Superscripts indicate that imperviousness coefficients were truthed by overlaying land use data on orthophotographs in a GIS: (1) estimates were the same; (2) modified previous study estimate.

Table 4A-2
Precipitation Gages Operated by the Water District in the Basin[1,2]

Station Number	Number	Station Name
2065	1	Alamitos
2080	4	Almaden
1517	8	Biel Ranch
1508	15	Castro Valley
2053	16	Guadalupe Slough
2079	17	Coe Park
1519	18	Coit Ranch
2075	21	Coyote
1514	23	Curtner Ranch
2096	24	Dahl Ranch
2069	34	Haskins Ranch
2066	36	Johnson Ranch
1520	37	Laguna Seca
2073	41	Anderson
2068	42	Lexington
2072	44	Loma Prieta
1521	48	Sunnyvale WTP
1522	53	Maryknoll
1512	67	Mt. Hamilton
2081	69	Mt. Umunhum
523	75	Peabody
509	77	Valley Christian
524	79	Rinconada WTP
518	98	Shanti Ashrama
070	99	Penitencia
510	100	Stevens Creek
067	102	UTC
511	108	West Yard
515	121	Mt. View Corp Yard
526	123	Guadalupe Watershed
1527	125	Vasona Pump Station
2071	127	Cow Ridge
1513	128	Calero
2099	129	Palo Alto
1453[2]	131	City of San Jose
516	132	Evergreen
529	134	Church Ave Perc. Ponds
503	136	Morgan Hill

[1] Locations of all precipitation gages are shown on Figure 4-14.

[2] The City of Palo Also operates three precipitation gages: at the Municipal Service Center (3201 E. Bayshore Road), in Foothills Park (3300 Page Mill Road), and at the Fire Station at 799 Embarcadero Road. The last of these is nonautomated.

[3] Indicates gages that are not owned by the Water District.

Table 4A-3
Linear Feet of Modified Stream Channel in the Santa Clara Basin Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
Adobe	Adobe Creek	2,094	Concrete Channel	Box Culvert
	Adobe Creek	4,972	Concrete Channel	Bridge
	Adobe Creek	164	Concrete Channel	Pipe Culvert
	Adobe Creek	500	Concrete Channel	Rock Lined -side/bottom
	Adobe Creek	4,518	Concrete Channel	Trapezoidal Concrete
	Adobe Creek	6,705	Concrete Channel	U-Frame Concrete
	Adobe Creek	13	Earth Levee	Earth Levee
	Adobe Creek	1,241	Excavated Earth	Concrete (bottom)
	Adobe Creek	36,189	Natural Unmodified	Natural Unmodified
	Barron Creek	16	Earth Levee	Earth Levee
	Purissima Creek	1,986	Natural Unmodified	Natural Unmodified
Arroyo la Laguna	Coyote Creek	9,274	Natural Unmodified	Natural Unmodified
	Lower Penitencia Creek	130	Concrete Channel	Trapezoidal Concrete
Baylands	Adobe Creek	12,906	Earth Levee	Earth Levee
	Calabazas Creek	106	Earth Levee	Earth Levee
	Coyote Creek	5,053	Natural Unmodified	Natural Unmodified
	Guadalupe River	3,178	Earth Levee	Earth Levee
	Guadalupe River	18,507	Natural Unmodified	Natural Unmodified
	Guadalupe Slough	29,674	Earth Levee	Earth Levee
	Matadero Creek	292	Concrete Channel	Rock Lined -side/bottom
	Matadero Creek	575	Earth Excavated	Bypass Channel
	Matadero Creek	8,400	Earth Levee	Earth Levee
	Palo Alto Flood Basin	27,277	Earth Levee	Earth Levee
	Permanente Creek	50	Concrete Channel	Box Culvert
	Permanente Creek	12,379	Earth Levee	Earth Levee
	San Francisquito Creek	2,736	Earth Levee	Earth Levee
	San Tomas Aquino Creek	29	Concrete Channel	Bridge
	San Tomas Aquino Creek	2,508	Earth Levee	Earth Levee
	Stevens Creek	15	Concrete Channel	Bridge
	Stevens Creek	21	Concrete Channel	Trapezoidal Concrete
	Stevens Creek	13,587	Earth Levee	Earth Levee
	Stevens Creek	176	Slope Concrete	Sack Concrete
	Stevens Creek	343	Slope Rock	Rock Lined (sides)
	Sunnyvale East Outfall	3,720	Earth Levee	Earth Levee
	Sunnyvale West Outfall	3,636	Earth Levee	Earth Levee

Table 4A-3 (continued)
Linear Feet of Modified Stream Channel in the Santa Clara Basin Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
Calabazas	Calabazas Creek	2,172	Concrete Channel	Pipe Culvert
	Calabazas Creek	3,806	Concrete Channel	Box Culvert
	Calabazas Creek	759	Concrete Channel	Bridge
	Calabazas Creek	16,727	Concrete Channel	Trapezoidal Concrete
	Calabazas Creek	680	Concrete Channel	U-Frame Concrete
	Calabazas Creek	794	Earth Excavated	Excavated Earth
	Calabazas Creek	10,000	Earth Levee	Earth Levee
	Calabazas Creek	67	Excavated Earth	Concrete (bottom)
	Calabazas Creek	131	Natural Modified	Modifies Floodplain
	Calabazas Creek	34,711	Natural Unmodified	Natural Unmodified
	Calabazas Creek	289	Slope Concrete	Sack Concrete
	El Camino Stormdrain	600	Concrete Channel	Box Culvert
	El Camino Stormdrain	3,469	Concrete Channel	Pipe Culvert
	El Camino Stormdrain	8,167	Concrete Channel	Trapezoidal Concrete
	El Camino Stormdrain	50	Concrete Channel	U-Frame Concrete
	Junipero Serra Channel	736	Concrete Channel	Box Culvert
	Junipero Serra Channel	2,396	Concrete Channel	Trapezoidal Concrete
	Junipero Serra Channel	15	Concrete Channel	U-Frame Concrete
	Junipero Serra Channel	2,034	Earth Excavated	Excavated Earth
	Prospect Creek	40	Concrete Channel	Arch Culvert
	Prospect Creek	428	Concrete Channel	Box Culvert
	Prospect Creek	280	Concrete Channel	Pipe Culvert
	Prospect Creek	1,239	Earth Excavated	Excavated Earth
	Prospect Creek	5,005	Natural Unmodified	Natural Unmodified
	Prospect Creek	35	Slope Concrete	Sack Concrete
	Regnart Creek	472	Concrete Channel	Box Culvert
	Regnart Creek	2,410	Concrete Channel	Pipe Culvert
	Regnart Creek	420	Concrete Channel	Trapezoidal Concrete
	Regnart Creek	600	Concrete Channel	U-Frame Concrete
	Regnart Creek	6,245	Earth Excavated	Excavated Earth
	Regnart Creek	4,792	Natural Unmodified	Natural Unmodified
	Regnart Creek	20	Slope Concrete	Floodwalls
	Regnart Creek	271	Slope Rock	Rock Lined (sides)
	Rodeo Creek	316	Concrete Channel	Box Culvert
	Rodeo Creek	2,412	Concrete Channel	Pipe Culvert
	Rodeo Creek	70	Concrete Channel	Rock Lined -side/bottom
	Rodeo Creek	562	Concrete Channel	Trapezoidal Concrete
	Rodeo Creek	96	Concrete Channel	U-Frame Concrete
	Rodeo Creek	2,053	Earth Excavated	Excavated Earth
	Rodeo Creek	4,242	Natural Unmodified	Natural Unmodified
	Rodeo Creek	64	Slope Concrete	Sack Concrete

Table 4A-3 (continued)
Linear Feet of Modified Stream Channel in the Santa Clara Basin Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
	Sunnyvale East Outfall	753	Concrete Channel	Box Culvert
	Sunnyvale East Outfall	558	Concrete Channel	Pipe Culvert
	Sunnyvale East Outfall	227	Concrete Channel	Trapezoidal Concrete
	Sunnyvale East Outfall	40	Concrete Channel	U-Frame Concrete
	Sunnyvale East Outfall	6,688	Earth Excavated	Excavated Earth
Coyote	Arroyo Aguague Creek	43,539	Natural Unmodified	Natural Unmodified
	Cochran Channel	1,347	Concrete Channel	Trapezoidal Concrete
	Coyote Creek	801	Concrete Channel	Bridge
	Coyote Creek	22,478	Earth Excavated	Excavated Earth
	Coyote Creek	18,418	Earth Levee	Earth Levee
	Coyote Creek	136,195	Natural Unmodified	Natural Unmodified
	Cribari Creek	1,299	Concrete Channel	Pipe Culvert
	Evergreen Creek	220	Concrete Channel	Box Culvert
	Evergreen Creek	14,281	Concrete Channel	Rock Lined -side/bottom
	Evergreen Creek	33	Concrete Channel	Trapezoidal Concrete
	Fisher Creek	839	Concrete Channel	Box Culvert
	Fisher Creek	11,460	Earth Excavated	Excavated Earth
	Fisher Creek	7,400	Earth Levee	Earth Levee
	Fisher Creek	18,335	Natural Unmodified	Natural Unmodified
	Flint Creek	20	Concrete Channel	Box Culvert
	Flint Creek	5,250	Concrete Channel	Pipe Culvert
	Flint Creek	1,350	Earth Excavated	Excavated Earth
	Flint Creek	11,508	Natural Unmodified	Natural Unmodified
	Flint Creek	381	Slope Gabion	Gabion (sides)
	Fowler Creek	2,070	Concrete Channel	Pipe Culvert
	Fowler Creek	13,180	Natural Unmodified	Natural Unmodified
	Lower Penitencia Creek	54	Earth Levee	Earth Levee
	Lower Silver Creek	2,065	Concrete Channel	Box Culvert
	Lower Silver Creek	4,980	Concrete Channel	Pipe Culvert
	Lower Silver Creek	2,079	Concrete Channel	Trapezoidal Concrete
	Lower Silver Creek	28,691	Earth Excavated	Excavated Earth
	Lower Silver Creek	211	Slope Rock	Rock Lined (sides)
	Miguelita Creek	1,005	Concrete Channel	Box Culvert
	Miguelita Creek	13,480	Concrete Channel	Pipe Culvert
	Miguelita Creek	4,550	Natural Unmodified	Natural Unmodified
	North Babb Creek	155	Concrete Channel	Box Culvert
	North Babb Creek	3,821	Concrete Channel	Pipe Culvert
	North Babb Creek	1,850	Concrete Channel	Trapezoidal Concrete
	North Babb Creek	345	Slope Concrete	Sack Concrete
	North Babb Creek	300	Slope Gabion	Gabion (sides)

Table 4A-3 (continued)
Linear Feet of Modified Stream Channel in the Santa Clara Basin
Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
	Norwood Creek	90	Concrete Channel	Box Culvert
	Norwood Creek	9,459	Concrete Channel	Pipe Culvert
	Norwood Creek	146	Concrete Channel	Rock Lined -side/bottom
	Norwood Creek	26	Concrete Channel	Trapezoidal Concrete
	Norwood Creek	51	Concrete Channel	U-Frame Concrete
	Norwood Creek	3,028	Earth Excavated	Excavated Earth
	Norwood Creek	3,649	Natural Unmodified	Natural Unmodified
	Quimby Creek	175	Concrete Channel	Box Culvert
	Quimby Creek	1,056	Concrete Channel	Pipe Culvert
	Quimby Creek	3,644	Earth Excavated	Excavated Earth
	Quimby Creek	6,025	Natural Unmodified	Natural Unmodified
	Ruby Creek	60	Concrete Channel	Box Culvert
	Ruby Creek	7,281	Concrete Channel	Pipe Culvert
	Ruby Creek	1,058	Earth Excavated	Excavated Earth
	South Babb Creek	270	Concrete Channel	Box Culvert
	South Babb Creek	4,490	Concrete Channel	Trapezoidal Concrete
	South Babb Creek	300	Earth Excavated	Excavated Earth
	South Babb Creek	14,076	Natural Unmodified	Natural Unmodified
	Thompson Creek	343	Concrete Channel	Box Culvert
	Thompson Creek	105	Concrete Channel	Rock Lined -side/bottom
	Thompson Creek	58	Concrete Channel	Trapezoidal Concrete
	Thompson Creek	133	Concrete Channel	U-Frame Concrete
	Thompson Creek	805	Earth Excavated	Excavated Earth
	Thompson Creek	4,895	Natural Modified	Modifies Floodplain
	Thompson Creek	19,867	Natural Unmodified	Natural Unmodified
	Thompson Creek	1,020	Slope Rock	Rock Lined (sides)
	Upper Penitencia Creek	72	Concrete Channel	Arch Culvert
	Upper Penitencia Creek	593	Concrete Channel	Box Culvert
	Upper Penitencia Creek	7,088	Earth Levee	Earth Levee
	Upper Penitencia Creek	49,297	Natural Unmodified	Natural Unmodified
	Upper Silver Creek	204	Concrete Channel	Box Culvert
	Upper Silver Creek	300	Concrete Channel	Pipe Culvert
	Upper Silver Creek	5,981	Concrete Channel	Trapezoidal Concrete
	Upper Silver Creek	151	Concrete Channel	U-Frame Concrete
	Upper Silver Creek	19,278	Natural Unmodified	Natural Unmodified
	Willow Springs Creek	4,926	Natural Unmodified	Natural Unmodified
	Yerba Buena Creek	9,492	Natural Unmodified	Natural Unmodified
	Unnamed	1,426	Earth Excavated	Excavated Earth
Guadalupe	Alamitos Creek	202	Concrete Channel	Bridge
	Alamitos Creek	545	Concrete Channel	Rock Lined -side/bottom

Table 4A-3 (continued)
Linear Feet of Modified Stream Channel in the Santa Clara Basin Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
	Alamitos Creek	1,078	Earth Excavated	Excavated Earth
	Alamitos Creek	11,697	Earth Levee	Earth Levee
	Alamitos Creek	189	Natural Modified	Modifies Floodplain
	Alamitos Creek	30,382	Natural Unmodified	Natural Unmodified
	Alamitos Creek	2,537	Slope Concrete	Floodwalls
	Alamitos Creek	56	Slope Gabion	Gabion (sides)
	Alamitos Creek	246	Slope Rock	Rock Lined (sides)
	Almendra Creek	122	Concrete Channel	Box Culvert
	Almendra Creek	934	Concrete Channel	Pipe Culvert
	Almendra Creek	338	Concrete Channel	Trapezoidal Concrete
	Almendra Creek	145	Natural Unmodified	Natural Unmodified
	Almendra Creek	249	Slope Rock	Rock Lined (sides)
	Barrett Canyon	2,040	Natural Unmodified	Natural Unmodified
	Calero Creek	40	Concrete Channel	Arch Culvert
	Calero Creek	30,311	Natural Unmodified	Natural Unmodified
	Canoas Creek	2,398	Concrete Channel	Box Culvert
	Canoas Creek	1,797	Concrete Channel	Gabion (sides & bottom)
	Canoas Creek	648	Concrete Channel	Trapezoidal Concrete
	Canoas Creek	25	Concrete Channel	U-Frame Concrete
	Canoas Creek	33,938	Excavated Earth	Concrete (bottom)
	Daves Creek	149	Concrete Channel	Arch Culvert
	Daves Creek	6,025	Concrete Channel	Pipe Culvert
	Daves Creek	1,015	Concrete Channel	Trapezoidal Concrete
	Daves Creek	15	Concrete Channel	U-Frame Concrete
	Daves Creek	239	Earth Excavated	Excavated Earth
	Daves Creek	923	Natural Unmodified	Natural Unmodified
	East Ross Creek	95	Concrete Channel	Box Culvert
	East Ross Creek	5,792	Natural Unmodified	Natural Unmodified
	Golf Creek	260	Concrete Channel	Box Culvert
	Golf Creek	2,792	Concrete Channel	Pipe Culvert
	Golf Creek	1,113	Concrete Channel	Rock Lined -side/bottom
	Golf Creek	84	Concrete Channel	Trapezoidal Concrete
	Golf Creek	320	Concrete Channel	U-Frame Concrete
	Golf Creek	4,236	Earth Excavated	Excavated Earth
	Golf Creek	137	Earth Levee	Earth Levee
	Golf Creek	2,823	Slope Concrete	Sack Concrete
	Golf Creek	27	Slope Rock	Rock Lined (sides)
	Greystone Creek	49	Concrete Channel	Arch Culvert
	Greystone Creek	328	Concrete Channel	Box Culvert
	Greystone Creek	64	Concrete Channel	Pipe Culvert

Table 4A-3 (continued)
Linear Feet of Modified Stream Channel in the Santa Clara Basin Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
	Greystone Creek	2,558	Concrete Channel	Trapezoidal Concrete
	Greystone Creek	2,642	Concrete Channel	U-Frame Concrete
	Greystone Creek	2,028	Earth Excavated	Excavated Earth
	Greystone Creek	345	Slope Concrete	Sack Concrete
	Guadalupe Creek	11,451	Earth Excavated	Excavated Earth
	Guadalupe Creek	28,574	Natural Unmodified	Natural Unmodified
	Guadalupe River	1,134	Concrete Channel	U-Frame Concrete
	Guadalupe River	25,576	Earth Excavated	Excavated Earth
	Guadalupe River	25,004	Earth Levee	Earth Levee
	Guadalupe River	16,933	Natural Unmodified	Natural Unmodified
	Guadalupe River	3,796	Slope Concrete	Sack Concrete
	Guadalupe River	5,848	Slope Gabion	Gabion (sides)
	Herbert Creek	4,222	Natural Unmodified	Natural Unmodified
	Jacques Gulch	4,913	Natural Unmodified	Natural Unmodified
	Larabee Gulch	4,672	Natural Unmodified	Natural Unmodified
	Lone Hill Creek	865	Concrete Channel	Box Culvert
	Lone Hill Creek	2,729	Concrete Channel	Pipe Culvert
	Lone Hill Creek	1,235	Concrete Channel	U-Frame Concrete
	Los Gatos Creek	1,076	Concrete Channel	Box Culvert
	Los Gatos Creek	2,030	Concrete Channel	Rock Lined -side/bottom
	Los Gatos Creek	9,501	Concrete Channel	Trapezoidal Concrete
	Los Gatos Creek	10,520	Concrete Channel	U-Frame Concrete
	Los Gatos Creek	25,537	Earth Excavated	Excavated Earth
	Los Gatos Creek	11,251	Natural Unmodified	Natural Unmodified
	Los Gatos Creek	740	Slope Gabion	Gabion (sides)
	McAbee Creek	2,156	Concrete Channel	Pipe Culvert
	Pheasant Creek	2,278	Natural Unmodified	Natural Unmodified
	Randol Creek	324	Concrete Channel	Box Culvert
	Randol Creek	417	Concrete Channel	Pipe Culvert
	Randol Creek	1,614	Concrete Channel	Rock Lined -side/bottom
	Randol Creek	564	Concrete Channel	Trapezoidal Concrete
	Randol Creek	1,360	Concrete Channel	U-Frame Concrete
	Randol Creek	5,883	Earth Excavated	Excavated Earth
	Ross Creek	6,238	Concrete Channel	Box Culvert
	Ross Creek	4,095	Concrete Channel	Pipe Culvert
	Ross Creek	7,376	Concrete Channel	Trapezoidal Concrete
	Ross Creek	1,494	Concrete Channel	U-Frame Concrete
	Ross Creek	10,318	Earth Excavated	Excavated Earth
	Ross Creek	320	Slope Concrete	Sack Concrete
	Ross Creek	2,106	Slope Rock	Articulated Concrete Block

Table 4A-3 (continued)
Linear Feet of Modified Stream Channel in the Santa Clara Basin
Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
	Santa Teresa Creek	100	Concrete Channel	Arch Culvert
	Santa Teresa Creek	50	Concrete Channel	Box Culvert
	Santa Teresa Creek	9,858	Natural Unmodified	Natural Unmodified
	Shannon Creek	5,940	Natural Unmodified	Natural Unmodified
	Short Creek	2,392	Natural Unmodified	Natural Unmodified
	Unnamed	1,640	No Data	No Data
Matadero/Barron	Arastradero Creek	5,200	Natural Unmodified	Natural Unmodified
	Barron Creek	584	Concrete Channel	Box Culvert
	Barron Creek	1,038	Concrete Channel	Bridge
	Barron Creek	7,319	Concrete Channel	Pipe Culvert
	Barron Creek	8,545	Concrete Channel	Trapezoidal Concrete
	Barron Creek	38	Concrete Channel	U-Frame Concrete
	Barron Creek	2,196	Earth Excavated	Excavated Earth
	Barron Creek	19	Earth Levee	Earth Levee
	Barron Creek	1,311	Natural Modified	Modifies Floodplain
	Barron Creek	5,077	Natural Unmodified	Natural Unmodified
	Deer Creek	13,878	Natural Unmodified	Natural Unmodified
	Matadero Creek	239	Concrete Channel	Box Culvert
	Matadero Creek	522	Concrete Channel	Bridge
	Matadero Creek	17,991	Concrete Channel	Trapezoidal Concrete
	Matadero Creek	798	Concrete Channel	U-Frame Concrete
	Matadero Creek	13,007	Natural Unmodified	Natural Unmodified
	Matadero Creek	983	Slope Rock	Rock Lined (sides)
	Stanford Channel	360	Concrete Channel	Box Culvert
	Stanford Channel	6,758	Concrete Channel	Pipe Culvert
	Stanford Channel	1,300	Concrete Channel	Trapezoidal Concrete
Lower Penitencia	Berryessa Creek	938	Concrete Channel	Box Culvert
	Berryessa Creek	1,600	Concrete Channel	Trapezoidal Concrete
	Berryessa Creek	438	Concrete Channel	U-Frame Concrete
	Berryessa Creek	12,909	Earth Excavated	Excavated Earth
	Berryessa Creek	6,950	Earth Levee	Earth Levee
	Berryessa Creek	4,699	Natural Modified	Modifies Floodplain
	Berryessa Creek	21,339	Natural Unmodified	Natural Unmodified
	Berryessa Creek	1,499	Slope Concrete	Sack Concrete
	Calera Creek	1,025	Concrete Channel	Box Culvert
	Calera Creek	378	Concrete Channel	U-Frame Concrete
	Calera Creek	2,311	Earth Excavated	Excavated Earth
	Calera Creek	1,950	Natural Modified	Modifies Floodplain
	Calera Creek	10,269	Natural Unmodified	Natural Unmodified
	Calera Creek	50	Slope Concrete	Sack Concrete

Table 4A-3 (continued)
Linear Feet of Modified Stream Channel in the Santa Clara Basin
Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
	Crosley Creek	6,648	Natural Unmodified	Natural Unmodified
	Los Buellis Creek	3,912	Natural Unmodified	Natural Unmodified
	Los Coches Creek	762	Concrete Channel	Box Culvert
	Los Coches Creek	2,886	Concrete Channel	Trapezoidal Concrete
	Los Coches Creek	795	Concrete Channel	U-Frame Concrete
	Los Coches Creek	1,818	Earth Excavated	Excavated Earth
	Los Coches Creek	10,614	Natural Unmodified	Natural Unmodified
	Lower Penitencia Creek	994	Concrete Channel	Box Culvert
	Lower Penitencia Creek	313	Concrete Channel	Bridge
	Lower Penitencia Creek	10	Concrete Channel	Rock Lined -side/bottom
	Lower Penitencia Creek	1,700	Concrete Channel	Trapezoidal Concrete
	Lower Penitencia Creek	282	Concrete Channel	U-Frame Concrete
	Lower Penitencia Creek	5,774	Earth Excavated	Excavated Earth
	Lower Penitencia Creek	4,492	Earth Levee	Earth Levee
	Lower Penitencia Creek	1,331	Natural Modified	Modifies Floodplain
	Lower Penitencia Creek	6,182	Slope Concrete	Floodwalls
	Lower Penitencia Creek	286	Slope Concrete	Sack Concrete
	Penitencia East Channel	198	Concrete Channel	Box Culvert
	Penitencia East Channel	26	Concrete Channel	Trapezoidal Concrete
	Penitencia East Channel	3,284	Earth Excavated	Excavated Earth
	Penitencia East Channel	71	Slope Concrete	Sack Concrete
	Piedmont Creek	479	Concrete Channel	Box Culvert
	Piedmont Creek	3,341	Concrete Channel	Pipe Culvert
	Piedmont Creek	2,280	Concrete Channel	U-Frame Concrete
	Piedmont Creek	1,540	Earth Excavated	Excavated Earth
	Sierra Creek	180	Concrete Channel	Box Culvert
	Sierra Creek	3,854	Concrete Channel	Pipe Culvert
	Sierra Creek	1,619	Concrete Channel	U-Frame Concrete
	Sierra Creek	5,402	Earth Excavated	Excavated Earth
	Sierra Creek	1,286	Natural Unmodified	Natural Unmodified
	Sierra Creek	44	Slope Concrete	Sack Concrete
	Tularcitos Creek	672	Concrete Channel	Box Culvert
	Tularcitos Creek	2,603	Concrete Channel	Pipe Culvert
	Tularcitos Creek	3,374	Earth Excavated	Excavated Earth
Permanente	Hale Creek	50	Concrete Channel	Arch Culvert
	Hale Creek	3,005	Concrete Channel	Box Culvert
	Hale Creek	30	Concrete Channel	Bridge
	Hale Creek	1,673	Concrete Channel	Pipe Culvert
	Hale Creek	3,066	Concrete Channel	Trapezoidal Concrete
	Hale Creek	50	Concrete Channel	U-Frame Concrete

Table 4A-3 (continued)
Linear Feet of Modified Stream Channel in the Santa Clara Basin Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
	Hale Creek	3,203	Earth Excavated	Excavated Earth
	Hale Creek	5,419	Natural Unmodified	Natural Unmodified
	Hale Creek	255	Slope Concrete	Sack Concrete
	Loyola Creek	3,867	Natural Unmodified	Natural Unmodified
	Magdalena Creek	2,350	Concrete Channel	Pipe Culvert
	Magdalena Creek	776	Earth Excavated	Excavated Earth
	Ohlone Creek	5,266	Natural Unmodified	Natural Unmodified
	Permanente Creek	3,952	Concrete Channel	Box Culvert
	Permanente Creek	1,912	Concrete Channel	Bridge
	Permanente Creek	200	Concrete Channel	Pipe Culvert
	Permanente Creek	1,369	Concrete Channel	Trapezoidal Concrete
	Permanente Creek	8,100	Concrete Channel	U-Frame Concrete
	Permanente Creek	278	Earth Levee	Earth Levee
	Permanente Creek	35,662	Natural Unmodified	Natural Unmodified
	Permanente Div. Channel	153	Concrete Channel	Box Culvert
	Permanente Div. Channel	101	Concrete Channel	Bridge
	Permanente Div. Channel	5,030	Concrete Channel	Trapezoidal Concrete
	Permanente Div. Channel	998	Concrete Channel	U-Frame Concrete
	Permanente Div. Channel	200	Slope Concrete	Floodwalls
	Summerhill Creek	988	No Data	No Data
	West Branch Permanente Creek	10,408	Natural Unmodified	Natural Unmodified
San Francisquito	Los Trancos Creek	34,553	Natural Unmodified	Natural Unmodified
	San Francisquito Creek	100	Concrete Channel	Box Culvert
	San Francisquito Creek	5,189	Earth Levee	Earth Levee
	San Francisquito Creek	31,774	Natural Unmodified	Natural Unmodified
	San Francisquito Creek	3,305	Slope Concrete	Sack Concrete
	San Francisquito Creek	3,130	Slope Rock	Rock Lined (sides)
San Tomas	Bonjetti Creek	7,730	Natural Unmodified	Natural Unmodified
	Booker Creek	3,177	Natural Unmodified	Natural Unmodified
	Mistletoe Creek	1,446	Natural Unmodified	Natural Unmodified
	Mistletoe Creek	25	Slope Concrete	Sack Concrete
	Page Ditch	42	Concrete Channel	Box Culvert
	Page Ditch	1,988	Concrete Channel	Pipe Culvert
	Page Ditch	30	Concrete Channel	Trapezoidal Concrete
	Page Ditch	3,549	Earth Excavated	Excavated Earth
	Page Ditch	11	Slope Concrete	Sack Concrete
	San Andreas Creek	3,056	Natural Unmodified	Natural Unmodified
	San Tomas Aquino Creek	18,849	Concrete Channel	Box Culvert
	San Tomas Aquino Creek	2,291	Concrete Channel	Bridge
	San Tomas Aquino Creek	25	Concrete Channel	Pipe Culvert

Table 4A-3 (continued)
Linear Feet of Modified Stream Channel in the Santa Clara Basin
Summarized by General and Detailed Channel Type[1]

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
	San Tomas Aquino Creek	4,133	Concrete Channel	Rock Lined –side/bottom
	San Tomas Aquino Creek	18,800	Concrete Channel	Trapezoidal Concrete
	San Tomas Aquino Creek	3,493	Concrete Channel	U-Frame Concrete
	San Tomas Aquino Creek	4,669	Earth Excavated	Excavated Earth
	San Tomas Aquino Creek	9,749	Earth Levee	Earth Levee
	San Tomas Aquino Creek	18,150	Natural Unmodified	Natural Unmodified
	San Tomas Aquino Creek	46	Slope Concrete	Sack Concrete
	San Tomas Aquino Creek	1,821	Slope Gabion	Gabion (sides)
	San Tomas Aquino Creek	1,214	Slope Rock	Rock Lined (sides)
	Sanborn Creek	2,283	Natural Unmodified	Natural Unmodified
	Saratoga Creek	1,330	Concrete Channel	Box Culvert
	Saratoga Creek	909	Concrete Channel	Bridge
	Saratoga Creek	1,686	Concrete Channel	Trapezoidal Concrete
	Saratoga Creek	659	Concrete Channel	U-Frame Concrete
	Saratoga Creek	1,853	Earth Excavated	Excavated Earth
	Saratoga Creek	6,263	Natural Modified	Modifies Floodplain
	Saratoga Creek	42,757	Natural Unmodified	Natural Unmodified
	Saratoga Creek	4,284	Slope Concrete	Sack Concrete
	Saratoga Creek	10,953	Slope Gabion	Gabion (sides)
	Saratoga Creek	104	Slope Rock	Rock Lined (sides)
	Smith Creek	303	Concrete Channel	Box Culvert
	Smith Creek	3,023	Concrete Channel	Pipe Culvert
	Smith Creek	37	Concrete Channel	Trapezoidal Concrete
	Smith Creek	3,110	Concrete Channel	U-Frame Concrete
	Smith Creek	669	Earth Excavated	Excavated Earth
	Smith Creek	2,229	Natural Unmodified	Natural Unmodified
	Vasona Creek	80	Concrete Channel	Box Culvert
	Vasona Creek	191	Concrete Channel	Pipe Culvert
	Vasona Creek	2,255	Natural Unmodified	Natural Unmodified
	Wildcat Creek	16	Concrete Channel	Arch Culvert
	Wildcat Creek	337	Concrete Channel	Box Culvert
	Wildcat Creek	248	Concrete Channel	Pipe Culvert
	Wildcat Creek	52	Concrete Channel	Trapezoidal Concrete
	Wildcat Creek	199	Concrete Channel	U-Frame Concrete
	Wildcat Creek	532	Earth Excavated	Excavated Earth
	Wildcat Creek	17,686	Natural Unmodified	Natural Unmodified
	Wildcat Creek	156	Slope Concrete	Floodwalls
	Wildcat Creek	43	Slope Gabion	Gabion (sides)
Stevens	Heney Creek	6,776	Concrete Channel	Pipe Culvert
	Montebello Creek	8,350	Natural Unmodified	Natural Unmodified

Table 4A-3 (concluded)
Linear Feet of Modified Stream Channel in the Santa Clara Basin Summarized by General and Detailed Channel Type1

Watersheds	Creeks	Length (feet)	General Channel Type	Detailed Channel Type
	Permanente Diversion Channel	182	Concrete Channel	Box Culvert
	Permanente Diversion Channel	432	Concrete Channel	Trapezoidal Concrete
	Stevens Creek	30	Concrete Channel	Arch Culvert
	Stevens Creek	285	Concrete Channel	Box Culvert
	Stevens Creek	2,355	Concrete Channel	Bridge
	Stevens Creek	136	Concrete Channel	Rock Lined –side/bottom
	Stevens Creek	790	Concrete Channel	Trapezoidal Concrete
	Stevens Creek	759	Concrete Channel	U-Frame Concrete
	Stevens Creek	1,983	Earth Excavated	Excavated Earth
	Stevens Creek	675	Earth Levee	Earth Levee
	Stevens Creek	149	Excavated Earth	Concrete (bottom)
	Stevens Creek	17,100	Natural Modified	Modifies Floodplain
	Stevens Creek	75,925	Natural Unmodified	Natural Unmodified
	Stevens Creek	1,675	Slope Concrete	Sack Concrete
	Swiss Creek	8,857	Natural Unmodified	Natural Unmodified
Sunnyvale East	Junipero Serra Channel	571	Concrete Channel	Pipe Culvert
	Junipero Serra Channel	7,533	Concrete Channel	Trapezoidal Concrete
	Junipero Serra Channel	10	Concrete Channel	U-Frame Concrete
	Sunnyvale East Outfall	3,193	Concrete Channel	Box Culvert
	Sunnyvale East Outfall	2,858	Concrete Channel	Pipe Culvert
	Sunnyvale East Outfall	146	Concrete Channel	Trapezoidal Concrete
	Sunnyvale East Outfall	408	Concrete Channel	U-Frame Concrete
	Sunnyvale East Outfall	12,753	Earth Excavated	Excavated Earth
	Sunnyvale East Outfall	2,360	Earth Levee	Earth Levee
Sunnyvale West	Sunnyvale West Outfall	1,042	Concrete Channel	Box Culvert
	Sunnyvale West Outfall	2,316	Concrete Channel	Pipe Culvert
	Sunnyvale West Outfall	200	Concrete Channel	Trapezoidal Concrete
	Sunnyvale West Outfall	203	Concrete Channel	U-Frame Concrete
	Sunnyvale West Outfall	2,730	Earth Excavated	Excavated Earth
	Sunnyvale West Outfall	6,590	Earth Levee	Earth Levee
	Sunnyvale West Outfall	37	Slope Concrete	Sack Concrete

Source: Waterways Management Model, Santa Clara Valley Water District

[1] Analysis was completed prior to the provisional revision of the Baylands boundary. Therefore, values depicted for the Baylands and the Arroyo la Laguna watershed do not reflect the revised boundary.

Appendix 4B
Process of Analyzing Projected Land Use Data

4B.1 Introduction

This appendix describes the data and procedures used to analyze projected development (residential and industrial/commercial) for hydrologic units in the Basin. The following references procedures executed using a GIS. The term “coverage”, as used below, connotes a common term used to refer to individual GIS data sets.

4B.2 Methods

Projected land use data (ABAG 1998) were transformed from their native MS Excel format to a Dbase format that was linked to a GIS coverage of U.S. Census tracts using the Tract-id.

Census tract boundaries were clipped to the Basin boundary using a GIS; thus, some tract areas were reduced. For such tracts, the acreage projected to be available for development, and to be developed for each land use (residential and industrial/commercial) was corrected by multiplying the projected acreages by a fraction representing the percent of the tract’s original size existing in the Basin. Small slivers (N = 45; median = 6 ac) were created by the process of clipping tracts to a redefined Basin boundary and were not included in the calculations of projected land uses for hydrologic units. They are distributed around the north and west perimeter of the Basin boundary; thus, the area per watershed attributable to such areas is minimal.

The percent of type of projected development was calculated for Basin watersheds using the following steps:

- The Census tract coverage (as clipped to the Basin) was intersected with the coverage of Basin watersheds using a GIS.
- Acreages for each type of development were summed by watershed, and results were exported to an MS Excel spreadsheet.
- The following calculations were made and presented in Table 4-7 and on Figures 4-10 through 4-12: the acreage of each watershed projected to be *available for development*, the acreage of each watershed projected *to be developed*, the percent of the available area projected to be developed, the percent of each watershed projected to be developed, and the percent increase (between 1995 and 2020) in the area of each watershed projected to be developed for each land use.

For some Census tracts, the acreage projected for development exceeded the available acreage. For such cases, the percentage of the tract projected as developed was reported as 100 percent. Most such cases occurred in very small Census tracts on the northwest border of the Basin (within Menlo Park’s jurisdiction); thus, their proportional effect on watershed area is minimal.