Stormwater Environmental Indicators Demonstration Project

Draft Report

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Technical information in this report was compiled from 16 Interim Technical Memoranda produced by the project team:

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Technical Memorandum #1: Preliminary Review and Program Assessment	Dan Cloak	Supervising Engineer, EOA, Inc.
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Macro-Invertebrate Assemblage	Francesca Demgen Kathleen Dorsey	Wetland Biologist, URS Kinnetics Laboratories, Inc.

The interim technical memoranda include additional detail, documentation, and data regarding implementation of the stormwater environmental indicators which were too voluminous and varied to be included in the project technical report. The memoranda are available on request from:

Santa Clara Valley Urban Runoff Pollution Prevention Program
EOA, Inc.
699 Town and Country Village
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www.scvurppp.org

A Quality Assurance Project Plan (QAPP) was prepared in two parts (Part 1: Walsh Avenue Catchment, and Part 2: Coyote Creek Watershed) under the direction of Marty Stevenson. of Kinnetics Laboratories. The GIS-generated maps and graphics were produced by Paul Randall and Lucy Buchan. Maya Hayden provided editorial assistance and coordination on the project report.

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Many of the reviewers attended project meetings in June, 1998 and February, 2000 where the utility of the indicators, and many of the recommended refinements, were discussed at length.

Contents

Abstract

[To appear in final draft]

Keywords: Stormwater, urban, indicators, geomorphology, imperviousness, fish, macroinvertebrates, BMPs.

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Acronyms

ABAG	Association of Bay Area Governments
ANCOVA	Analysis of CoVariance
ANOVA	Analysis of Variance
BASMAA	Bay Area Stormwater Management Agencies Association
BMPs	Best Management Practices
CCRS	Coyote Creek Riparian Station
CDC	California Division of Conservation
CDFG	California Deparment of Fish and Game
CFR	California Federal Register
CUPA	Certified Unified Program Agency
CWP	Center for Watershed Protection
DWR	Department of Water Resources
EMC	Event Mean Concentrations
EOA, Inc.	Eisenberg, Olivieri, and Associates, Inc.
EPT	Ephemeroptera, Plecoptera, Tricoptera
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
GPS	Global Positioning System
HHW	Household Hazardous Waste
IBI	Index of Biological Integrity
ICID	Illicit Connections/Illegal Discharges
IND	Industrial/Commercial Discharger Control
KLI	Kinnetic Laboritories, Inc.
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point Source
NWS	National Weather Service
PA	Participating Agency
PIP	Public Involvement and Participation
QA/QC	Quality Assurance/Quality Control
RBPs	Rapid Bioassessment Protocols
RWQCB	Regional Water Quality Control Board
SCBWMI	Santa Clara Basin Watershed Management Initiative
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SCVWD	Santa Clara Valley Water District
SEIDP	Stormwater Environmental Indicators Demonstration Project
SIC	Standard Industrial Classification
SJSU	San Jose State University
SWMP	Storm Water Management Plan
SWPPP	Storm Water Pollution Prevenion Plan
SWRCB	State Water Resources Control Board
TIEs	Toxicity Identification Evaluations
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
URMP	Urban Runoff Management Plan
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USGS	United States Geological Survey
WERF	Water Environment Research Foundation
WQC	Water Quality Criteria
WQO	Water Quality Objective

1. Introduction

The Stormwater Environmental Indicators Demonstration Project (SEIDP) was part of USEPA's Environmental Indicators/Measures of Success Project, funded under Clean Water Act Section 104(B)(3).

The first phase of USEPA's project consisted of a literature review and publication of an annotated bibliography of environmental indicator resources. In the second phase, stakeholders helped select appropriate indicators and helped develop of a flexible methodology for using indicators. Results of these two phases were published by the Center for Watershed Protection (CWP) as *Environmental Indicators to Assess Stormwater Control Programs and Practices* (Claytor and Brown, 1996). That report includes "indicator profiles", or fact sheets, describing 26 stormwater environmental indicators that may be implemented to evaluate stormwater program effectiveness. The authors also outline a two-level methodology for selecting and testing indicators, and illustrate scenarios for applying the indicators.

The SEIDP was part of the third phase that focused on local demonstration projects and testing of the indicator methodology described in Claytor and Brown (1996). The Water Environment Research Foundation sponsored the SEIDP jointly with the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP).

1.1 Measuring Stormwater Program "Effectiveness"

As mandated by 1987 amendments to the Federal Clean Water Act, municipal stormwater programs are required to:

⇒ Effectively eliminate non-stormwater discharges to storm drains.[1]

⇒ Require those engaging in activities that may cause the discharge of pollutants to storm drains to implement "best management practices" (BMPs) to reduce the quantity of pollutants discharged to the "maximum extent practicable."

USEPA's 1990 Phase I stormwater regulations (40 *CFR* 122.26) specified required elements for these municipal programs, including surveillance and enforcement to eliminate illicit connections and illegal dumping, inspection of industrial facilities and construction sites, and public education.

The purpose of these regulations was to protect the nation's waters for fishing, swimming, and other uses by reducing the potential effects of stormwater pollutants.

The 1990 regulations required that applications for storm water NPDES permits include: "Estimated reductions in loadings of pollutants from discharges of municipal storm sewer constituents from municipal storm sewer systems expected as the result of the municipal storm water quality management program." Accordingly, most stormwater NPDES programs have included sampling of stormwater discharges and receiving waters and analysis of these samples for regulated pollutants, including nutrients and toxics such as heavy metals.

In effect, the 1990 regulations set two standards for "effectiveness." The first standard is to show that specified control measures have been implemented to the "maximum extent practicable." The second, implied standard requires that programs demonstrate that mandated control measures are actually reducing the quantity of pollutants discharged.

Extensive studies — including this one — have generally been unable to show that the specified control measures significantly reduce the quantity of pollutants discharged from municipal storm drains. Inherent variability in stormwater pollutant concentrations, magnified by variability in runoff volume, tends to confound efforts to detect any downward trend in pollutant loads. In addition, other sources —for example, atmospheric fallout and the natural presence of trace metals in soils — may contribute a substantially to the total load of many pollutants. However, these difficulties in measurement also

[1] Except for some discharges (such as condensate from cooling systems) that are "exempt" if managed properly.

obscure the uncomfortable possibility that USEPA's mandated BMPs and control measures simply don't have any significant effect on the quantity of pollutants in runoff.

Another, equally important, concern is whether reductions in urban runoff pollutant loads — even if they were actually achieved — would have any meaningful effect on the beneficial uses of receiving waters. The most important effects of pollutants may be localized and transitory (for example, suppressed dissolved oxygen caused by dumping soapy water in a stream) rather than cumulative and widespread (for example, chronic toxicity related to the total amount of copper washed off annually from a whole watershed). Many typical urban runoff pollutants (e.g., lead and zinc) are rarely concentrated enough to cause toxicity in receiving waters. Urban runoff pollutants are typically bound to fine sediments and interact with sediments and organic matter, reducing their availability to affect fish or other aquatic life.

Beginning in the early 1990s, as the stormwater NPDES permit program was implemented, USEPA began to reassess stormwater monitoring parameters and goals with an eye towards development of comprehensive monitoring programs that characterize overall conditions in the receiving water and provide benchmarks for assessing the success of stormwater management efforts[2] (Claytor and Brown, 1996).

This reassessment tends to redefine, and broaden, what regulators expect stormwater programs to achieve. The fundamental intent of the 1990 stormwater regulations — to reduce average annual loading of toxic pollutants in runoff — has been found less relevant, and a move is on to redirect stormwater programs to address other, more significant problems affecting water bodies that receive urban runoff.

[2] Perhaps as a result of this reassessment, USEPA's Phase II stormwater regulations, issued in 1999, require that municipalities covered under the new stormwater NPDES permits simply "evaluate program compliance, the appropriateness of your identified best management practices, and progress towards achieving your identified measurable goals."

As a group of storm water regulators and managers concluded after a 1995 series of meetings: "Storm water programs will only be effective when a paradigm shift occurs in regard to our approaches to dealing with it as a pollutant source. Perception has to move from traditional, end-of-pipe, water-chemistry, broad-spectrum pollutant monitoring, treatment and command-and-control enforcement, to a mindset focusing on receiving water body quality and the beneficial uses that the community desires for that water body" (Rensselaerville Institute, 1995).

Urbanization has myriad and complex effects on downstream water bodies. Consider, for example, the cascading interaction between land users and adjacent urban streams. Alteration of the landscape, and changes to watershed imperviousness, change the quantity and timing of runoff and the amount of sediment reaching streams. As a result of these hydrologic changes, the configuration of the stream channel (width, depth, meanders, riffle/pool length) begins to change toward a new equilibrium with its watershed. The resulting movement of sediment (e.g. downcutting and bank erosion) affects water quality and physical habitat quality. Bank loss and flooding then leads adjacent property owners to physically alter the stream (e.g. riprap, channelization) in an effort to control the changes resulting from the disequilibrium. The physical alteration damages or eliminates the remaining habitat.

The nature of these problems, and their solutions, are quite different from the pollution-prevention mandate of the 1990 stormwater regulations. In effect, stormwater programs now face *three* sets of standards for effectiveness:

1. Implementation of BMPs and other control measures to the "maximum extent practicable."
2. Reduction in the quantity of pollutants discharged from storm drains.
3. Protection and enhancement of beneficial uses.

One can hypothesize circumstances where these standards coincide, i.e., where storm drain pollutants (and specifically, average annual pollutant loading) have discernable effects on beneficial uses and mandated BMPs can measurably reduce the loading of these pollutants. Of Claytor and Brown's (1996) three "theoretical scenarios to illustrate the potential application of stormwater indicators in real world situations," two imagine just such a situation.

However, our experience managing and monitoring stormwater programs suggests that such situations are atypical. In our experience, implementation of the mandated BMPs does not measurably reduce average pollutant loadings, and the expected changes to those loadings would not discernibly improve attainment of beneficial uses. Further, the major effects of urbanization on beneficial uses — and particularly, the effects of flow management and channel alteration — appear outside the influence of stormwater programs as designed and mandated under the NPDES permit program.

This incommensurability in goals and monitoring parameters has put stormwater program managers in a double bind.

As stewards of local government dollars, stormwater program managers must comply with enforceable NPDES permit provisions at minimum cost to the public, and they must not expand their efforts beyond what has been approved by their agencies' public process. But they must also answer to the desire of regulators, environmentalists, and the public to address the real problems affecting the uses of local streams, lakes and estuaries.

Urban watershed management provides a potential solution to this double bind, because it can place the stormwater pollution-prevention program in the context of a multi-agency, community-wide effort to protect and enhance urban waters. It may be possible to define a stormwater program role that stays within the general pollution-prevention mandate, makes efficient and reasonable use of public dollars, and contributes significantly to watershed management. Achieving consensus among municipal managers, regulators, and the public regarding the appropriate role for stormwater pollution prevention programs is a worthy early objective of an urban watershed management program.

With these considerations in mind, we started this project by proposing a working definition of an "effective" stormwater program as one that:

- ⇒ meets the obligations stated in its NPDES permit and management plan.
- ⇒ makes decisions openly and is responsive to contributions and new ideas from regulators and the public.
- ⇒ is continuously improving.
- ⇒ is actively involved in broad, stakeholder-based efforts to control pollution and to assess, protect and enhance beneficial uses of local waters.

1.2 Background on the Santa Clara Valley Urban Runoff Pollution Prevention Program

SCVURPPP includes 13 cities and towns within Santa Clara County and within the Santa Clara Basin, which is the watershed of South San Francisco Bay (Figure 1-1). SCVURPPP also includes the Santa Clara Valley Water District (which provides flood management and water supply services within the area) and Santa Clara County. (Table 1-1).

The Santa Clara Basin is a broad, northward draining valley between the Santa Cruz Mountains to the west and the Diablo Range to the east. Its interface with South San Francisco Bay is lined with sloughs, salt ponds and salt and brackish marshes that lead up to grasslands and woodland habitat above the basin floor. The Basin floor is flat and fertile. Since the mid-1950s, housing development, business and industrial parks, shopping centers, and freeways have replaced agricultural land uses. This development was triggered by the emergence of the electronics industry. Stanford University in Palo Alto spawned the earliest firms engaged in electronics and further supported the growth by building the Stanford Industrial Park. As available land in Palo Alto became scarce, the electronics and semiconductor industry moved south into Mountain View and Sunnyvale, then into Santa Clara and Cupertino. By the 1970s, industries were concentrated in the northern portion of the valley, with residential areas extending southward. Very-low-density, affluent residential

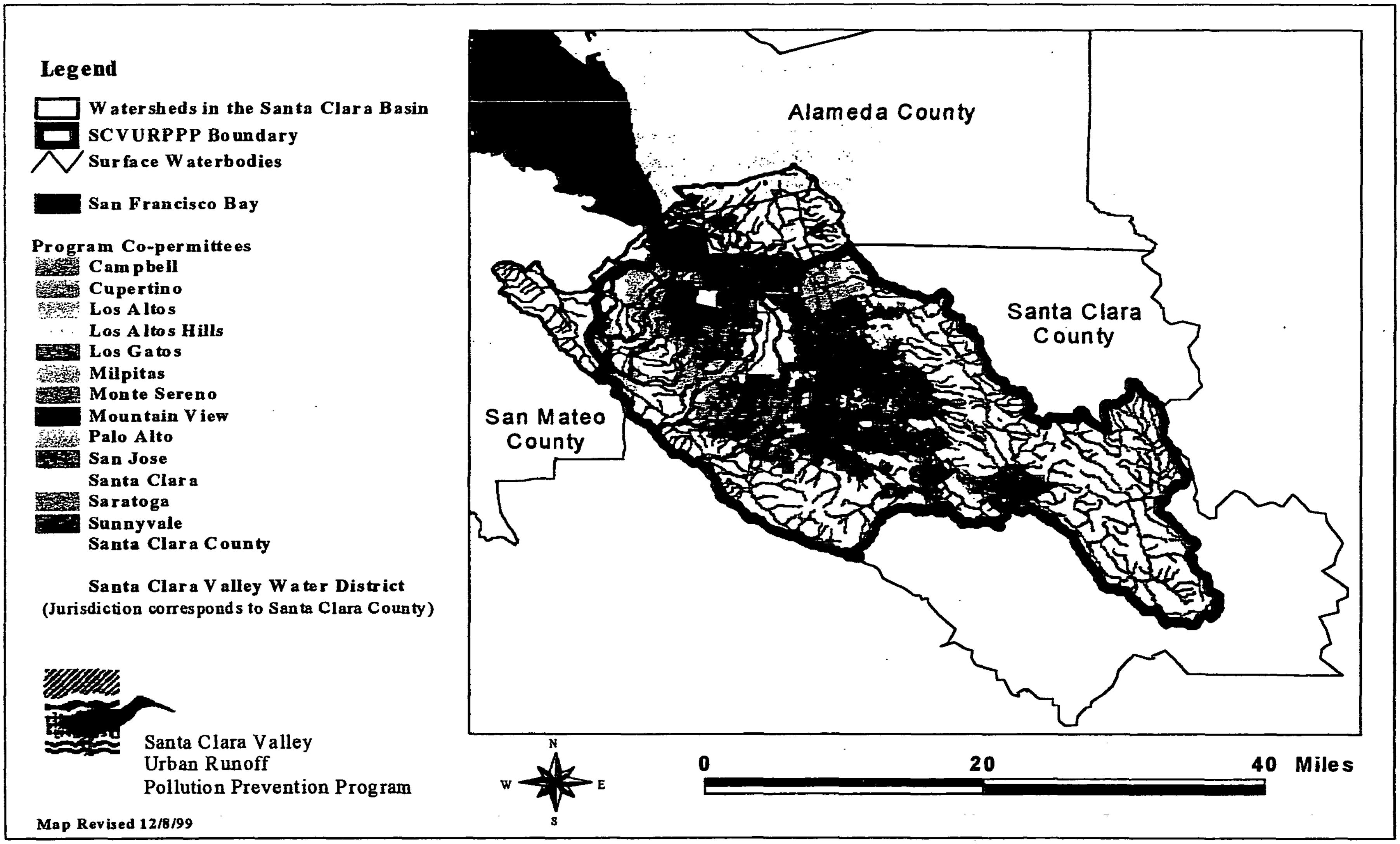


Figure 1-1. SCVURPPP area, Program Co-permittee jurisdictions, and Santa Clara Basin Watershed Boundary.

Table 1-1. Santa Clara Valley Urban Runoff Pollution Prevention Program Co-Permittees

Milpitas • San Jose • Santa Clara • Sunnyvale • Mountain View • Palo Alto • Cupertino • Saratoga • Campbell • Monte Sereno • Los Gatos • Los Altos • Los Altos Hills • County of Santa Clara • Santa Clara Valley Water District

areas developed in the western foothill communities.

The 1998 population of the Santa Clara County is nearly 1.7 million, 95 to 96 percent of who live within the Program area. According to the Association of Bay Area Governments' (ABAG's) *Projections 1996*, the county's population in the county will grow to about 1.9 million by 2015, and the economy will add 215,000 new jobs.

The Santa Clara Basin has warm, dry summers. Total annual rainfall, almost all of which occurs between October and April, varies from 60 inches in the Santa Cruz Mountains to about 12 inches in the eastern parts of the Basin. Creeks and streams that originate in the Santa Cruz Mountains and the Diablo Range drain through the Santa Clara Basin into South San Francisco Bay. These creeks include Coyote Creek on the east side of the valley, the Guadalupe River watershed, which drains the south-central portion of the valley, and several small, relatively urbanized watersheds that drain the west side of the valley. Two water pollution control plants, in Sunnyvale and San Jose, discharge to tidal sloughs. A third plant, in Palo Alto, discharges to South San Francisco Bay. (There are no wastewater discharges to South Bay creeks.)

The SCVURPPP, formerly the Santa Clara Valley Non-point Source Control Program, has been recognized as one of the most advanced such programs in the U.S.[3] SCVURPPP's 15 member agencies were among the first in California, and in the U.S., to begin implementing control measures for urban runoff pollution prevention.

The Program was organized in response to the 1986 Regional Water Quality Control Plan for the San Francisco Bay Region (Basin Plan). The 15 agencies prepared a plan (CH2MHill and EOA, Inc. 1987) to characterize urban nonpoint sources and to identify and evaluate existing and additional controls. The 15 agencies then signed a Memorandum of Understanding to jointly contribute to a series of monitoring and BMP studies leading to a control plan.

These materials became the basis for an NPDES permit application. In June 1990, the California Regional Water Quality Control Board (RWQCB) issued an early NPDES municipal stormwater permit jointly to the 15 agencies, or Co-permittees (RWQCB 1990). Permit provisions recognized that the Program had already accomplished significant work, which the RWQCB considered equivalent to municipal stormwater permitting requirements promulgated by EPA later that year.

As part of the 5-year NPDES permit cycle, the 15 Co-permittees developed and submitted a second SWMP to the Regional Board on June 30, 1995. The Regional Board approved the SWMP and issued the second NPDES storm water permit on August 23, 1995. The SWMP included metals control measures to address a TMDL and wasteload allocation for copper and nickel in South San Francisco Bay. The permit also required that the Program develop "watershed management measures." The 1995 Permit required the Program to develop a set of Performance Standards during 1995-1996. The permit defined Performance Standards as "the level of implementation necessary to demonstrate the control of pollutants in storm water to the maximum extent practicable."

During 1996 and 1997, the Program's Management Committee, comprising representatives from each of Santa Clara County's 15 cities and towns, Santa Clara County, and the Santa Clara Valley Water District, reviewed the Program's goals and organization. The review provided the context for the rewriting and resubmittal of the Program's Urban Runoff Management Plan (SCVURPPP 1997).

The stormwater program has now completed its second 5-year permit cycle, and has applied for what may be the nation's first "third generation" NPDES stormwater permit.

[3] The Program received EPA's First Place Award for Best Stormwater Program in 1994.

1.2.1 SCVURPPP Goals and Objectives

SCVURPPP's mission is: "To assist in the protection of beneficial uses of receiving waters by preventing pollutants generated from activities in urban service areas from entering runoff to the maximum extent practicable."

The mission:

⇒ Targets pollutant reduction measures that are needed to help protect beneficial uses.

⇒ Focuses on urban pollutant sources (as opposed to nonpoint sources generally).

⇒ Sets a specific benchmark for implementation (as opposed to doing "anything and everything" related to pollutant sources).

This focused approach is consistent with the Program's idea of working with other parties or institutions that are better equipped to carry out specific pollution control strategies. The Program concentrates its own efforts on identifying pollution sources, and implementing pollution prevention measures, that are clearly within the authority and ability of the Co-permittees.

The SCVURPPP's approach is to work with other parties or institutions that are better equipped to carry out specific pollution control strategies, focusing Program resources on identifying pollution sources and implementing pollution prevention measures that are clearly within the authority and ability of the 15 Co-permittees. The SCVURPPP's goals are:

GOAL 1: Comply with Permit

⇒ Effectively prohibit non-stormwater discharges (unless exempt or managed according to approved conditions).

⇒ Reduce, to the maximum extent practicable, pollutants in stormwater runoff.

⇒ Comply with permit submittal requirements.

GOAL 2: Determine Success

⇒ Periodically evaluate the attainment of beneficial uses in selected waterways.

⇒ Evaluate changes in public awareness and behavior.

⇒ Evaluate effectiveness of specific control measures at pollution reduction.

GOAL 3: Adjust Activities to Meet Changes

⇒ Define what constitutes success (how much is enough?) as it relates to programmatic and technical MEP.

⇒ Utilize what we learn to plan the next steps.

GOAL 4: Achieve Acceptance of Urban Runoff Management Activities

⇒ Effectively facilitate public input into Program planning process.

⇒ Integrate urban runoff goals at various intra-agency levels.

⇒ Develop and maintain a proactive interrelationship with regulatory authorities.

⇒ Publicize the efforts of the Co-permittees (Program)

GOAL 5: Integrate Urban Runoff Program Elements into other Programs

⇒ Promulgate an understanding of the role of the urban runoff program.

⇒ Encourage other agencies to become involved in urban runoff issues.

⇒ Encourage action by the appropriate agencies.

1.2.2 Comparison to Goals and Objectives of Other Stormwater Programs

To help insure broad applicability of this study, we also obtained goals and objectives from selected stormwater programs throughout the Bay area, California, and the U.S. Table 1-2 compares goals and objectives from the Alameda Countywide Clean Water Program, San Mateo Countywide Stormwater Pollution Prevention Program, Marin County Stormwater Pollution Prevention Program (Bay Area); Fresno-Clovis Storm Water Quality Management Program (Fresno, CA); City of Eugene Stormwater Management Program (Eugene, OR); Hampton Roads Planning District Regional Stormwater Management Program (Chesapeake, VA); and the

Table 1-2a: Comparison of Stormwater Program Goals and Objectives (Bay Area Programs)

Alameda Countywide Cleanwater Program (Alameda County, CA)	San Mateo Countywide Stormwater Pollution Prevention Program (San Mateo County, CA)	Marin County Stormwater Pollution Prevention Program(Marin County, CA)
Goal: Comply with the NPDES permit, maximize regulatory certainty by participating in regulatory planning processes, effective program management Objectives: 1) Annual reviews and reporting of member agencies' activities 2) Participation in BASMAA	Goal: Achieve Compliance with NPDES Objectives: 1) Develop cost-effective method for program 2) Incorporate focused, pragmatic approach 3) Build partnerships with other organizations 4) Track progress and incorporate process of continuous improvement	Goal: Develop and implement baseline controls to prevent pollutant discharges in storm water Objectives: 1) Require local agencies to investigate specific runoff discharges. 2) Require agencies to quantify pollutant loads, and implement control strategies to stop pollutants in runoff. 3) Require local agencies to file a Report of Waste discharge
Goal: Continue work w/ municipal maintenance staff to ID ways to optimize removal of pollutants and minimize maintenance discharges Objectives: 1) Implement performance standards and develop additional ones to address parking lots, sidewalks, flood control operations, municipal swimming pools, fountains, and recreational water bodies. Goal: Eliminate illicit discharges Objectives: 1) Conduct field surveys of storm drainage system 2) Identify sources of non-stormwater discharges 3) Provide technical assistance in identifying sources w/ non-member agencies that provide spill response/clean-up	Goal: To work with municipal public works to identify ways to optimize removal of pollutants. Objectives: 1) Implement performance standards; outreach and training for staff/public 2) Coordinate other STOPP subcommittees, other public agencies/private industries 3) Assist with regulatory compliance and planning	Goal: Implement services that directly remove pollutants from drainage system, prevent and respond to illicit discharges Objectives: 1) Determine how creek surveys can help prioritize municipal activities 2) Implement volunteer monitoring of watershed projects 3) Inspect businesses to find potential sources of pollutants 4) Inspect gutters, swales, ditches, inlets, and outfalls
Goal: PIP: educate area residents and encourage less polluting behavior. Objectives: 1) Target outreach about residential yard and garden care 2) Reinforce existing poll. prevention messages 3) Support watershed-based approaches 4) Evaluate effectiveness and update performance standards 5) Assist with staff training and continue collaboration with other educational groups	Goal: Educate public on differences between sanitary/storm sewer systems and causes of pollution Objectives: 1) Achieve public involvement through outreach and education 2) Conduct targeted campaigns, informational outreach activities 3) Implement performance standards, train PIP staff, build partnerships with companies and agencies	Goal: Educate the public about need to prevent stormwater pollution and protect creek/wetland habitat Objectives: 1) Distribute stormwater pollution prevention information 2) notify creek-side homeowners 3) Create an MCSTOPPP web page 4) Stencil storm water drain inlets

Table 1-2a: Comparison of Stormwater Program Goals and Objectives (Bay Area Programs)

Alameda Countywide Cleanwater Program (Alameda County, CA)	San Mateo Countywide Stormwater Pollution Prevention Program (San Mateo County, CA)	Marin County Stormwater Pollution Prevention Program(Marin County, CA)
Goal: Implement and ensure compliance with new development and construction controls. Objectives: 1) Provide guidance on cost-effective stormwater quality controls 2) Control construction related discharges 3) Promote outreach 4) Implement and update performance standards 5) Coordinate with flood control agency	Goal: Minimize water quality/beneficial use impacts of land development Objectives: 1) Prohibit non-stormwater discharges from construction sites 2) Reduce stormwater pollutant discharges from development/construction to the maximum extent practicable 3) Require compliance with BMPs and erosion, sedimentation control at construction sites.	Goal: Minimize pollutants in runoff from construction and development Objectives: 1) Limit potential development in county 2) Adopt control measures on new site development 3) Distribute brochures on BMPs for construction industry 4) Participate in ABAG training in erosion and sedimentation control methods 5) Develop partnership with Marin Builder's Association
Goal: Reduce pollutants in stormwater runoff and effectively eliminate non-stormwater discharges to storm drains from industrial and commercial facilities Objectives: 1) ID and minimize potential pollutant sources through facility inspections, outreach activities with businesses, and appropriate follow-up/enforce	Goal: minimize/eliminate potential stormwater pollution sources at industrial facilities; prohibit illicit discharges Objectives: 1) Help municipalities implement performance standards 2) Providing training and outreach materials to municipal staff and industries 3) Provide incentives for businesses to comply 4) Continuously evaluate effectiveness of STOPPP	Goal: Control industrial pollutants and enforce stormwater ordinances Objectives: 1) Develop a business inspection plan for each local program 2) Incorporate facility inspections into existing fire inspection programs 3) Prohibit non-stormwater discharges to creeks and storm drains 4) Require BMP implementation 5) Prohibit alterations to watercourses without permission
Goal: Use monitoring and special studies to characterize stormwater pollutant problems and identify improved solutions Objectives: 1) Track and coordinate with SFEI RMP and BASMAA's Monitoring Committee 2) Continued routine monitoring 3) Conduct special studies to id sources of pollutants and potential controls 4) Data management Goal: Determine the tangible water quality and aquatic resource benefits of using a focused watershed management approach in urbanized watersheds Objectives: 1) Participate in watershed management projects led by other agencies 2) Conduct pilot watershed project 3) Identify results, incorporate into Program	Goal: Identify effective BMPs and develop tools needed to identify creek drainage basin-specific, water quality issues Objectives: 1) Participate in the BASMAA Monitoring strategy 2) Evaluate the effectiveness of BMPs 3) Assess the state of significantly urbanized watersheds 4) Evaluate effectiveness of watershed studies	OTHER: Goal: Use local Program administration to create financing and planning efforts for MCSTOPPP Objectives: 1) Document expenditures on local programs and describe local program budgets 2) Develop plan for outreach, inspection, and enforcement at businesses that may pollute stormwater 3) Create Enforcement Committee to develop enforcement options to abate pollution 4) Fund a Flood Control naturalist

Table 1-2b: Comparison of Stormwater Program Goals and Objectives (Programs outside of Bay Area)

City of Eugene Stormwater Management Program (Eugene, OR)	Fresno-Clovis Storm Water Quality Management Program (Fresno, CA)	Hampton Roads Planning District Regional Stormwater Management Program (Chesapeake, VA)	Jefferson County, Kentucky Metropolitan Sewer District (Jefferson County, KY)
Goal: Meet requirements of Clean Water Act for nonpoint source pollution Objectives: 1) Develop proactive acquisition program for existing drainage channels 2) Determine feasibility of establishing and maintaining water quality facilities 3) Create and enforce water quality standards for new development, including post-construction 4) Clarify and strengthen enforcement of regulations to eliminate improper disposal of pollutants	Goal: Protect resources and beneficial uses from degradation by urban runoff Objectives: 1) Identify pollutants in urban runoff that pose threat to natural resources 2) Control sources of pollutants which pose greatest threat 3) Comply with federal NPDES mandate to control discharge of pollutants into stormwater drainage system 4) Develop cost-effective program to prevent stormwater pollution	Goal: Satisfy VPDES stormwater permit requirements Objectives: 1) Enhance erosion and sedimentation control 2) Manage illicit discharges, spill response, and remediation Goal: Manage stormwater quantity and quality to maximum extent practicable Objectives: 1) Implement BMPs and retrofit flood control projects to provide water quality benefits 2) Support site planning and plan review activities 3) Manage pesticide, herbicide, and fertilizer applications	*Under an EPA Region 4 NPDES permit, which contains very specific language as to what the program must achieve. Therefore, they have not formally developed a set of objectives.* *NOTE: The last goals/objectives listed in this table for Jefferson county are more comparable to those listed for Bay Area programs above.*
	Goal: Assess Effectiveness of Program Objectives: 1) Use focus groups to refine and update communication style and enhance cultural appropriateness 2) Reassess public attitudes, perceptions and practices of storm water quality and related environmental issues	Goal: Implement Regional Studies Objectives: 1) Undertake regional studies to support local stormwater management programs 2) Develop indicators of program effectiveness 3) Develop more cost-effective approach to existing monitoring program	Goal: Evaluate BMP's and each of the 5 program areas. Objectives: 1) Establish evaluation process 2) Define evaluation method (performance measure) and report results of assessment. 3) Performance evaluation of BMP's Goal: Implement monitoring program Objectives: 1) Assess specific wet weather impacts 2) Characterize stormwater/non-point source run-off quality from discrete land uses 3) Collect data to identify water quality trends 4) Utilize information from local volunteer monitoring programs

Table 1-2b: Comparison of Stormwater Program Goals and Objectives (Programs outside of Bay Area)

City of Eugene Stormwater Management Program (Eugene, OR)	Fresno-Clovis Storm Water Quality Management Program (Fresno, CA)	Hampton Roads Planning District Regional Stormwater Management Program (Chesapeake, VA)	Jefferson County, Kentucky Metropolitan Sewer District (Jefferson County, KY)
Goal: Educate the public about water related issues Objectives: 1) Evaluate ways transportation authorities can reduce pollutant discharge 2) Develop program for cleanup after structural fires and vehicular accidents to prevent contaminants from washing into storm drains 3) Support Tree planting programs 4) Coordinate with county government to expand programs, which provide means for proper disposal of commonly used pollutants	Goal: Educate the public to better understand and participate in control of urban runoff pollution Objectives: 1) Inform the public about Fresno Metropolitan Flood Control District's efforts to manage storm water quality 2) Educate public about sources of stormwater pollution 3) Educate public about proper use and disposal of materials which contribute to stormwater pollution 4) Assess effectiveness of PIE activities and encourage behavioral change. Goal: Maintain and Promote School Education Program Objectives: 1) Develop clean stormwater learning activities materials 2) Provide teacher workshops 3) Make presentations 4) Participate in programs to promote awareness Goal: Conduct Outreach Activities Objectives: 1) Expand distribution networks and materials 2) Presentation program for service groups, businesses 3) Implement stormwater quality management events 4) Promote hotline for illegal dumping 5) Enhance multi-cultural outreach	Goal: Implement Public Education and Training Objectives: 1) Employ an Environmental Education Coordinator 2) Increase public understanding of stormwater issues 3) Augment and enhance local stormwater education programs 4) Increase participation by public in programs and activities to reduce stormwater pollution.	Goal: Educate public in good housekeeping/pollution prevention Objectives: 1) Utilize BMPs to protect storm sewers during street maintenance 2) Clean catch basins, storm sewers and channels regularly 3) Evaluate alternative deicing chemicals 4) Conduct BMP Maintenance 5) Provide guidance on proper disposal of waste materials 6) Continue existing programs Goal: Develop public outreach programs Objectives: 1) Implement Adopt a Stream/Creek Sweep programs 2) Distribute pamphlets on non-point source pollution 3) Synthesize annual report with statewide comparison 4) Educate staff

Table 1-2b: Comparison of Stormwater Program Goals and Objectives (Programs outside of Bay Area)

City of Eugene Stormwater Management Program (Eugene, OR)	Fresno-Clovis Storm Water Quality Management Program (Fresno, CA)	Hampton Roads Planning District Regional Stormwater Management Program (Chesapeake, VA)	Jefferson County, Kentucky Metropolitan Sewer District (Jefferson County, KY)
Goal: Implement the West Eugene Wetlands Plan Objectives: 1) Develop program to inventory public/private parcels used for mitigation 2) Implement field program to detect/prevent illegal dumping of pollutants. 3) Monitor stormwater from industrial facilities 4) Implement effective erosion control program	Goal: Coordinate with other programs Objectives: 1) Participate in statewide coordination efforts to develop consistent messages about stormwater pollution prevention. 2) Review state, national and regional storm water quality program activities 3) Develop materials to communicate BMPs	Goal: Legislative/ Regulatory Monitoring Objectives: 1) Monitor state and federal legislative and regulatory activities that may have impact on local stormwater management programs 2) Develop briefing materials for use by localities, and consideration by governing bodies	
Goal: Maintain quality and effectiveness of stormwater system Objectives: 1) Evaluate existing maintenance program to ensure efficiency 2) Seek modification of federal regulations for design and maintenance of open water channels 3) Modify existing land use regulations Goal: Protect public and adjoining land use from flood/drainage damage Objectives: 1) Develop comprehensive drainage basin plans 2) Maximize capacity of existing stormwater facilities 3) Use FEMA 100-year floodway boundaries and waterway setbacks as recommended through adopted plans	Goal: Provide stable and equitable funding source Objectives: 1) Provide funding for acquisition of waterway corridors related to stormwater conveyance 2) Develop program to provide financial incentives to property owners who protect natural areas on their property	Goal: Meet needs of Citizens Objectives: 1) Address flooding and drainage problems 2) Maintain the stormwater infrastructure 3) Protect waterways 4) Provide the appropriate funding for the program	OTHER: Goal: Detect and Eliminate illicit discharge and improper disposal Objectives: 1) Implement an aggressive follow-up program 2) Revisit and retest contaminated outfalls, and determine source 3) Develop tracking system to estimate volume of discharge 4) Amend local ordinances Goal: Develop aggressive program to control non-point pollution sources from construction Objectives: 1) Require new-development to follow BMPs and keep all sedimentation on-site. 2) Offer training for designers, planners, developers, equipment operators 3) Provide guidance materials 4) Conduct scheduled inspections of BMPs 5) Require BMP maintenance schedule Goal: Implement post-construction controls Objectives: 1) Initiate watershed assessments 2) Initiate BMP pilot projects 3) Reduction to on-site imperviousness

Jefferson County, Kentucky Metropolitan Sewer District (Jefferson County, KY).

The consistency of goals among the programs reflects their common Federal pollution-prevention mandate. Most programs also show interest in a broader approach to protecting and enhancing beneficial uses of urban streams. The latter goal seems to be emphasized more among programs that are operated by flood control districts, as opposed to those operated by municipalities (who may have less direct responsibility for streams).

1.2.3 Performance Standards

Most activities of SCVURPPP Co-permittees — and the level of implementation for those activities — are defined in Performance Standards. Performance Standards describe a specific result, or level of effort, that constitutes the "maximum extent practicable" based on current technical knowledge, available resources and local conditions. The Program has model Performance Standards for:

⇒ Illicit Connection and Illegal Dumping Elimination Activities.

⇒ Industrial/Commercial Discharger Control Programs.

⇒ Public Streets, Roads and Highways Operation and Maintenance.

⇒ Storm Drain System Operation and Maintenance.

⇒ Water Utility Operation and Maintenance.

⇒ Planning Procedures.

⇒ Construction Inspection.

In addition, the Program prepared a Public Information and Participation (PIP) framework that the Co-permittees have used to develop their individual PIP programs and the Management Committee has used to develop a joint PIP program. The Performance Standards are updated as part of the Program's process of continuous improvement.

The model Performance Standards assist Co-permittees to develop their local programs. Co-permittees have the option of adopting the model Performance Standards without changes, or may develop their own Performance Standard by adapting the model Performance Standard to suit their local conditions. In developing their own Performance Standards, Co-permittees cite their specific characteristics to justify a different degree of implementation

1.2.4 Santa Clara Basin Watershed Management Initiative

SCVURPPP's June 1995 Proposed Storm Water Management Plan contained five Watershed Management Measures, beginning with institutional arrangements and leading, after some years of planning, to area-wide watershed management. Since that time the Program has helped forge a new approach that brings in stakeholders at the beginning of the planning process. The Program's 1997 Urban Runoff Management Plan incorporates participation in the Santa Clara Basin Watershed Management Initiative (SCBWMI).

In April 1996, the U.S. Environmental Protection Agency, the SWRCB and the RWQCB initiated the SCBWMI. These regulatory agencies recognized that, up to that time, issues affecting watersheds have been addressed by a "patchwork" of separate regulatory actions. There was a need to coordinate regulatory activities on a basinwide scale.

The regulatory agencies invited various interested parties (stakeholders) to discuss their interest in watershed management and how to begin planning watershed use and protection. Program staff and Co-permittee staff have participated in this Core Group, and various SCBWMI workgroups, since their inception.

A fact sheet issued by this Core Group states: "Many diverse factors impact the basin, including water quality, land use, flood protection, water supply and habitat protection. A holistic strategy is required to confront and manage these issues. By addressing all sources of pollution that threaten the Bay, we can achieve a sustainable balance of human and natural uses and needs. Regulators, along with local community, environmental, agricultural and business representatives, must maintain a continuous, productive dialogue to protect the Santa Clara Basin."

While this study was underway, (June 1998 – June 2000), SCBWMI stakeholders collaborated to produce a Watershed Characteristics Report, which is intended to lay the groundwork for a Watershed Management Plan. A detailed assessment of three of the basin's 14 watersheds is currently underway. The SCBWMI will participate in assessment of the Coyote Creek watershed during 2000-2001; that assessment will make use of data and analyses conducted under this study.

1.2.5 Continuous Improvement

The SCVURPPP is dedicated to a process of continuous review and improvement, which includes seeking new opportunities to control stormwater pollution and to protect beneficial uses. When such opportunities arise, the Program revises, updates and adds to its activities, control measures, BMPs and Performance Standards. The changes are documented in annual reports. Regional Board staff and Co-permittees participate in annual reviews of the Program's work and the setting of priorities for the coming year. This review is also an opportunity to check progress on activities required under the Program's permit and on previous Program commitments.

In addition, annual Co-permittee review meetings facilitate in-depth review of specific activities and documentation, and help familiarize Regional Board staff with the issues and challenges faced by local urban runoff program coordinators. The reviews also provide an opportunity for local staff to comment on the Program's work and identify additional ways that the Program could assist local pollution-prevention efforts. A meeting summary and list of action items follows up each local program review.

As the SCBWMI assesses urban watersheds and develops a watershed management plan, the Core Group and workgroups regularly identify special studies, or institutional needs, that the Program (among SCBWMI stakeholders) is best suited to implement. For its part, the Program has identified four general areas of support for the SCBWMI:

⇒ Support for field work and other watershed assessment tasks.

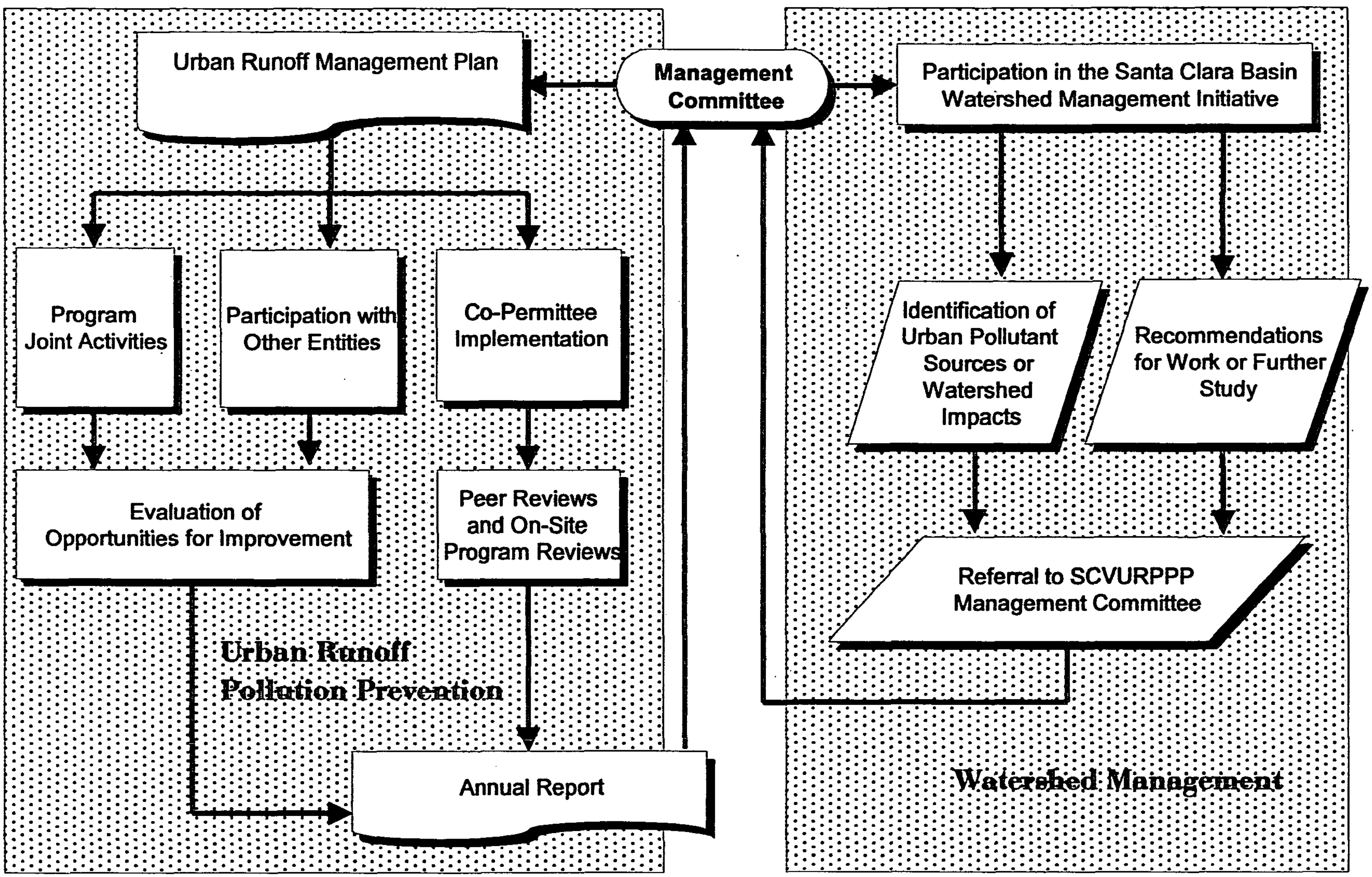
⇒ Administrative support for SCBWMI workgroups.

⇒ Support related to land use issues in watershed planning.

⇒ Support for outreach and public education.

The Program's continuous improvement process is illustrated in Figure 1-2.

Fgure 1-2. Continuous Improvement



2. Project Objectives

⇒ The SEIDP's objectives were to:

⇒ Evaluate the usefulness of the two-level Stormwater Indicator Methodology under semi-arid conditions;

⇒ Evaluate the use of environmental indicators under semi-arid conditions for two scales of analysis; within a watershed, emphasizing chemical, physical and biological indicators, and within an industrial catchment emphasizing programmatic indicators;

⇒ Select, test, and refine protocols for monitoring environmental indicators in semi arid conditions;

⇒ Develop guidance on selection and use of environmental indicators, and disseminate guidance to other stormwater programs in California, Oregon and the west to assist in validation of environmental indicators throughout the west.

Claytor and Brown's (1996) stormwater indicator methodology (Figure 3-1) distinguishes between two levels of analysis:

⇒ Level I, Problem identification.

⇒ Level II, Assessment of stormwater management program.

The Level I methodology consists of five steps that include (1) establishing which entities are responsible for implementing management of a monitoring program, (2) gathering and reviewing historical data to identify problems that have been previously associated with stormwater programs and effectiveness of management efforts to address such problems, (3) identifying receiving water impacts, (4) inventory resources and identify constraints to implementing a monitoring program, and (5) assess baseline conditions of receiving waters.

The Level II methodology consists of six steps that include (1) stating the stormwater program goals, (2) inventorying prior and ongoing stormwater program management activities, (3) developing and implementing program activities to achieve program goals, (4) developing and implementing a monitoring program using indicators to evaluate the success of the stormwater management program, (5) assessing monitoring results and evaluating stormwater program effectiveness, and (6) re-evaluating the stormwater management program.

To test the usefulness of the indicator methodology, we applied both the Level I and Level II steps to the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP, or Program).

To evaluate individual indicators, and to select, test, and refine protocols for implementing those indicators, we applied 20 of Claytor and Brown's 26 indicators at three different spatial scales: within the 350 square-mile Coyote Creek watershed, within the 28-acre industrial Walsh Avenue catchment (Figure 3-2) and throughout the Program area. Different environmental indicators were evaluated at each scale (Table 3-1).

In Coyote Creek, environmental indicators were used to conduct three types of comparisons:

1) temporal comparisons in the upstream reference areas, where land uses have not changed recently,

2) temporal comparisons at the stations in Coyote Creek that have transitioned from rural to urban and

3) spatial comparisons between the upstream reference stations and the downstream urban stations.

In the Walsh Avenue catchment, water quality indicators, programmatic indicators, social indicators, and site indicators were used to gauge success of Program implementation. Results from water quality monitoring were used to evaluate if changes in water quality can be correlated to the Program's efforts.

We applied three social indicators to the SCVURPPP area.

3.1 Study Areas

3.1.1 Coyote Creek Watershed

The Coyote Creek watershed (Figure 3-3) is fairly typical of an urban watershed in California. The pattern of an intact headwaters region and a more developed region in the lower gradient downstream portions of the watershed, impacts from current and historic mining, grazing, and agriculture, modifications to hydrology and geomorphology, are all factors affecting many Western streams and rivers today.

Coyote Creek watershed is located in the Santa Clara Basin, at the northern extent of California's Central Coast Range, and the southern extent of the San Francisco Bay Area. Coyote Creek flows approximately 70 miles from its headwaters in the Western Diablo Range, northeast of Morgan Hill, to where it discharges to South San Francisco Bay, in the city of Milpitas. Approximately 55 percent of the watershed is above Anderson Dam and is composed primarily of rural land under the jurisdiction of Santa Clara County. The drainage area below the dam is both rural and urban, with

Figure 3-1. Claytor and Brown (1996) Stormwater Indicator Methodology - two levels of analysis.

STORMWATER INDICATOR METHODOLOGY
LEVEL I, PROBLEM IDENTIFICATION

① ESTABLISH MANAGEMENT SPHERE

Who will be responsible for implementation? A government agency (municipality, county, or state) or a site-specific industry? What other programs are being implemented within the watershed? Can this program be developed and implemented on a watershed-wide or basin basis?

⇓

② GATHER/REVIEW HISTORICAL DATA

Identify what programs and studies have already been implemented in the watershed.
Determine what problems associated with stormwater have already been identified.
Assess the effectiveness of earlier efforts and programs.

⇓

③ IDENTIFY POTENTIAL RECEIVING WATER IMPACTS

Identify uses and characteristics which may be impacted by stormwater runoff.
Hydrology and Hydrodynamics (Flooding, Drainage)
Biological Integrity (Fish Diversity, Macro. Community)
Non-contact Recreation (Sports Fishing)
Supply (Potable Water)
Contact Recreation (Swimming)
Aqua-culture (Shellfish Harvesting, Food Fishing)

⇓

④ INVENTORY RESOURCES AND IDENTIFY CONSTRAINTS

Determine manpower and funding limitations.
Identify regulatory-mandated deadlines and programs.

Staffing
Scheduling Constraints
Funding
Regulatory Compliance

⇓

⑤ ASSESS BASELINE CONDITIONS

Use rapid (qualitative) assessment methods versus detailed quantitative techniques to assess baseline conditions.

Indicator Options by Receiving Water Use

Concern:	Hydrology & Hydrodynamics	Biological Integrity	Non-contact Recreation	Water Supply	Contact Recreation	Aqua-culture
Type of Indicator to be Considered:	*Physical* *Social* *Programmatic* *Site*	*Biological* *Water Quality* *Social* *Programmatic* *Site*	*Water Quality* *Physical* *Biological* *Social* *Programmatic* *Site*	*Water Quality* *Biological* *Social* *Programmatic* *Site*	*Biological* *Water Quality* *Physical* *Social* *Programmatic* *Site*	*Biological* *Water Quality* *Physical* *Social* *Programmatic* *Site*

STORMWATER INDICATOR METHODOLOGY
LEVEL II, ASSESSMENT OF MANAGEMENT PROGRAM

① STATE GOALS FOR PROGRAM

Based on baseline conditions, resources, and constraints, articulate goals for stormwater management program in terms of measurable achievements.

Example: We want to increase the level and diversity of the fish population in the next 5 years.

To accomplish this, we must improve biological integrity, water quality, and physical conditions.

② INVENTORY PRIOR AND ONGOING EFFORTS

Identify prior stormwater management efforts and assess success of prior efforts.

Identify current stormwater management efforts both within the municipal boundaries and the larger watershed.

Assess success of ongoing efforts.

Incorporate complementary programs and goals.

Identify potential conflicts.

③ DEVELOP AND IMPLEMENT MANAGEMENT PROGRAM

Identify and implement specific program facets in order to achieve goal.

Example: In order to increase the fish population, we will retrofit BMPs, require stormwater BMPs all new development, remove fish barriers, and re-introduce some aquatic species.

④ DEVELOP AND IMPLEMENT MONITORING PROGRAM

Based on goals, program structure, resources and constraints, select indicators to be used to assess success of stormwater management program. Level II indicators will likely be more quantitative in comparison to Level I techniques. Quantitative analysis is required to identify pollutant sources and assess success of program.

Example: macro-invertebrate assemblage, fish assemblage, public opinion surveys, toxicity testing.

⑤ ASSESS INDICATOR RESULTS

Analyze indicator monitoring results.

What do the monitoring results indicate about the success of the stormwater management program?

Have the indicators accurately reflected the effectiveness of the management program?

What do the indicators suggest about the ability of the stormwater indicator monitoring program to measure of overall watershed health?

⑥ RE-EVALUATE MANAGEMENT PROGRAM

Re-evaluate resources and constraints.

Update (if necessary) assessment of baseline conditions.

Review and revise program goals.

Review and revise indicator monitoring program.

Implement revised management program.

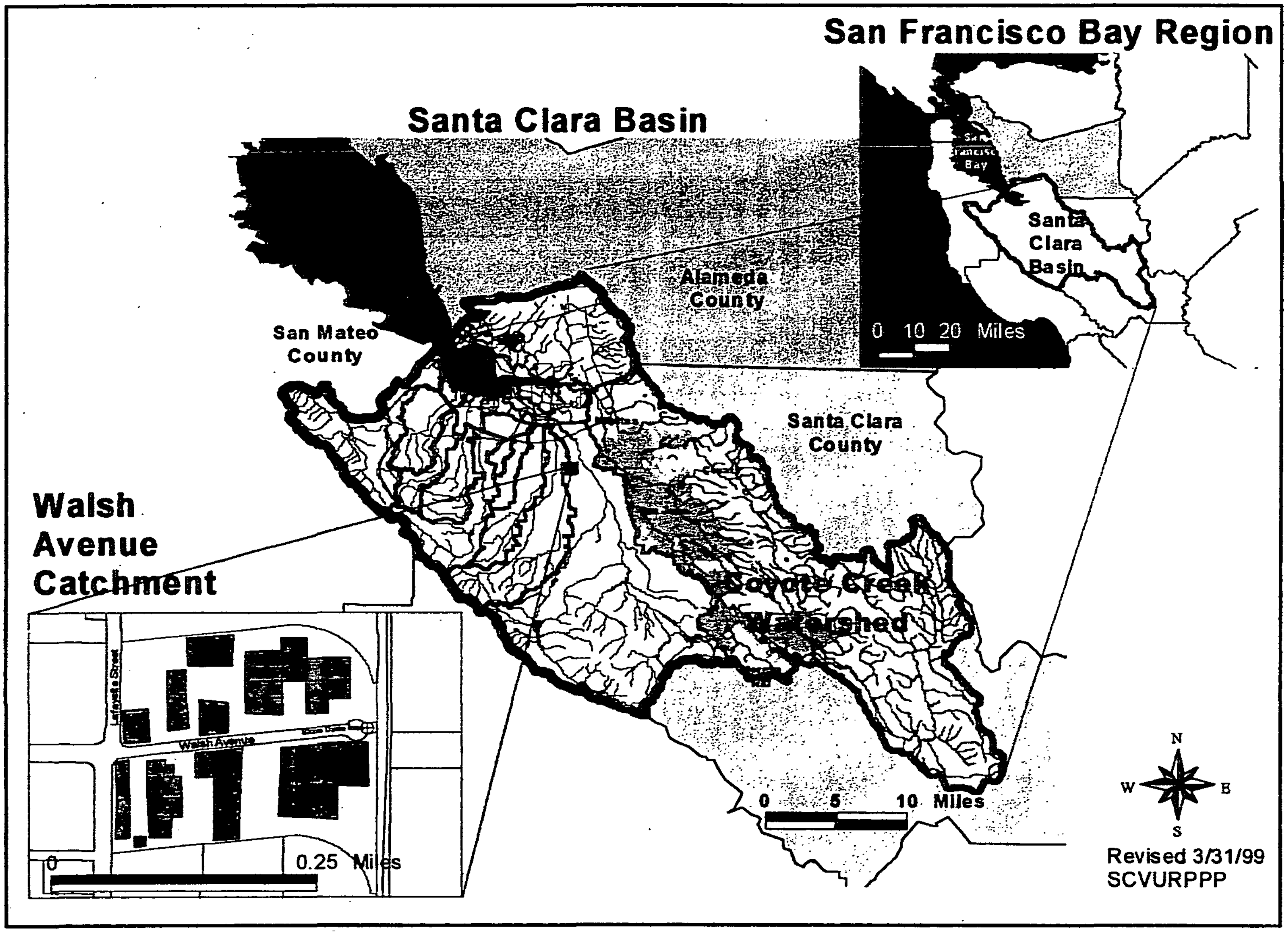


Figure 3-2. Stormwater Environmental Indicator Demonstration Project study areas – Coyote Creek watershed and Walsh Avenue Catchment – and regional hydrologic units.

Table 3-1. Center for Watershed Protection Indicators Tested

Claytor and Brown Categories	#	Indicator Name	Walsh	Coyote	Program Area
Water Quality Indicators	1	Water quality pollutant constituent monitoring		√	
	2	Toxicity testing	√		
	3	Non-point source loadings	√		
	4	Exceedance frequencies of water quality standards		√	
	5	Sediment contamination		√	
	*6**	*Human health criteria*			
Physical and Hydrological Indicators	7	Stream widening/downcutting		√	
	8	Physical habitat monitoring		√	
	*9**	*Impacted dry weather flows*			
	10	Increased flooding frequency		√	
	11	Stream temperature monitoring		√	
Biological Indicators	12	Fish assemblage		√	
	13	Macro-invertebrate assemblage		√	
	*14**	*Single species indicator*			
	*15**	*Composite indicators*			
	*16**	*Other biological indicators*			
Social Indicators	17	Public attitude surveys			√
	18	Industrial/commercial pollution prevention	√		
	19	Public involvement and monitoring			√
	20	User perception			√
Programmatic Indicators	21	Number of illicit connections identified/corrected		√	
	22	Number of BMP's installed, inspected, and maintained	√		
	23	Permitting and compliance	√	√	
	24	Growth and development		√	
Site Indicators	*25**	*BMP performance monitoring*			
	26	Industrial site compliance monitoring	√		

** Claytor and Brown indicators which were not implemented as part of the Stormwater Environmental Indicators Demonstration Project.*

approximately 36 percent of the area urbanized, under the jurisdiction of the cities of San Jose and Milpitas.

The Santa Clara Basin is situated between two parallel, northwest-trending mountain ranges and geological faults. The Santa Cruz Mountains and San Andreas Fault occurs along the western edge and the Diablo Range and Hayward and Calaveras Faults on the eastern edge of the basin. Both ranges originated as volcanic sea floor and were created by tectonic lifting along the major fault zones. The exposed rocks of the two ranges are composed of the Franciscan Formation, consisting of silt, shale, sandstone and serpentine rock. This formation is highly susceptible to landslides and produce moderate to high sediment yields (DWR 1978).

The Santa Clara Valley is a large trough resulting from the tectonic activity and long-term accumulation of sediments from the adjacent mountain ranges. During the past 30,000 years, the southern portion of the valley has largely been shaped by erosive processes acting on the ranges and depositing sediments at the mouths of rivers forming alluvial fans. The northern portion of the valley has been greatly influenced by deposition of silt and clays from glacial meltwater and subsequent rise and fall in sea level. Transportation and deposition of gravels, sands, silts and clay continue to shape the Basin as a result of gradual erosion as well as episodic events, such as earthquakes, fires and floods.

The Coyote Creek Watershed is composed of five ecoregion subsections, but is dominated by two regions that differ primarily in precipitation, elevation and gradient (Bailey et al. 1994). The Western Diablo Range ecoregion is composed of Franciscan sedimentary, volcanic and metamorphic rocks that are intensely folded and faulted. The plant communities are typically composed of grassland, scrub or chaparral habitat on the tops of hills, and oak woodlands in the steep valleys and canyons. The elevation range of the section is between 1000 and 4000 feet above sea level. The climate ranges from 20 to 30 inches of mean annual precipitation. The mountains are steep with narrow canyons, water runoff is rapid and all but the larger streams are dry throughout the summer season.

The other predominant ecoregion is the Santa Clara Valley, which is primarily an alluvial plain that was deposited during in the Late Quaternary Period. Elevation within the region ranges from sea level to 1000 feet. The predominant natural plant communities are valley oak and annual grasslands. The climate ranges from 12-20 inches of mean annual precipitation. Fluvial erosion and deposition are the major geomorphic processes that occur in this region. The alluvial plain slopes gently and has a nearly level floodplain with alluvial fans. Runoff is rapid, and most streams are dry in the summer season. Coyote Creek, however, is sustained by ground water and by regulated flows from two permanent dam-reservoir systems (see below), and thus flows year-round.

The Santa Clara Basin ground water system is characterized by two interconnected subbasins. The larger of the two subbasins (the northern Santa Clara Valley) is more important with respect to local water supply, and is composed of two distinct geological regions. The permeable, unconsolidated region, located north of the Coyote Narrows (Figure 3-3), is composed of alluvial fill that allows surface water to infiltrate and recharge the under ground aquifer. Between the recharge zone and the South Bay is the unconsolidated region, which is divided vertically into two major water bearing zones. These two zones are located above and below a thick layer of clay, or aquiclude, which prevents ground water movement and exchange between the two zones. The Coyote Valley subbasin is also filled with alluvial sediments, and connects to the Santa Clara subbasin to the north through the Coyote Narrows. During the 1920's and 30's, pumping of groundwater for urban and agricultural uses resulted in significant land subsidence in the Santa Clara Basin. To protect the underground aquifer and maintain a water supply to the Santa Clara Valley, dams and water diversions were built to provide an alternative water source to the over-pumped aquifer. The Santa Clara Valley Water District (SCVWD) currently promotes ground water recharge by managing 393 acres of percolation ponds throughout the County.

As is typical of the majority of rivers and streams in California and the Western U.S., the

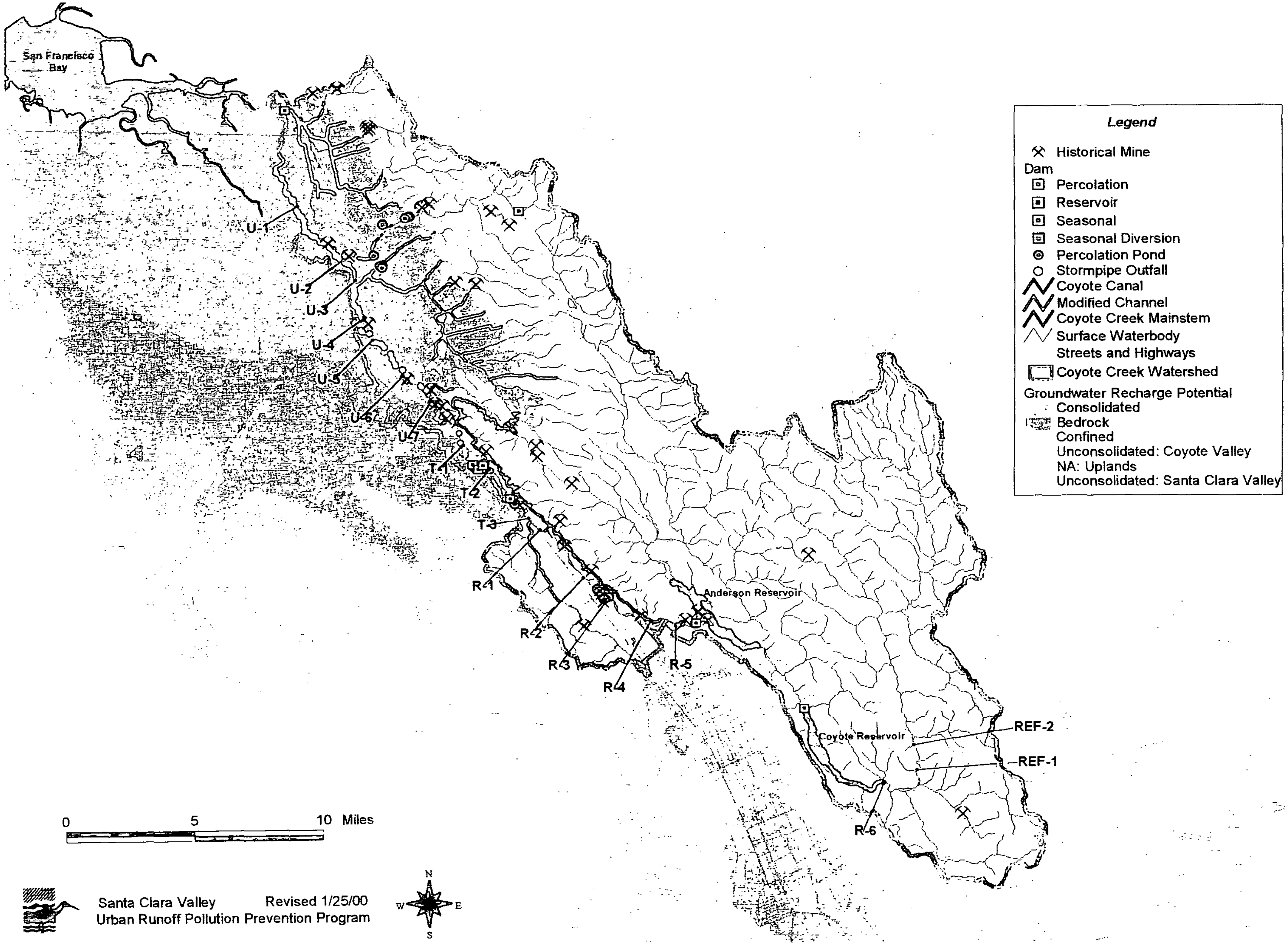


Figure 3-3. Geology, Hydrology and Land Use Features of Coyote Creek Watershed, Santa Clara County.

hydrology and geomorphology of Coyote Creek along the valley floor has been highly modified. At the base of the Diablo Range, the Creek is impounded by two dams, which form Coyote and Anderson Reservoirs. Coyote Dam was built in 1936 and its reservoir has a capacity of 22,925 acre-feet. Two miles downstream the creek empties into Anderson Reservoir, which was built in 1950 and has a capacity of 89,073 acre-feet. Streamflow from both dams is regulated between April and October. and runoff above Coyote Dam accounts for about 75 percent of the total runoff for the entire Anderson/Coyote watershed (Iwamura 1999). Nine tributaries drain to the two reservoirs and transport large amounts of sediment; however the dams effectively reduce the amount of sediment transported downstream. Management of flows released from the dams have also reduced peak flows and increased summer flows for groundwater recharge.

About 0.5 mile below Anderson Dam, water is diverted (April – October) by the Coyote Creek Diversion Dam into a concrete channel (Coyote Canal) that bypasses the natural channel. Water is reintroduced to the natural channel approximately six miles downstream at the Coyote Narrows, just upstream of the Coyote Percolation Ponds. Such diversion dries the natural channel during the summer months. A fish screen was installed in 1999 to prevent downstream passage of fish into the Coyote Canal.

Between Anderson Dam and the Creek-mouth, three major percolation pond systems are located within or adjacent to Coyote Creek. The percolation ponds, located two miles below Anderson Dam in Santa Clara County Park property, were historic gravel quarry pits. These ponds occur off the natural channel, but connect to the creek during high flows through a breach in a levee. The Coyote Percolation Ponds, just downstream of Coyote Narrows, were originally pits created by gravel mining in the natural channel and are now managed by the SCVWD as a ground water recharge system. A permanent concrete dam was built in the 1930's to increase the size of these ponds (Joe Aguilera, SCVWD, personal communication). In 1999, a fish ladder was constructed to allow passage over the dam. Approximately 1.5 miles farther downstream are the Ford Percolation Ponds, three separate ponds in the natural channel created by seasonal spreader dams. These dams were removed[4] in 1997 and Coyote Creek now flows unimpeded through the historic pond area.

Ten sand and gravel mines were operated historically on Coyote Creek below Anderson Dam. Evidence of the mining operations include presence of gravel pits and exposed river flood plains, resulting from the removal of riparian vegetation. Instream gravel pits cause stream degradation typical of gravel extraction, e.g. bank erosion, and changes in stream elevation and morphology, that negatively impact fisheries and their habitats (Kondolf 1994). Increased sediment deposition in some sections of the Coyote Creek below Anderson Dam is an indication that bank erosion continues to be a problem (Ken Reiller, SCVWD, pers comm, 1999).

The boundary between the mountains of the Diablo Range and the alluvial plain that forms the valley floor is sharply defined. At least four major tributaries flow from the mountains across this alluvial plain to Coyote Creek. Sixty-eight storm drain outfalls from the cities of Morgan Hill, Milpitas and San Jose also contribute flow to reaches of Coyote Creek below Anderson Dam. The runoff from the City of Morgan Hill is mostly transported from an adjacent watershed.

Much of the riparian corridor below Anderson Dam is intact. Orchards, farmlands and urban development have replaced the original riparian vegetation that occurred in the high terraces of the channel. The middle terrace has managed to survive, dominated by cottonwoods, with few remaining oak and sycamore trees. Much of this riparian corridor is managed by the Santa Clara County Parks and receives some recreational use. The lower Coyote Creek is considered to be one of the highest quality riparian corridors remaining in the southern San Francisco Bay region (U.S. Army Corps of Engineers 1986).

The urbanized area of Coyote Creek watershed, has dramatically increased since the 1960's. During this time, population has increased greatly, and agricultural and grazing land have been converted to residential communities in

[4] Reinstallation is contingent upon permit approval by the CDFG.

the southern region of the Santa Clara Valley, and along the base of the Western Diablo range.

The lower reaches of Coyote Creek have been partially modified for flood protection. Setback levees and a high bypass channel have been constructed in the lowest section of Coyote Creek. In addition, several miles of tributary stream channels have been similarly modified, including the lower portions of Upper and Lower Penitencia, Berryessa, Lower and Upper Silver Creeks.

As Coyote Creek nears the South Bay a transition occurs from a freshwater environment to an estuarine environment where the channel and adjacent baylands contain many acres of brackish marsh, salt marsh and mudflats. Originally, an earthen dam was constructed to prevent saltwater intrusion into agricultural lands. Recently (1995), the SCVWD installed a replacement steel dam just upstream of the original dam site. Difficulty with dam operation has precluded installation since 1997. A study is being conducted (1998 – 2000) to assess its impact and viability of continued operation (Jae Abel, SCVWD, personal communication, 1999). The reach of Coyote Creek downstream of Standish Dam receives fresh water discharged from the San Jose-Santa Clara Water Pollution Control Plant.

3.1.2 Walsh Avenue Catchment

The Walsh Avenue Catchment is a 28-acre industrial area located on the north and south sides of Walsh Avenue between the Southern Pacific Railroad lines and Lafayette Street in the eastern portion of the City of Santa Clara. Currently, 32 industrial and commercial businesses operate in the catchment area. Activities include metal plating, high-tech equipment assembly, parts distribution, and warehouse storage. Two businesses have submitted a Notice of Intent to the California State Water Resources Control Board under California's General Industrial Stormwater NPDES permit (Figure 3-4). These two businesses also maintain pretreatment permits for industrial sewage discharge to the San Jose/Santa Clara Water Pollution Control Plant. Three businesses formerly covered under the statewide permit have terminated coverage, either because they ceased specific operations covered under the permit or because they have closed the business.

All surface drainage from the catchment flows to a stormdrain inlet located at the end of Walsh Avenue (Figure 3-5) and discharges to the Guadalupe River. This inlet has served as a water quality monitoring station since 1988.

The catchment was selected as a study area for this project because it contained only industrial businesses and drained to a single storm drain inlet. In addition, including historic water quality sampling data was available, and the Program had a history of outreach and involvement in this area.

History of Program Involvement in the Catchment

In 1992-93 the Program and the City of Santa Clara implemented a pilot project in the Catchment to reduce loads of zinc, copper, lead and other pollutants in stormwater discharge through a comprehensive inspection program designed to identify pollutant sources and to provide assistance to facility owner/operators of source control measures and BMPs. The Catchment was selected for the pilot because of its small size and because of high levels of zinc, copper, and lead found in runoff from the Catchment (Woodward-Clyde 1993).

A secondary objective of the 1992-93 Walsh Avenue Pilot Inspection Program was to develop generic industrial inspection guidelines that could be applied by other Program participants to locate and control important industrial sources of storm water pollution within their jurisdictions. These inspection guidelines included hands-on training for inspectors, the development of written procedures and forms, and the prioritization of facilities for inspection. Over the course of this pilot study, 23 facilities were inspected. Eleven of these 23 facilities warranted a reinspection due to problems that were identified to likely contribute pollutants to stormwater. Eighteen of the current businesses in the Catchment also participated in the 1993 pilot study.

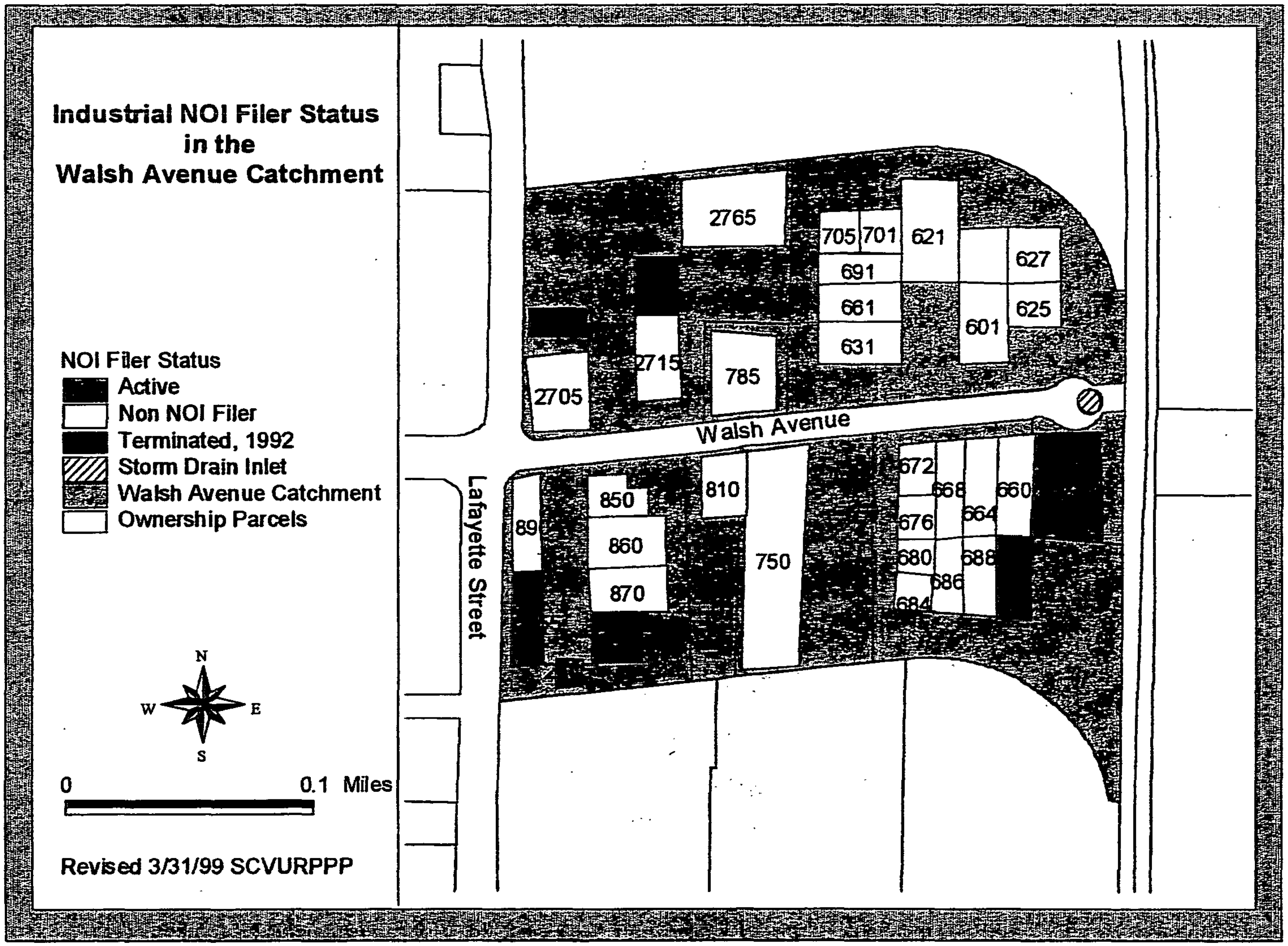


Figure 3-4. Industrial facilities within the Walsh Avenue catchment illustrated by NOI filer status.

In addition to the pilot inspection program, the Program has conducted routine sampling and analysis of runoff from this Catchment since 1988. Monitoring has involved monitoring of flow, metals, performing whole effluent toxicity testing, and conducting Toxicity Identification Evaluations (TIEs). Stormwater monitoring involved installation of an automated flow monitor and a water quality sampler programmed to collect flow-weighted, composite samples.

Background on the City of Santa Clara's Industrial/Commercial Stormwater Inspections

The City of Santa Clara adopted the Program's model Performance Standard for Industrial/Commercial Discharger Control (IND), but made minor modifications to tailor the model to the specific types of business within the City. The model Performance Standard and supporting documents provide for:

- ⇒ Inspections of industries which have filed a Notice of Intent (NOI) to be covered under the SWRCB statewide NPDES permit for stormwater discharges associated with industrial activities;
- ⇒ Investigation of other facilities that are identified within selected Standard Industrial Classification (SIC) codes;
- ⇒ Inspections of selected commercial facilities;
- ⇒ Distribution of information on industrial/commercial Best Management Practices;
- ⇒ Action, under local authority, on all violations of local municipal ordinances; and
- ⇒ Referral to the Regional Board of any significant problems which cannot be addressed promptly and fully under local authority.

The cities within SCVURPPP tailor the organization and implementation of their industrial inspections based on the number of facilities to be inspected (i.e., the size of the city), funding resources, and available staff. For example, the City of San Jose (a much larger municipality adjacent to Santa Clara) employs staff dedicated solely to urban runoff pollution-prevention inspections. The City of Sunnyvale (also adjacent to Santa Clara) operates its own sewage treatment plant, and has combined stormwater and wastewater pretreatment inspections into a single unit for consistent implementation of discharge regulations and communication with industrial businesses.

The City of Santa Clara coordinates a Unified Program for inspections under California's mandated Certified Unified Program Agency (CUPA) law. The Unified Program is a State and local effort to consolidate, coordinate, and make consistent six existing programs regulating hazardous waste and hazardous materials management. The six elements of the Unified Program are:

1. Hazardous waste generators and onsite treatment of hazardous wastes
2. Spill prevention control and counter measure plans for above-ground storage tanks
3. Underground storage tanks
4. Hazardous material release response plans and inventory
5. Risk management and prevention
6. Uniform Fire Code Hazardous Materials Management Plans and Inventories

Under CUPA, a single local agency is responsible for the elements of the Unified Program within its jurisdiction. Counties, cities or local agencies may become certified as Participating Agencies (PA) to implement one or more of the six program elements within the PA's jurisdiction. The City of Santa Clara's Fire Department is a PA.

The Fire Department conducts annual inspections of industries and commercial establishments throughout the City. At a minimum, facilities that have filed an NOI are to be inspected at least every 3 years.

Inspections are documented using a *NPS Inspection Violation Notice*. The City reported that documentation of violations is kept on file at the Fire Department (in some cases, also at the Street Department/Storm Drain Maintenance Division).

3.2 Project Approach in Coyote Creek

In Coyote Creek, physical, hydrological, water-quality, and biological indicators were used to conduct three types of comparisons:

⇒ Temporal comparisons in the upstream reference areas, where land uses have not changed recently.

⇒ Temporal comparisons at the stations in Coyote Creek that have transitioned from rural to urban.

⇒ Spatial comparisons between the upstream reference stations and the downstream urban stations.

Baseline data for this project were provided by a previous EPA-sponsored study (Pitt and Bozeman 1982) on the sources and effects of urban runoff in Coyote Creek. The study, conducted from March 1977 to August 1980, was intended to:

⇒ identify and describe important sources of urban runoff pollutants

⇒ describe the effects of these pollutants on water quality, sediment quality, aquatic organisms, and the creek's associated beneficial uses

⇒ assess potential measures for controlling the problem pollutants in urban runoff.

Pitt and Bozeman sampled locations within a 16 mile "urban" area extending upstream from the confluence of Silver Creek, and within a "non-urban" area located upstream of the urban reach but downstream of Anderson Reservoir. The following parameters were examined:

⇒ basic hydrologic condition

⇒ water quality (including runoff and receiving water)

⇒ sediment properties and quality

⇒ general habitat characteristics

⇒ aquatic biology (including fish, benthic organisms, attached algae, and rooted aquatic vegetation)

The study concluded that water quality, sediment and biological conditions in Coyote Creek were generally degraded as a result of urbanization. Where sampling design and methodology were comparable, we used data collected from the 1977-1980 study for temporal comparisons.

We collected field data from a total of 21 locations along Coyote Creek (Figure 3-5). Fisheries were sampled and physical habitat assessed at 18 100-meter reaches) during June, July, and September 1999. At nine of these 18 locations, we sampled macroinvertebrates (May and June 1999) and surficial sediments (June and October 1999). During this period, we continuously monitored water temperature, dissolved oxygen, pH, and conductivity at five locations (two of which coincided with the fisheries and physical habitat sampling locations). All sampling stations were georeferenced in a geographic information system (GIS) (ArcView, Environmental Systems Research Institute) using geographic coordinates obtained using a global positioning system (Trimble GPS Pathfinder Pro XL).

Our sampling sites were a subset of the 40 locations sampled by Pitt and Bozeman. Pitt and Bozeman classified sites as either urban or non-urban depending on the land use composition in the drainage areas. We modified their classification to include urban, rural, transition (i.e., in transition from predominantly rural land uses such as open space or low-density residential that existed in 1980 to more densely developed urban land uses by 1999), and reference (e.g., least-impacted) classes. Our transition, rural, and reference sites corresponded to their non-urban sites. We sampled eight urban sites, three transition sites, six rural sites, and two reference sites (Figure 3-5).

Selection of reference sites was based upon finding locations that were minimally impacted by urbanization and representative of natural conditions in the watershed. We used the following criteria:

⇒ Extensive, natural, riparian vegetation, representative of the region;

⇒ Representative diversity of substrate materials;

Site Designation	Name	Pitt & Bozeman (1982)	Fish	Physical Habitat	Macroinvertebrates	Sediment	Temperature/D.O.	1988-1995 Water Quality
U-1	Trimble	U	•	•				
S-4	Montague							•
U-2	Upper Penitencia/ Berryessa	U	•	•				
U-3	Mouth of Silver Creek	U	•	•				
U-4	William	U	•	•		•		
U-5	Derbe	U	•	•	•	•		
TS-1							•	
U-6	Senter	U	•	•	•			
U-7	Sylvandale	U	•	•	•	•		
T-1	Crosslees	R	•	•	•	•		
T-2	Tennant	R	•	•				
T-3	Metcalfe	R	•	•	•	•		
R-1	Coyote	R	•	•				
R-2	Riverside	R	•	•				
R-3	Miramonte	R	•	•	•	•		
R-4	Burnett	R	•	•				
R-5	Cochran	R	•	•	•	•	•	
R-6	Mile 0266		•	•				
Ref-1	66 Mustang		*	•	•	•		
TS-5							•	
Ref-2	Gilroy Hot Springs	R	•	•	•	†		

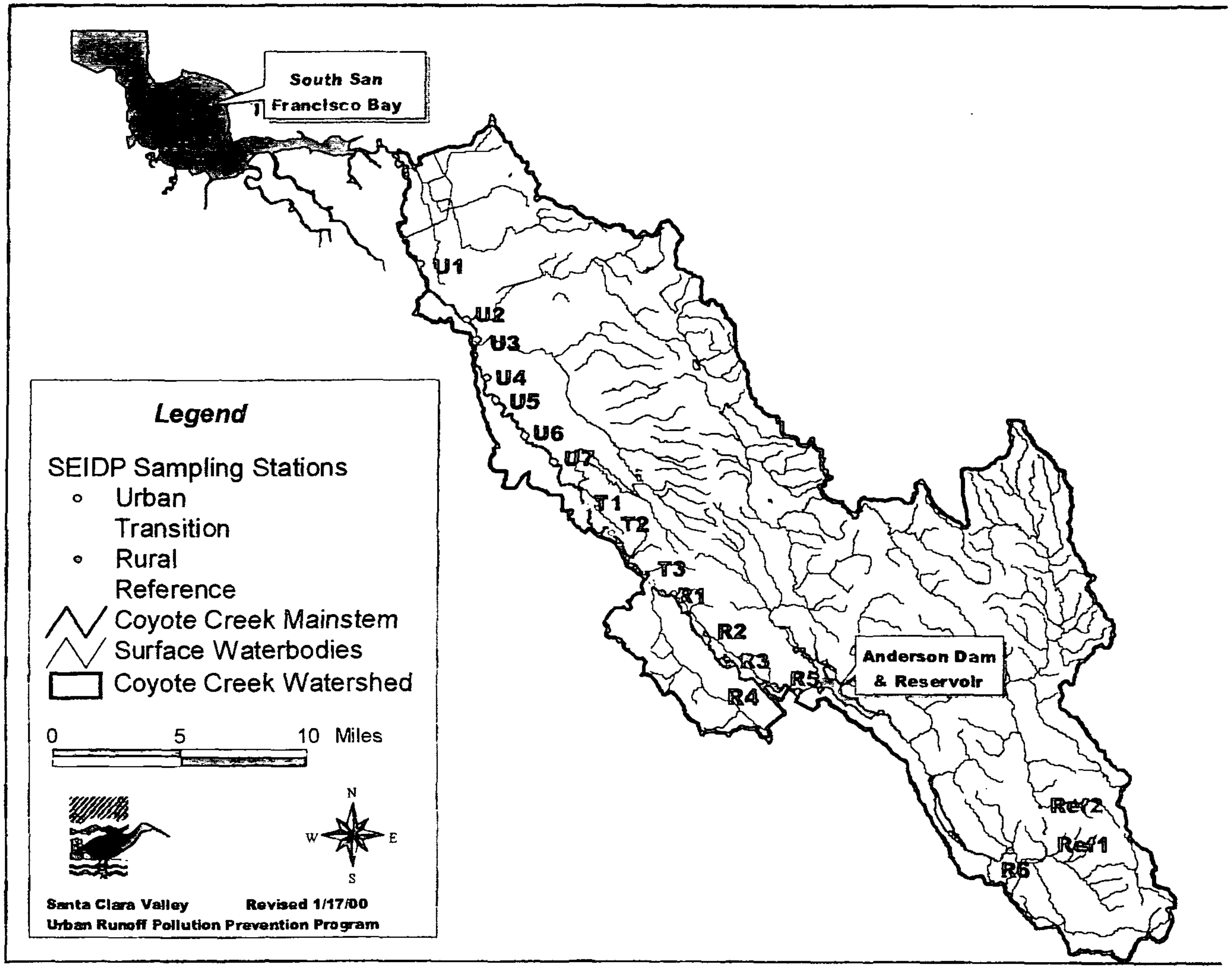


Figure 3-5. Sampling Sites. U = urban T = transition R = rural Ref = reference. Also shown (in the table) are names used to refer to the sites. Sites sampled by Pitt and Bozeman (1982) are noted by their designation U= Urban R= Rural.
The table shows the following additional sites in their relative locations:
S-4 = Water Quality Sampling Site 1988-95
TS = Sites for additional 1999 monitoring (temperature, dissolved oxygen, pH, conductivity).
***In September station Ref-1 was dry, and no data were collected**
†Due to the lack of water at Ref-2 during the October sediment survey,sediments were sampled at a site 2.5 miles downstream.

⇒ Natural channel structures of the region (i.e. pools, riffles, runs, backwaters, glides);

⇒ Natural hydrograph;

⇒ Undisturbed banks, and banks that provide cover;

⇒ Natural water color and odor;

⇒ Presence of representative animals, birds, mammals, amphibians and reptiles (Gibson et. al., undated).

We did not identify sites that met these criteria *and* existed within the same ecoregion subsection (Bailey et al. 1994) as the urban, transition, or rural sites. Although many rivers and large streams exist in the ecoregion subsection where all urban, transition, and all but one rural site are located (Santa Clara Valley Subsection, 261Ae), they are similarly influenced by urbanization. The two reference sites in this study do represent least-impacted conditions in the watershed, but their location in the upper watershed means that they do not fully represent the natural conditions of the downstream sampling sites.

Reference conditions are difficult to establish in highly urbanized regions. In the San Francisco Basin, the majority of the basin floor and foothills have been developed, leaving only headwater reaches relatively unimpacted by direct, urban influences. The basin is also characterized by significant natural variation within short distances due to the diversity of physiography and microclimate. Both sets of circumstances make it difficult to establish reference conditions within this region. The California Department of Fish and Game (CDF&G) has proposed to establish reference conditions using macroinvertebrates in five regions of California (Harrington et al. 1999). Under this proposal, the entire SF Bay Area is contained in the Central Coast Region.

3.2.1 Physical and Hydrological Indicators

Stream Widening and Downcutting

Channel widening and downcutting has been suggested as a potential indicator for detecting changes in the magnitude and frequency of stormflows (Claytor and Brown, 1996). Changes in stream geometry can be documented over time by measuring channel cross-sections at fixed locations, bankfull widths and depths within representative reach types, or the percent bank scour over specified lengths of channel. Claytor and Brown suggest that measurements must be conducted over a period of time that reflects changes in upstream land use.

Our approach included the following steps:

⇒ Develop a stream classification to characterize the condition and geomorphologic processes that occur in Coyote Creek and to identify optimal locations to apply this indicator.

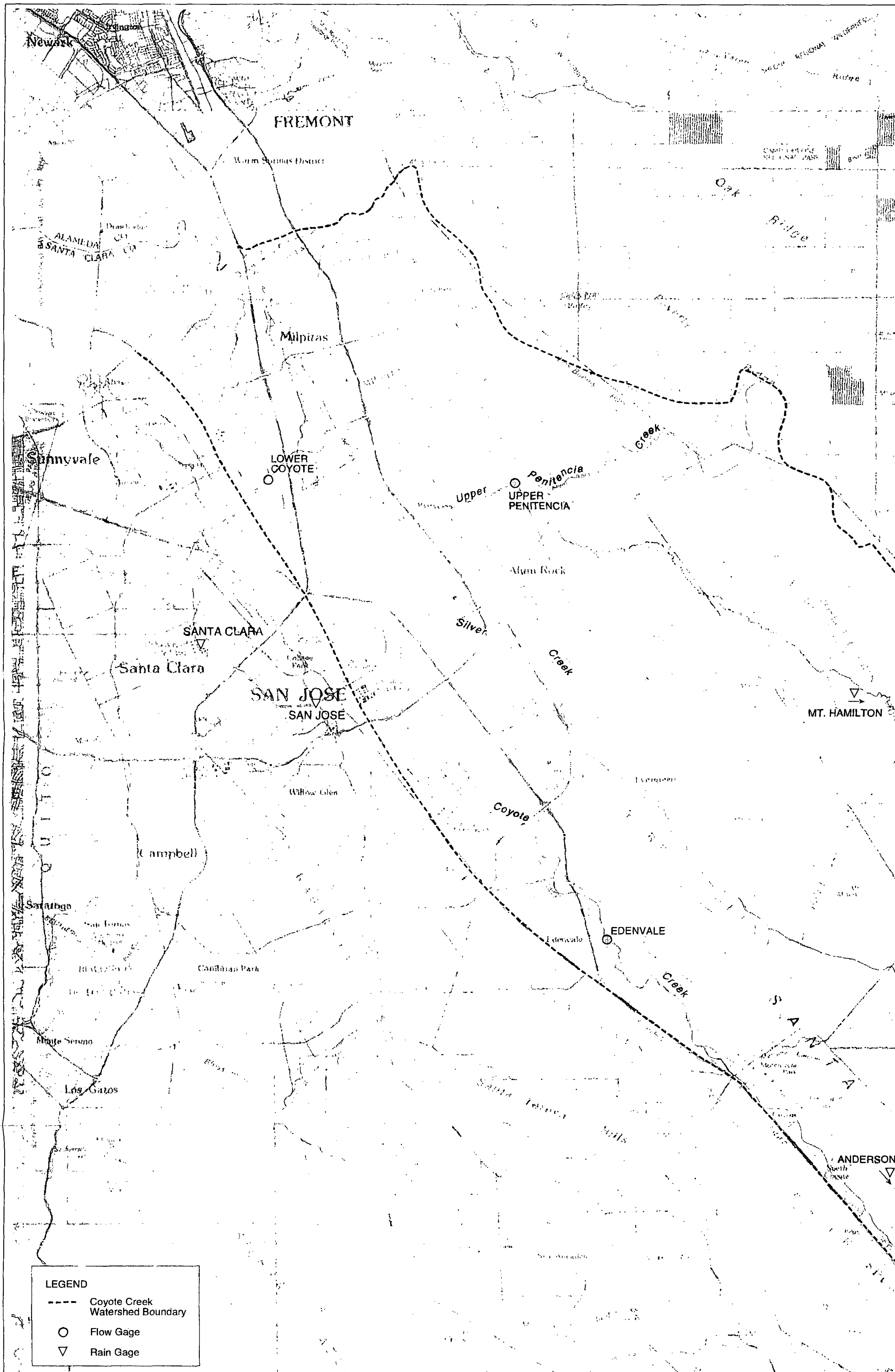
⇒ Evaluate the cross section data and aerial photos at representative reaches of the creek to determine if temporal changes to channel geometry have occurred at each section.

⇒ If channel widening or downcutting is detected, determine if channel changes can be correlated with urbanization.

We obtained digital stream channel and watershed information for Coyote Creek (Table 3-2) from a variety of sources and compiled it using a Geographic Information System (GIS) database (ArcView, Environmental Systems Research Institute)

We created a stream gradient and a longitudinal profile of Coyote Creek, from its mouth at Dixon Landing Rd to the headwaters of its Middle Fork Coyote Creek, using the GIS. We used United States Geological Survey (USGS) 7.5 minute topographic digital quadrangle maps to identify elevations where contour lines crossed Coyote Creek, then intersected these points with the USGS 24,000 scale hydrography layer. We calculated percent slope by dividing the length of each stream segment between elevation points by the respective change in elevation.

We classified distinct river reaches, using information on the geology, hydrology, land use and channel characteristics, to describe the geomorphic form and function of the Coyote Creek mainstem. The relative contribution of these factors varied according to the position along the creek. For example, gradient and planform was more important in the headwaters; geology, hydrology and channel width most important in the middle sections below dam; and



Project No. 51981183NA	Coyote Creek	LOCATION OF RAIN AND FLOW GAGES	Figure 3-6
URS Greiner Woodward Clyde			

51981183NA00-03000/021799/qos

Table 3-2. Data sources used to develop an accurate land use base map for the Coyote Creek watershed.

Data Source	Scale	Spatial Extent	Owner
County Assessor Parcel	1:500	Coyote Watershed	Santa Clara County
Protected Lands	1:24,000	Coyote Watershed	Green Info Network
Vacant Land Inventory	1:500	City of San Jose Jurisdiction	City of San Jose
Easements	1:500	Santa Clara Basin	Santa Clara Valley Water District
Water Ways Management Model	1:12,000	Santa Clara Basin	Santa Clara Valley Water District
1995 Land Uses	1:24,000	Coyote Watershed	Association of Bay Area Governments
1998 Digital Orthophotos	1 meter	City of San Jose Jurisdiction	City of San Jose
Digital USGS Topographic Quadrangles	1:24,000	Coyote Watershed	United States Geological Survey

channel type and land use most important in the lower creek and tidal area.

We reviewed existing channel cross-section data at the Santa Clara Valley Water District (SCVWD) Survey and Hydrology Departments. We searched for historical cross section data that were repeatedly surveyed at the same location over a time interval that would represent different stages of urbanization. Preliminary research at the SCVWD indicated a scarcity of data for Coyote Creek, so we broadened our search to include Upper Penitencia Creek, a tributary to Coyote Creek, which had been recently surveyed by the SCVWD. We investigated the feasibility of resurveying historical cross sections for both creeks, to conduct new surveys when current data did not exist. We also evaluated digital cross section data, developed by the SCVWD for HEC2 models, as an alternative source of channel morphology information. We obtained stream discharge measurements at two flow gauges located at Coyote Creek at Edenvale and Upper Penitencia Creek at Piedmont Avenue. In addition, we reviewed survey files and conducted interviews with SCVWD hydrologists to track information on bankfull widths and depth measurements taken at representative reaches over time.

We reviewed existing aerial photographs at the SCVWD Survey Department to determine if the resolution and frequency of these photos were suitable for measuring temporal changes in channel morphology. Specifically, we searched for photos along Coyote and Upper Penitencia Creek, from which we could measure temporal changes in channel widths and active channel area (areas of the channel lacking established vegetation) and calculate the percentage of channel-bank scour over time.

Physical Habitat Monitoring

Claytor and Brown (1996) suggest that physical habitat evaluations be conducted to determine the potential of water bodies to sustain aquatically healthy systems. By examining the condition of aquatic habitats, it may be possible to determine whether available habitat or water quality are limiting aquatic biological health.

We used a modified version of a California Department of Fish and Game (CDFG) habitat typing protocol (Flosi et al. 1998) to characterize habitat at the 100m reaches where we sampled fish and macroinvertebrates. Gradient (percent slope) and stream flow (cubic feet per second) were also measured. Homogeneous areas of habitat greater than or equal to one wetted channel width constituted separate habitat units and were typed to a Level IV typing designation (Flosi et al. 1998). The following creek attributes were characterized: habitat unit dimensions (mean length, width and depth), instream shelter, substrate composition and embeddedness, riparian canopy cover, bank composition and vegetation, maximum depth, pool tail crest depth, and pool tail substrate composition.

Gradient

Gradient (percent slope) was measured between flag markers using a survey level, stadia rod, and hip chain (Harrelson et al. 1994). Percent slope was calculated by dividing the measured distance between the upstream and downstream reach marker flags by elevation difference. Elevation and percent gradient were also estimated for the entire creek using a GIS to analyze channel morphology (see methods applied for the Stream Widening and Downcutting Indicator) and used to support and verify field measurements.

Stream Flow

Flow was measured at each reach using a bucket wheel current meter (Model 1205 "mini" meter, Scientific Instruments, Milwaukee, Wisconsin) attached to a wading rod. Total discharge was calculated using a standard 6/10 method at 8 - 10 points across a transect line. Scientific Instruments guidelines for data collection and total discharge calculation methods were followed. A single flow measurement was taken following habitat typing of each reach over a three-week period in late June - early July. Sampling did not account for temporal variations in flow during this three-week period. Coyote Creek flows vary with discharge at Anderson Dam. Our estimates of flow are not necessarily representative of flow conditions at other times during late June and early July, or in May and September when fish and macroinvertebrates were sampled. They do, however, reflect conditions at the time each reach was surveyed for habitat.

Habitat Unit Measurements

Habitat units were numbered chronologically, beginning at the downstream end of each reach. Side channels were noted according to the habitat unit from which they split and were also typed completely. Where a habitat unit extended beyond the boundaries of the designated reach, the entire length of the habitat unit was included and typed if the majority of the unit (by length) fell within the reach. This resulted in some variation among total lengths of reaches. In dry creek sections, only length was measured.

Habitat Type

Riffle, flatwater, and pool habitat units were classified to the finest resolution in the protocol (Level IV) as riffles (by gradient), flatwater (by depth and velocity), or pools (by location in the stream channel and cause of formation, e.g., obstruction, blockage, constriction, or merging flows).

Habitat Unit Dimensions

For each habitat unit, mean thalweg length was measured (ft) with a hip chain and thread. Mean width and depth was measured using a stadia rod. For habitat units designated as pools, maximum depth and depth at the pool tail crest were measured to estimate the pool's residual volume. The dominant pool tail substrate was also recorded (see substrate section for composition categories and size breakdown).

Instream Shelter

Flosi et al. (1998) rate instream shelter (0 – 3) based on habitat needs for salmonids. The percent of instream shelter was estimated by viewing the habitat unit from the upstream and downstream ends (estimating instream shelter from an overhead view, as suggested in the protocol, was not feasible in many areas due to steep banks and vegetation (e.g., poison oak)). The percentage of the following shelter types were estimated: undercut banks, small woody debris (diameter < 12"), large woody debris (diameter > 12"), artificial debris (e.g. tires, shopping carts, auto parts, garbage), root masses, terrestrial and aquatic vegetation, surface turbulence, and boulders (d > 10").

Turbidity and depth as cover were also estimated based on the following criteria: none - clear (substrate clearly visible) and/or shallow water (< 1ft); low - slightly turbid (substrate visible) and/or depth >1ft.; moderate – cloudy water (substrate visible in limited areas) and/or depth > 2 – 3 ft; high -- very cloudy water (substrate not visible), and/or depth > 3 - 4 ft. These data were meant only to provide qualitative estimates of instream shelter, and were not meant to quantify column turbidity or suspended sediment.

Substrate

Habitat unit substrate composition was classified as silt/clay, sand (diameter < 0.08"), gravel (d = 0.08 - 2.5"), small cobble (d = 2.5 - 5"), large cobble (d = 5 - 10"), boulder (d > 10"), and/or bedrock. One hundred percent of the substrate was classified into these categories by visual estimation. Where visibility was difficult due to turbidity or depth, substrate was estimated by feel, using a stadia rod where necessary. Percent of substrate exposed was also measured by visual estimate.

Substrate embeddedness was estimated as the shiny, buried portion versus the duller, exposed portion of substrate between 0.08 and 10 inches in diameter (gravel - large cobble). Three to five samples of substrate were taken randomly within the habitat unit and averaged for an estimate of substrate embeddedness. Where silt/sand was the dominant substrate, embeddedness was noted as 100 and later removed from the overall reach analysis. Thus, calculations of mean reach embeddedness include only substrates generally suitable to spawning, rather than indicating mean embeddedness of substrate within the entire reach.

Riparian Canopy

Canopy cover was measured using a convex densiometer at the center of each habitat unit. The percentage of horizon vegetation canopy consisting of deciduous and non-deciduous (including woody parts of deciduous vegetation) cover was measured from both an upstream and downstream view and averaged (% deciduous + % non-deciduous = % total canopy cover).

Bank Composition and Vegetation

For each habitat unit, right and left bank (downstream facing convention) composition was observed at the bankfull discharge level and categorized as follows: bedrock, boulder, cobble/gravel, or silt/sand/clay. Dominant bank vegetation from bankfull discharge level to 20 feet upslope was recorded as either grass/herbs/forbs, brush, deciduous trees, non-deciduous trees, no vegetation, and percent of bank vegetation was estimated.

Increased Flood Frequency

To evaluate the relationship between flooding frequency and urbanization, we collected data for historic and current land development, precipitation, streamflow, and flood improvement projects.

Urbanized area was estimated using a planimeter to measure the edge of developed areas from historic US Geological Survey (USGS) topographic maps (dated 1895, 1939, 1953, 1955, 1961, 1978, and 1980) and a current street map. Developed areas were defined as those having high road-density of roads, which resulted in including small portions of undeveloped land. Current urbanized area was estimated based on urban land use data (ABAG 1995).

Flow data were obtained for three gages in the watershed; Coyote Creek at Edenvale, Coyote Creek at Station S4 (from the Santa Clara Valley Non-Point Source Control Program, SCVNPS, monitoring program) and Upper Penitencia Creek at Doral Drive (Figure 3-6). The data were comprised of mean daily flow and daily peak flow in cubic feet per second (cfs). Rainfall data were obtained from three gages; San Jose, Mt. Hamilton and Anderson Reservoir (Figure 3-6), and included hourly values at the San Jose gage and daily volume in inches at the other gages. Notably, the Edenvale and the Upper Penitencia Creek flow gages are located upstream of most of the urbanized area. Only eight years of flow data were available below the urbanized area draining to Coyote Creek.

Flood frequency, location, and extent was analyzed by comparing historic documents of flood improvement studies and flood damage reports that were related to Silver, Penitencia, Coyote, and Berryessa Creeks. The number of storms exceeding channel capacity was summarized.

The influence of urbanized area on flood frequency was examined by comparing changes in urbanized area, including the construction of Anderson Dam, to flood, flow, and rainfall records (National Climatic Data Center and the SCVWD).

Stream Temperature Monitoring

We used Yellow Springs Instruments (YSI) 600 XLM Sondes to monitor temperature, and other water quality parameters (dissolved oxygen (DO), pH, and conductivity) at five locations on Coyote Creek (Figure 3-5). Locations were selected to represent the urbanization gradient along Coyote Creek and water quality conditions at benthic macroinvertebrate sampling sites. Specific locations were chosen based on field crew safety, accessibility, and equipment security. We selected YSI 600 XLM Sondes for this project because they can record and store multiple water quality parameters and can be deployed for long time periods with minimal maintenance (Table 3-3).

Prior to deployment, all Sondes were prepared, maintained and calibrated according to the 600 XLM Operations manual. Upon first deployment, Sondes were set to sample at 15-minute intervals. Subsequently they were reset to sample at 30-minute intervals, to accommodate a longer duration of unattended sampling due to increased battery life.

Upon deployment, the Sondes were placed in 24-in long, 2-in diameter slotted PVC well casings that were capped on either end with PVC end caps perforated with holes. Sondes were secured at site locations using cable ties to prevent movement within the casing, and to allow water to move freely past the probes while protecting the Sonde from physical damage. Sonde casings were secured lengthwise to a cinder block (16 in x 8 in x 8 in) using a stainless steel hose clamp and two plastic cable ties to keep the probes from coming into contact with the creek bottom. This setup allowed the Sonde to extend over the edge of the cinder block approximately four inches on either end. For security reasons the cinder block was tethered and locked to a fixed object (exposed tree roots, trees, etc.) on shore. The Sonde was positioned on the substrate perpendicular to the bank so that its sensors extended toward the center of the creek.

Table 3-3: Sonde Specifications
Operating Environment
Medium: fresh, sea, or polluted water
Temperature: -5 to +45 °C
Depth: 0 to 200 feet (61 meters)
Storage Temperature:
-40 to + 60 °C for sonde and all sensors except pH and pH/ORP
-20 to + 60 °C for pH and pH/ORP sensors.
Material: PVC, Stainless Steel
Diameter: 1.7 inches (4.4 cm)
Length: 21.3 inches (54.1 cm)
Weight: 1.48 pounds (0.67 kg) with batteries
Computer Interface: RS-232, SDI-12
Internal Logging Memory Size: 384 Kilobytes (150,000 individual parameter readings)
Power: 4 AA-size Alkaline Batteries or External 12 VDC
Battery Life: 25 to 30 days at 20 deg. C with a 15-minute logging interval and a 40-minute dissolved oxygen warm up.

Field maintenance of the probes was scheduled every two weeks for the duration of a sampling event. The primary purpose of this maintenance was to ensure that the Sondes were not accumulating sediment and algae on the sensors. Maintenance procedures consisted of extracting the Sonde from its housing, visually inspecting the sensors and Sonde for damage or accumulation of debris and algae, rinsing the sensors in clean water to shake loose any algae and/or silt that may have accumulated in or around the probes, brushing and cleaning the slotted PVC well casing, reinserting the Sonde into the casing and re-deploying it.

At the end of each sampling period, the Sondes were extracted from their housings, and data were downloaded immediately in the field using a portable computer. When this was not possible, data were downloaded upon returning to the laboratory. All Sondes were placed in clean water during transport to the laboratory to keep the probes hydrated. Once data were downloaded and backed up, the data were reviewed to determine if any significant problems had occurred during the deployment.

Once data were downloaded from the Sondes, the probes were checked for measurement accuracy. These QA/QC checks consisted of running the Sonde in real time sampling mode using known calibration standards for each parameter. Any difference between the actual measurement and the known standard was recorded as drift. Calibration standards were the following: pH 7.0 and pH 10.0 buffer solutions; specific conductance, 1mS/cm conductivity solution (typical of levels measured in the lower reaches of Coyote Creek); DO was based upon water-saturated air. DO calibration involved filling a cup with 0.125 inches of water, and attaching it to the probe so that the sensor was enclosed but still vented to the atmosphere. The probe was allowed to sit for 10 minutes to allow the air to become water saturated and the temperature to equilibrate. Percent DO was then recorded and compared to pre-deployment values for each parameter.

During all phases of this project, sampling-related activities were recorded in a single binder. Documentation included logs for calibration, dissolved oxygen membrane replacement, and deployment drift measurements, maps, coordinates and sketches of monitoring station sites, photographs, and miscellaneous notes.

We calculated minimum, maximum, and mean daily temperature for each station. Temperatures recorded on dates of Sonde deployment and retrieval were typically not included in the analysis since they did not record when daily minima and maxima were likely to occur. Minima and maxima were also plotted against daily air temperature maxima and minima obtained from two weather stations (San Jose and Morgan Hill). We also correlated the daily temperature range with sampling date.

Riparian canopy distribution at, and upstream of, each station was recorded and assessed together with observations made during habitat typing. Finally, temperature stations were mapped along with known percolation ponds, reservoirs, and tributaries to help identify factors contributing to differences between stations. Historical temperature data sources were identified through a literature search and by contacting agencies and professionals involved in the Coyote Creek watershed, including the Santa Clara Valley Water District (SCVWD), US Environmental Protection Agency (USEPA), United States Geological Survey (USGS), San Jose State University (SJSU), and the Coyote Creek Riparian Station (no longer in operation, but data available through SCVWD).

3.2.2 Water Quality Indicators

Water Quality Pollutant Constituent Monitoring

We examined the usefulness of water quality monitoring data collected 1988-1995 to detect trends in concentrations of constituents in stormwater runoff and in exceedance frequencies of water quality standards.

Detecting Trends in Water Quality Constituents

Trend analysis can be approached in several ways. A simple approach is the time-trend analysis where data are plotted with date sampled along the x-axis and concentrations along the y-axis. A linear regression can be fitted to the data to determine if a significant time trend is present. The difficulty with using runoff water quality data in trend analysis is its high variability. Figure 3-7 shows the variability of copper, lead, nickel, zinc and total suspended solids (TSS) relative to their mean value. On the figure a concentration of 1.0 is the mean concentration; a concentration of 2.0 would be twice the mean concentration, etc. It is not unusual to measure concentrations that are two, three, or more times the mean concentration. Without being able to explain some of this

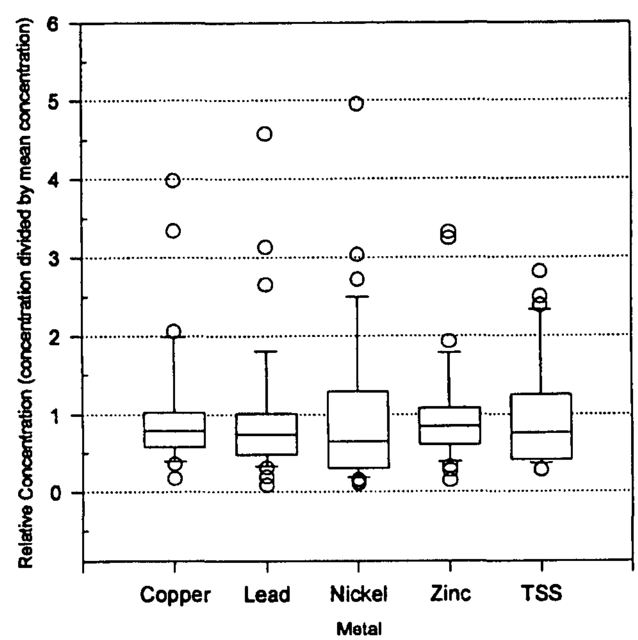


Figure 3-7. Variability of Concentrations Measured

variability, it is difficult to identify a trend in data. In addition, variability in concentration increases the uncertainty in estimates of the mean (average) concentrations and loads.

Much of the variability in urban runoff water quality is random, but some variability can be explained by hydrologic and antecedent conditions for each storm event. Seasonal effects may be more apparent in semi-arid climates such as found in the Southwestern United States which typically have dry summers and wet winters. Seasonal effects are often exacerbated by El Niño events or prolonged droughts, which can cause large variations in seasonal rainfall and runoff.

The existing Coyote Creek hydrology and water quality database was used to determine if a predictable relationship between water quality and hydrology could be developed. A relationship which explains a significant amount of the variably in observed water quality could be used to better detect changes in water quality due to BMP implementation.

Data Sources

Water quality and stream flow in Coyote Creek were monitored during 38 storm events between April 1988 and April 1995. In addition, rainfall has been continuously measured since 1948 in the watershed. However, complete data (both flow water quality and rainfall) are available for only 32 of the 38 events.

Hydrology

Rainfall data from the San Jose Gage (Alert gage No. 1453, National Weather Service Gage (NWS) # 7821) was used to represent rainfall for each monitored storm event in the Coyote Creek watershed. Stream flow data was collected at the water quality monitoring station using water depth sensors calibrated to stream flow rates using a rating curve.

Water Quality

Water quality data were collected using flow-composite samplers programmed to collect a discrete sample after a given volume of flow (trigger volume) had passed the station. The trigger volume was adjusted prior to each event based on the forecasted rainfall amounts. The discrete samples are pumped into a large composite bottle contained within the sampler and transported back to the laboratory for analysis. Results from the composite sample analysis are representative of the flow-weighted average concentration and are called event mean concentrations (EMC).

Data Summary Methods

Hydrology

Hydrology data (rainfall and flow) for both event and antecedent conditions were summarized for each monitored storm event in Coyote Creek watershed. Rainfall event statistics included total storm volume, average intensity, and peak intensity. Antecedent rainfall conditions were represented by total rainfall that occurred during the previous 14 days and 28 days, total rain to date and dry period days. The SYNOP computer program was used to summarize the rainfall record for the San Jose gage.

In SYNOP the definition of a storm event is based upon an inter-event time and minimum precipitation. The inter-event time is the time between storm mid-points. An inter-event time of 24 hours was used with a minimum of 0.1 inch volume to calculate the statistics.

About nine years of flow data were available (two years before 1990 and seven after) from the Coyote Creek Station S4 flow gage. For each storm event the average, peak and total flow were obtained. To represent antecedent conditions the total flow that occurred 14 and 28 days prior to the storm event plus season to date were extracted from the data.

Water Quality

Water quality data from Station S4 was recently summarized as a part of a regional effort to collect data from the San Francisco Bay Area into a single database (BASMAA 1996). General statistics for parameters of concern were summarized from the water quality database. Data were excluded if the percent capture was less than 75%. The percent capture is the percentage of time the water quality sampler was sampling for a given monitoring event. Events with low capture are not considered representative of a given event. Events 2,5,6 and 7 had low capture and were not used in the analysis. The percent capture for event #38 was not used due to an extreme (100 year) event preceding this storm.

Metal concentrations associated with particulates were calculated from the total and dissolved metals and TSS data using the following relationship:

Particulate (:g/g) = {[Total (:g/l) - Diss (:g/l)]/ TSS (mg/l)} * 1000 :g/mg.

The percentage of metal present as dissolved was also calculated.

Water Quality Trend Detection

We examined temporal trends in key water quality parameters using linear regression, correlation, stepwise regression, and analysis of variance and analysis of covariance with power analysis.

Simple Time Trend Analysis

Simple time-trend linear regression analysis was used to determine if a water quality changed during the monitoring period. Linear trends were evaluated for flow-weighted concentrations of total and particulate copper (Cu), total and particulate zinc (Zn), and total suspended solids (TSS). Analysis of variance was used to determine if the linear trend was significant.

Analysis of Variance on Grouped Years

Analysis of variance (ANOVA) was used to determine if one group of data were significantly different from another group and to perform power analysis. Data grouping was necessary to use the ANOVA and power analysis techniques. Data from each water year (winter- spring) were grouped into two groups (wet or dry) based on the annual rainfall amounts. Average EMCs for each group were compared using analysis of variance (ANOVA) to determine if they were significantly different from one another. ANOVA tests were performed using total copper as indicator variable using log-transformed data because the data were log-normally distributed based on the Shapiro-Wilks test for normality.

Power Analysis

A power analysis was performed to determine how large of a change in water quality could be reliably detected for a given sample size. Power analysis determine the probability of detecting a given change in concentration (if present) for a particular data set and takes into account the amount of variability in the data.

Hydrology-Water Quality Model

The hydrology and water quality data were examined to develop hydrology-water quality model for Coyote Creek for use in the trend analysis.

The relationship between individual hydrologic parameters and water quality was first examined by calculating the Pearson correlation coefficient. One hundred times the square of the correlation coefficient indicates how much of the water quality variability is explained by each hydrology parameter assuming they are linearly related.

Step-wise linear regression was then used to determine the form of the relationship. For this analysis the hydrologic data were separated into two classes: rainfall and flow. The stepwise regression analysis was conducted separately for each parameter (Total, Dissolved, and Particulate, Copper, Lead, Nickel, and Zinc and Total Suspended Solids) with each class because rainfall and flow are highly correlated which would otherwise confound the analysis. A mixed stepwise regression (forwards and backwards) was performed using a selection and removal significance criteria of $p < 0.2$. The best hydrology-water quality model was then chosen for inclusion in the grouped water year in an analysis of covariance (ANCOVA). A power analysis was performed on the ANCOVA for comparison with the ANOVA results.

Exceedance Frequencies of Water Quality Standards

We analyzed rainfall and water quality data (see methods described above) and compared the stormwater monitoring data to two different water quality standards: Water Quality Objectives and Water Quality Criteria. The San Francisco Bay Basin Plan Water Quality Objectives (WQOs) are the current regulatory objectives for the protection of aquatic life in the San Francisco Bay Basin. For freshwater systems such as stormwater, the objectives are hardness-dependent and are to be compared to total metal concentrations. In recognition that the dissolved metals fraction is more representative of metal bioavailability, USEPA adopted Interim Final

Water Quality Criteria (WQC) which are to be compared to dissolved metal fractions.

The freshwater WQOs are expressed as:

$$e^{(A*ln\,(TH)\,+B)}$$

where TH = total hardness as $CaCO_3$ (mg/L), and A and B are metal-specific factors for acute and chronic toxicity.

The freshwater WQC are expressed as:

$$e^{(A*ln\,(TH)\,+B)\,*\,CF}$$

where CF refers to the acute or chronic conversion factors for dissolved metals.

Two different exposure durations are included in the WQOs and WQC: acute, which are based on a minimum 1-hour exposure duration; and chronic, which are based on a minimum 4-day exposure duration. SYNOP analysis was used to determine the distribution of storm event duration's during the monitoring period. The number of exceedances of acute and chronic objectives and criteria were evaluated for each water year to determine if trends were apparent.

Sediment Characteristics and Contamination

Many pollutants found in stormwater runoff attach to sediments and can adversely impact aquatic communities. Benthic organisms feed and inhabit deposited sediments, while nonbenthic organisms may be exposed to contaminated sediments through re-suspension, by ingesting benthic organisms, and by exposure to the sediment as it settles.

We sampled surficial sediments to assess sediment contamination during two field surveys conducted at the completion of the storm season (June 28 – 29, 1999) and again just prior to the start of the subsequent storm season (October 21, 1999). This sampling regime was also selected to coincide with the periods sampled in the 1978 – 79 baseline study (Pitt and Bozeman 1982).

We sampled nine sites in Coyote Creek (Figure 3-5), each consisting of 100-meter reaches that corresponded to the reaches sampled for fish and macroinvertebrate assemblages. The sediment sampling sites were chosen based on the quantity of historical data from each location, the location of each site relative to macroinvertebrate sampling locations, and the location of each site relative to land use patterns (e.g., urban, rural, transition, and reference) along the main stem of Coyote Creek.

We collected surficial sediments, (top 2 cm) and composited samples to limit the influence of local variability. A total of five samples of equal volume were collected from locations throughout the reach. Sampling was designed to focus on areas with finer sediments in order to ensure representative sampling of potential contaminants. Each of the five samples was taken from depositional areas located within each reach to improve chances of locating sites where fine material would have an opportunity to accumulate. The decision to sample the top two centimeters of sediment was also an effort to collect recently deposited material. During each survey, one of the field samples was split and submitted blind to the laboratory.

Samples were analyzed for particle size and trace metals (copper, lead, arsenic, mercury, cadmium and chromium). Analytical methods and data quality objectives for each analysis are summarized in Table 3-4. Sediment particle size analysis was performed according to methods described by Plumb (1981). Sediments were digested using EPA Method 3050 and then trace metals were analyzed by ICP-MS using EPA Methods 7061 (arsenic), 6020 (cadmium, chromium, copper and lead), and 7471 (mercury). All sediment trace metal data are reported on a dry-weight basis.

Quality assurance measures applied to the laboratory analyses included use of laboratory duplicates, certified reference materials and matrix spike/spike duplicates (KLI 1999). Repeated measures such as field splits, laboratory duplicates, and matrix spike/spike duplicates were used to assess precision of the measurements. Recovery of the target analytes from certified reference materials and spikes added directly to the sample matrices were used to evaluate accuracy of the analyses.

Table 3-4. Summary of Analytical Methods, Sample Handling, Detection Limits and Data Quality Objectives.

Parameter	Units (dry wt.)	EPA Method	Maximum Holding Time	Preservation	Target Detection Limit (mg/Kg)	Accuracy (% Recovery)	Laboratory Duplicate RPD (Percent)
Particle Size	%	Plumb[1]		Cool, 4°C	0.1	NA	NA
Arsenic	mg/kg	7061	6 months	Cool, 4°C	0.1	±25	30
Cadmium	mg/kg	6020	6 months	Cool, 4°C	0.1	±25	30
Chromium	mg/kg	6020	6 months	Cool, 4°C	0.1	±25	30
Copper	mg/kg	6020	6 months	Cool, 4°C	0.1	±25	30
Lead	mg/kg	6020	6 months	Cool, 4°C	0.1	±25	30
Mercury	mg/kg	7471	28 days	Cool, 4°C	0.02	±25	30

[1]Plumb, R. H. Jr. 1981. Procedures for Handling and Chemical Analysis of Sediment and Water Samples. AD/A103 788 State University College at Buffalo, Buffalo, NY.

3.2.3 Biological Indicators

Fish Assemblages

Sampling

We sampled fish assemblages using the Rapid Bioassessment Protocols (RBPs) (Barbour et.al. 1997). Fish were collected from a 100-meter reach containing multiple habitat types. We set block nets (0.25 inch mesh) at the reach ends and electrofished using a Smith Root 12-B backpack unit with hand-held anode pole and trailing cathode. One fisher and two netters (0.125 inch mesh) fished one pass from downstream to upstream. Fish were transferred to buckets and live wells equipped with aerators on hot days. Stations with the least riparian cover were fished first in the morning, before hottest part of day.

All fish greater than 20 mm in length were processed. The first 25 fish of each species were weighed, measured, and anomalies noted. The remaining fish of that species were counted and weighed as an aggregate. We took care to include a distribution of size classes in the 25 fish. Special handling procedures were implemented for processing rainbow trout (*Oncorhynchus mykiss*); all trout were processed and returned to the creek immediately.

A voucher collection was made, storing fish in 10% buffered formalin. This collection is housed at Kinnetic Laboratories in Santa Cruz, California. Some cyprinid specimens were submitted to Randall Baxter of the California Department of Fish and Game for confirmation. Robert Leas provided verification of some cottid specimens.

Fish were sampled during three events to coincide with baseline study (Pitt and Bozeman 1982) sample collection schedule. The 5-person field team completed 2 - 4 stations per day. The first sampling period was from May 20 to June 4, 1999 (nine workdays). The second sampling was from June 21 to 29, 1999 (seven workdays). The third sampling was from September 14 to October 8, 1999 (seven workdays). The field team recorded data on standard forms in the RBP manual: Fish Sampling Field Data Sheet (each sampling event), Habitat Assessment Field Data Sheet (once), and Physical Characterization/Water Quality Data Sheet (once).

Data Analysis

The RBPs define 12 metrics, grouped into three categories, for evaluating fish assemblages: Species Richness and Composition, Trophic Composition, and Abundance and Condition. We selected metrics from each category based on their applicability to Coyote Creek, and potentially to other streams in semi-arid areas (Table 3-5). Due to the format in which the baseline study reported fisheries data, we could only use a subset of these metrics to compare to the 1999 SEIDP data. Metrics were calculated for each combination of station and sampling period.

We could not create an Index of Biological Integrity (IBI) using our data because reference conditions and scoring criteria are not available for this region. However, our sampling data and metric analyses could be combined with the results of other studies conducted in the region and used to help build a regionally appropriate IBI.

We used Analysis of Variance (ANOVA) to analyze the fish assemblage metrics and test (α = 0.05) the following hypotheses: the means of the monthly samples were the same; the means of the station groups were the same. We used an unbalanced one-way ANOVA model since the number of observations differed for each combination of seasonal time period and station group (Zar 1999). Differences between the observed and predicted values (residuals) were tested for normality and homogeneity of variance using the Shapiro-Wilks and Levene's test, respectively. If either test was failed, we repeated the ANOVA using logarithmically transformed values. If either test again failed, we repeated the analysis using the ranked values in a non-parametric ANOVA.

Two variables failed each test (Shapiro-Wilks, Total Number of Individuals and Total Biomass; Levenes, Number of Native Species, Number of Native Individuals). Logarithmic transformations normalized only the two variables that had previously failed the Shapiro-Wilks test. Therefore, the Number of Native Species and the Number of Native Individuals were tested using nonparametric ANOVAs,

In addition to the two main factors, sampling period and station group, we included as interaction terms. If the critical value associated with the test statistic of the interaction term was > 0.05, the interaction was considered to be insignificant, and each main factor was analyzed separately. If the interaction was significant, each combination of station group and sampling season was analyzed.

We tested whether duplicate data were from the same population by pairing data from the station and duplicate location immediately upstream (Gilbert 1987). Duplicate values were subtracted from station values. Differences were tested for normality (α = 0.05, Shapiro-Wilks test). If differences were normal we tested them using paired t-tests. Otherwise, we examined the skewness of nonnormal differences. If the absolute value of the skewness exceeded 1.0, we used the sign test to test if the difference was zero. Otherwise we used the signed-rank test.

Correlating Imperviousness with Aquatic Health Degradation

We examined the association between percent imperviousness and aquatic health by comparing percent imperviousness individually to fish metrics. Metrics we tested included number

Table 3-5: Metrics used to evaluate the fish assemblage indicator. A single asterisk indicates metrics that were used to compare the 1999 to the 1978-79 baseline (Pitt and Bozeman 1982) fisheries data. A double asterisk indicates a metric that was only used for the comparison to the baseline study.

Metrics	Description
Species Richness and Composition	
1a.	Number of Native Species *
1b	Number of Native Individuals
##	Total Number of Species**
3a	Percent of Cyprinid and Centrarchid Species
3b	Percent of Cyprinid and Centrarchid Individuals
6	Proportion of Individuals as Tolerant Species
Trophic Composition	
8a	Number of Insectivorous and Invertivorous Species
8b	Number of Insectivorous and Invertivorous Individuals
Abundance and Condition	
10	Total Number of Individuals
12	Total Number of Diseased Individuals
13	Total Biomass
##[0]	Biomass of Native Individuals**

of native species, nonnative species, total species, tolerant species, total individuals, native individuals, and diseased individuals, as well as percent of native species, tolerant species, diseased individuals, and total biomass. We identified tolerant species from Moyle and Marchetti 1999, which included common carp, *cyprinis carpio*, fathead minnow, *Pimephales promelas*, green sunfish, *Lepomis cyanellus*, black bullhead, *Ameirurus melas*, red shiner, *Notropis lutrensis*, and golden shiner, *Notemigonus crysoleucas*. We could not calculate indices of biological integrity for comparison with imperviousness because as already discussed, reference conditions have not been established for this region, and we could not identify reference sites with similar physical characteristics as our urban and rural sampling stations.

We tested associations statistically using simple linear regressions (Zar 1999). Data were tested for normality and homogeneity of variance using the Kolmogorov-Smirnoff (K-S) test and the Levene Median test, respectively. Ratio data were arcsine transformed. Data failing the K-S test were logarithmically transformed. Analyses using the transformed data that failed the K-S and/or Levene tests (percent tolerant species and percent native species) were repeated using logistic regression (Trexler and Travis 1993). Because one sampling station (R3) exhibited unusually high values for metrics related to the number of individuals, we repeated analyses without this site. Because one of the reference sites (Ref1) was not sampled in September, metrics were also calculated both without this site, and using mean values calculated from the May and June sampling periods. Results from the complete data set and the subset were compared.

Macroinvertebrate Assemblages

Field Sampling

We used the multihabitat approach described in the revised Rapid Bioassessment Protocol (RBP) for Use in Streams and Rivers (Barbour et al. 1997) to sample macroinvertebrates. We chose to sample multiple habitats rather than riffle habitat alone because gradient, substrate and velocity variations among the stations on Coyote Creek create a broad diversity of invertebrate habitats and to acquire data that would be comparable to our baseline study (Pitt and Bozeman 1982).

Sampling was conducted in conjunction with the fishery work for the May sampling event on the following dates: May 20 - 21, 25 - 27, and June 3. We sampled macroinvertebrates independently of fishes in June (17 – 18) to improve efficiency. Samples for each station were recorded on a "Benthic Macroinvertebrate Field Data Sheet." We sampled using a D-frame dip net, 0.3 meters high and wide, with 500 micrometer mesh. Cobbles and gravels were kicked, jabs were made among vegetation and roots, and in-stream woody debris was rubbed to dislodge macroinvertebrates. At each station, 20 subsamples were collected and composited in the field, resulting in a single sample, preserved in formalin. The subsamples were distributed proportionately among the habitats in the 100 meter reach. The completed sheets showed the location and habitat type for each of the 20 sub-sampling locations.

Laboratory Sorting and Subsampling

Approximately 72 hours after formalin preservation in the field, macroinvertebrate samples were transferred to 70% ethanol at Kinnetic Laboratories, Inc. in Santa Cruz, California. Subsampling and sorting of the collected material generally followed the procedures outlined in the Draft RBPs (Barbour et al. 1997) and the Quality Assurance Project Plan for Stormwater Environmental Indicators Pilot Demonstration Projects (KLI 1999a).

Initially, large woody debris, large leaves, or gravel were removed from samples with considerable amounts of these materials (approximately half the samples). This was done to make the material more uniform in size for subsampling. Material from these samples was spread out in a tray and each large leaf, twig, etc. was dip-rinsed in a large beaker and inspected to insure no organisms remained attached. The rinse water was sieved (0.5 mm mesh) and the debris in the sieve and tray were returned to the sample jar. The tray and sieve were visually inspected for organisms and rinsed thoroughly between samples.

With the objective of obtaining four replicate, 100-organism subsamples (± 20%) from each original sample, the material in the jar was gently mixed before opening, sieved, and spread as evenly as possible across a tray into which a grid composed of thirty-six 6.0 cm by 6.0 cm squares was placed. Material was spread over 18, 24, or 36 grids, depending on its volume. Material from four random grids was removed and placed in new, smaller jar and properly labeled inside and out. These subsamples were themselves subsampled due the presence of high numbers of organisms. However, spreading the much smaller volume of material in these subsamples appeared obviously destructive to the sample (and organisms), therefore, we placed small clumps of the sample (again, well mixed and drained) within grids in the tray (ranging from 10 to 36 grids), taking care to make them as similar in size and composition of material as possible. Material from a single random grid was then removed and placed in ethanol in a 10 cm x 1.5 cm petri dish marked into fourths. If a dish contained more than 120 organisms we used low-power microscopes (≥ 10-power) to randomly sort material into the dish's quarters. In this way a third level of subsampling was easily accomplished, with a maximum number of four "grids" to sort. If the dish contained less than 80 organisms, another random grid was placed in a new petri dish and sorted by quarter again until 100 ± 20 organisms were removed. Thus, all original samples were subsampled (or split) up to three times. Annelids, molluscs, arthropods, and miscellaneous taxa were placed in separate vials and labeled on the inside, indicating the station, sample date, subsample "level", and sorter. The remaining sorted debris were placed in a third and final jar for QA/QC. The four 100-organism replicates from each station were identified to the lowest practical taxonomic level and the data were entered into a spreadsheet.

Laboratory QA/QC procedures involved resorting 30% of the volume of each sample sorted to check sorting efficiency and accuracy. Individuals other than those who conducted the original sorting conducted the resorting of samples. If the number of organisms found in the detrital remains exceeded ten percent of the total organisms found during the original sort, the sample was considered a QA/QC failure and was completely resorted. If the 100% resort still failed at the 90% efficiency level then a new sorting sheet was started and the process was repeated until 90% efficiency was achieved. We maintained records of the subsampling, sorting, and resorting processes for each sample.

Data Analysis

The RBPs group metrics for evaluating macroinvertebrate assemblages into three categories: Taxa Richness; Trophic Composition, and Tolerance/Intolerance. We selected metrics based on their applicability to Coyote Creek, and potentially to other streams in semi-arid areas (Table 3-6). Due to the format in which the baseline study reported fisheries data, we could only use a subset of these metrics to compare to the 1999 SEIDP data. Metrics were calculated for each combination of station and sampling period.

The tolerance/intolerance metrics evaluated here were based on a rating system developed by the CDFG (Ode 1999), similar to the Hillsenhoff index. The CDFG system rates macroinvertebrate taxa on a scale of 0 to 10 as follows: least tolerant organisms had ratings of 0, 1, 2, and 3 and the most tolerant organisms were those rated 8, 9, and 10. This rating scale is based on professional judgment. It does not imply tolerance or intolerance to any particular pollutant, nor it is not mathematically relational.

We used ANOVA to analyze the macroinvertebrate assemblage metrics and test ($\alpha = 0.05$) the following hypotheses: the means of the monthly samples were the same; the means of the station groups were the same. Testing procedures were the same as those described previously for the fish assemblage indicator. Five variables failed either both (% EPT taxa, % Low Tolerance Taxa, % Low Tolerance Individuals) or one of the tests (Number of Low Tolerance Taxa – Shapiro Wilks; % High Tolerance Taxa – Levenes). Logarithmic transformation only normalized one variable (% Low Tolerance Taxa). Therefore, we tested the other failed variables using non-parametric ANOVAs.

Table 3-6: Metrics used to evaluate the macroinvertebrate assemblage indicator. A single asterisk indicates metrics that were used to compare the 1999 to the 1978-79 baseline (Pitt and Bozeman 1982) macroinvertebrate data. A double asterisk indicates a metric that was only used for the comparison to the baseline study.

Metric Category	*Metric Description*
Taxa Richness	Total Number of Taxa * Total Number of Ephemeroptera, Plecoptera, Tricoptera (EPT) Taxa * Percentage of EPT Taxa**
Trophic Composition	Percent of EPT Individuals * Ratio of EPT to Chironomid and Oligochaete (CO) Individuals *
Tolerance, Intolerance Measures	Number of Low Tolerance Taxa Percent of Low Tolerance Taxa Percent of Low Tolerance Individuals Number of High Tolerance Taxa Percent of High Tolerance Taxa Percent of High Tolerance Individuals

3.2.4 Programmatic Indicators

Number of Illicit Connections Identified/Corrected

We obtained records for reported ICID incidents from annual reports (FY 93-94 through FY 97-98) submitted to the Program by the Cities of San Jose and Milpitas. (Reports for FY 92-93 did not show ICID incidents by category.) We entered these records into a relational database and summarized illegal discharge incidents by pollutant category and year and illicit connections by year only. Pollutants likely associated with ICID incidents were determined by reviewing matrices that list pollutants associated with general human activities (SCVURPPP 1999) and with industrial activities (United States Environmental Protection Agency 1995). For several illegal dumping categories (e.g., illegal dumping – hazardous, illegal dumping – non-hazardous, parking lots, and spills), we reviewed descriptions of events reported (throughout San Jose) by municipal inspectors, and summarized the pollutants involved.

The City of San Jose maintains their recent illegal dumping incident data (1995 - 1998) in a relational database. We georeferenced the locations of such incidents reported in San Jose using a geographic information system (GIS), and identified those occurring only in the Coyote Creek watershed. We also georeferenced most stormdrain outfalls draining to Coyote Creek. Mapping stormdrain outfalls and illegal dumping incident sites illustrated which downstream reaches may be affected by pollutants generated from these sites. We could not include the City of Milpitas' incident data in this spatial analysis because their inspection records are available in hardcopy only and are not cross-referenced by incident type nor by fiscal year.

We examined temporal trends in all illegal dumping incidents reported by both cities. We subsequently compared the results of this trend analysis to temporal trends observed in the three years of georeferenced San Jose data. We also summarized increases in population and in Co-permittee inspection/outreach efforts and compared them to temporal trends in the number of reported ICID incidents.

We considered the types of pollutants associated with each category of ICID incident, along with the summaries of ICID incidents, to extrapolate the probable increase or decrease in the quantity of various pollutants discharged.

Permitting and Compliance

Claytor and Brown (1996) describe the Permitting and Compliance Indicator as follows:

"Tracking the number and type of NPDES stormwater permits issued, the number of stormwater discharges in compliance with their permits, and the number and type of BMPs implemented in conjunction with the permits allows municipalities to gauge the relative impact of various pollutant sources (i.e. urban vs. industrial vs. construction), determine if regulatory baselines are being met, and identify the need for additional enforcement activities."

California's statewide National Pollutant Discharge Elimination System (NPDES) permits regulate stormwater runoff from industrial facilities and construction sites. Industrial facilities with specified standard industrial classification (SIC) codes must apply for coverage under the statewide industrial stormwater permit (State Water Resources Control Board 1997). Construction sites that disturb more than five acres must apply for coverage under the statewide construction stormwater permit. Facilities are required to recognize and comply with their responsibility by filing a notice of intent (NOI) with the State Water Resources Control Board (SWRCB). Once covered under the statewide permit (Permit), NOI filers are required to develop, implement, and annually update a stormwater pollution prevention plan (SWPPP), sample and analyze stormwater discharges twice a year, and submit annual reports. Facilities that change or cease operations may present justification to be removed from coverage by the Permit.

The SWRCB delegates responsibility for enforcing the Permit to the nine Regional Water Quality Control Boards (RWQCBs) (California Regional Water Quality Control Board 1992). The RWQCB for the San Francisco Bay Basin (Region 2) does not inspect or enforce the Permit at industrial sites, but does inspect some construction sites.

The SWRCB's initial list of NOI filers was developed in 1992-1993 by holding public hearings and by disseminating information through trade associations. Some local governments also distributed information about the Permit requirements in utility bills. Approximately 5,000 industries submitted NOIs that first year. Since then, the number of NOI filers has fluctuated. Some sites terminated Permit coverage because their activities, though associated with a regulated SIC class, were exempt, or because they modified their facilities. The nine RWQCBs require NOI filers to develop and implement SWPPPs but do not require NOI filers to submit any proof of having done so.

SCVURPPP's Co-permittees are not responsible for enforcing the statewide NPDES permits. Stormwater NPDES-permitted agencies in neighboring Alameda County developed a memorandum of understanding with the RWQCB that provides for local enforcement of the statewide stormwater NPDES permits. No such agreement covers the Program Co-permittees. However, the Co-permittees do informally assist the RWQCB to enforce the statewide permits as part of their activities to prevent pollutants in runoff from reaching municipal storm drains.

We selected the following criteria to evaluate program effectiveness:

1. Percent of those facilities that should have applied for coverage the statewide Permit that had filed NOIs with the SWRCB.
2. Percent of NOI filers that submitted annual and monitoring reports.
3. Percent of NOI filers that maintained an annually updated Storm Water Pollution Prevention Plan (SWPPP) on-site.

In connection with the third criterion, we also evaluated the number and type of BMPs implemented.

Because of the large number of industrial facilities in the Coyote Creek watershed, and the difficulty in identifying non-filers, we evaluated industrial activity there for the first criterion only. We supplemented this characterization by applying the second two criteria to the 32 businesses in the Walsh Avenue catchment.

To identify the number and type of businesses in the Coyote Creek watershed covered under California's NPDES Permit, we downloaded from the SWRCB database (swrcb.ca.gov) records of businesses filing NOIs in the San Francisco Bay Region. We queried the database by zip code to identify records within the Coyote Creek Watershed, and by address to match the address range within the Walsh Avenue catchment. We subsequently used a geographic information system (GIS) to georeference these data and identify and map their locations within the study areas. Mapping NOI filer locations

Table 3-7. Pollutants monitored by NOI industrial facilities in the Coyote Creek watershed, as a requirement of the National Pollutant Discharge Elimination System permit (SWRCB 1995). Monitoring parameters are listed by standard industrial classification (SIC) sector (digit places designated as "X" indicate that subsectors exist, in which cases only a subset of monitoring parameters may apply).

Sector	Industrial Activity	SIC Code	Monitoring Parameters
B	Paper, Allied Products Manufacturing	26XX	COD
C	Chemical, Allied Products Manufacturing	28XX	Al;Fe;N+N;Zn;Pb;P
D	Asphalt Paving/Roofing/Lubricant Manufacturers	295X	TSS
E	Glass/Clay/Cement/Gypsum Manufacturer	32XX	Al;TSS;Fe;Zn
F	Primary Metals	33XX	Al;Zn;TSS;Cu;Fe
J	Mineral Mining & Dressing	14XX	TSS;TDS;N+N
L	Landfills and Land Application Sites	4953	TSS;Fe
M	Automobile Salvage Yards	50XX	TSS;Fe;Pb;Al
P	Land Transportation Facilities	41XX;42XX	none listed
R	Ship and Boat Building or Repairing Yards	373X	none listed
S	Air Transportation Facilities	45XX	BOD;COD;NH;pH
U	Food and Kindred Products	20XX	BOD;COD;TSS;N+N
W	Furniture and Fixtures	25XX;2434	none listed
X	Printing and Publishing	27XX	none listed
Y	Rubber/Plastic Manufacturer	30XX	Zn
AA	Fabricated Metal Products	34XX	Zn;N+N;Fe;Al
AC	Electronic/Electrical/Photographic/Optical Goods	36XX	none listed

Legend:

Al	Aluminum	NH	Ammonia
BOD	Biological Oxygen Demand	P	Phosphorus
COD	Chemical Oxygen Demand	Pb	Lead
Cu	Copper	TSS	Total Suspended Solids
Fe	Iron	Zn	Zinc
N+N	Nitrate + Nitrite		

United States Environmental Protection Agency. 1995. Federal Register Part XIV Final National Pollutant Discharge Elimination System Storm Water Multi-Sector General Permit for Industrial Activities; Notice. United States Environmental Protection Agency, Washington District of Columbia.

enabled us to identify which stream reaches receive runoff from these sites.

We evaluated construction activity in the Coyote Creek watershed for the second and third criteria, but not for the first. (Municipalities issue building permits only after receiving a copy of the NOI; therefore, 100% of construction sites should meet the first criterion.)

To identify potential pollutants in runoff from NOI facilities, we created a lookup table that included SIC codes and associated pollutants that NOI filers are required to monitor (Table 3-7). By linking this lookup table to the georeferenced NOI data we developed a mechanism for predicting which pollutants may be delivered to specific stream reaches within Coyote Creek watershed.

We applied all three criteria to industrial facilities in the Walsh Avenue catchment. We interviewed site managers at 29 of 32 businesses within the catchment and received completed surveys from 27 (see methods for Industrial/Commercial Pollution Prevention, Indicator #18). We also interviewed City of Santa Clara inspection staff to identify their methods for insuring that businesses are complying with filing requirements. SIC codes were obtained from business licenses filed with the City of Santa Clara.

We evaluated the percentage of eligible facilities that filed NOIs by comparing SIC codes and industrial activities noted during our survey and site visits to the list of active filers gleaned from the California State Water Resource Control Board's (SWRCB) list. We obtained from SWRCB staff hardcopies of annual and monitoring reports for filers in the Catchment. We evaluated the percent of NOI filers that submitted annual and monitoring reports by calculating the percent of NOI filers that had submitted annual and monitoring reports since their regulation under the Permit. We compared the percentage of reporters to filers within the Catchment, against the corresponding percentage within the nine Bay Area counties. Using our survey results, we calculated the percentage of NOI filers within the catchment that had current, on-site SWPPPs.

Growth and Development

Urbanization of watersheds contributes to changes in basin hydrology, channel morphology, and water-quality constituents. Cumulatively these changes affect instream habitat structure and associated biological communities. Quantifying the relationship between urbanization and aquatic ecosystem health is an important step toward preserving and enhancing biological resources in urban watersheds.

Percentage of impervious watershed area has been identified as a common indicator of urbanization often used for community-level and watershed assessment and planning (Arnold and Gibbons 1996; Claytor and Brown 1996, May et al. 1997a, Center for Watershed Protection 1998). Impervious surfaces, including roads, sidewalks, roof tops, and parking lots prevent or inhibit rainfall from infiltrating to soil and groundwater. Accumulated salts associated with runoff may further reduce soil infiltration capacity. Soil compaction from development 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.

Urbanization causes watershed-wide change, thus it is important to evaluate imperviousness at this scale. Increased imperviousness within riparian corridors can cause more immediate and broad impacts to aquatic ecosystem functions. Lammert and Allan (1999) found that land use within riparian corridors was a better predictor of biotic condition than land use within subwatersheds; they concluded that the scale of investigation influences the strength of predictive variables. In this study we assessed imperviousness at the watershed scale, and at a finer spatial scale (within riparian corridors).

Imperviousness has most often been estimated using variations of two techniques (Center for Watershed Protection 1998): (1) direct measurement from remotely sensed data or from topographic maps; and (2) estimation from land use data, zoning, road area or density, or population. Combining techniques and/or several data sources can improve the overall estimate of imperviousness particularly when accuracy varies among data sets. (By "accuracy" we mean precision of locations, spatial resolution, and currency of data.) For example, the estimate of impervious area directly connected to storm drain systems could be improved by combining high-accuracy road area data with lower-accuracy land use data. The best choice of technique (or combination of techniques) depends on the accuracy required, on available data sources and budget, and on watershed size.

Defining Hydrologic Units

We estimated percent imperviousness for subwatersheds draining to the 18 sampling stations on Coyote Creek (Figure 3-5). To identify drainage area tributary to each sampling station, we modified an existing subwatershed data set (Buchan 1999a) that was based on natural topography and the City of San Jose's storm drain network. We defined the "local" drainage area influencing each sampling site as the watershed area from each site to the watershed of the next upstream sampling site. We defined the "cumulative" drainage area to each site as the total upstream area. However, because Anderson Dam (Dam) greatly modifies the Creek's hydrologic regime and sediment transport, we omitted the area above the Dam from the cumulative drainage area for stations below the Dam (U1 – R5). The majority of land above the Dam is undeveloped with minimal impervious area that could influence sites downstream of the Dam.

Basemap Development

We developed a basemap of land uses in the watershed using eight data sources (Table 3-8). Our primary data source was the April, 1999 Santa Clara County Assessor's database, which included information on ownership and land use type for most parcels in the Coyote Creek watershed. Parcels with unknown land uses (2,402 parcels covering 23.5% of the watershed) were reclassified in a geographic information system (GIS; ArcView, Environmental Systems Research Institute) using additional data sources (Table 3-8). We used one-meter resolution digital orthophotographs to groundtruth parcels that were reclassified using the smaller scale data sources, and to identify land uses for remaining parcels with unknown land uses. We similarly groundtruthed, and reclassified as necessary, parcels in public ownership because land use designations for publicly owned parcels are less accurate than for privately owned parcels since the County does not regularly assess them (Bob Easley, Santa Clara County Assessor Office, personal communication, 1999). Parcels were reclassified using the categories included in the Assessor's database with several exceptions where additional categories were defined.

Calculating Percent Imperviousness

A literature search was conducted to identify studies that had the most accurate imperviousness estimates (based on their methods and data sources), and were in regions with similar climate and land use patterns. We selected imperviousness coefficients from the most applicable previous studies (Bredehorst 1981, Buchan 1999a). 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. These coefficients were rounded to two significant digits (Iraj Nasseri, Chief Hydrologist, Los Angeles Flood Control District, personal communication, 1999). For land use classes that were not sampled by Bredehorst (1981) (some subclasses of public parks, schools and right-of-way land uses), we used coefficients developed by Buchan (1999a). We estimated coefficients for the reclassified, formerly "unknown", land uses by visually assessing all such parcels.

To estimate watershed imperviousness we created a lookup table containing the impervious coefficients for each land use and joined it with the land use basemap in the GIS. Imperviousness for land uses was estimated by multiplying land use acreages by imperviousness coefficients. Impervious watershed area was estimated by intersecting the parcel and right-of-way coverages with watersheds in a GIS and calculating the

Table 3-8. Data sources used to develop an accurate land use base map for the Coyote Creek watershed.

Data Source	Scale	Spatial Extent	Owner
County Assessor Parcel	1:500	Coyote Watershed	Santa Clara County
Protected Lands	1:24,000	Coyote Watershed	Green Info Network
Vacant Land Inventory	1:500	City of San Jose Jurisdiction	City of San Jose
Easements	1:500	Santa Clara Basin	Santa Clara Valley Water District
Water Ways Management Model	1:12,000	Santa Clara Basin	Santa Clara Valley Water District
1995 Land Uses	1:24,000	Coyote Watershed	Association of Bay Area Governments
1998 Digital Orthophotos	1 meter	City of San Jose Jurisdiction	City of San Jose
Digital USGS Topographic Quadrangles	1:24,000	Coyote Watershed	United States Geological Survey

percent imperviousness. We also calculated the cumulative percent imperviousness of each subwatershed.

To demonstrate the influence of data accuracy on estimates of percent imperviousness, we compared estimates of imperviousness derived from the land use basemap to those generated from an earlier study (Buchan 1999c) that used coarser scale (1-hectare) 1995 land use data (ABAG 1996). To demonstrate the influence of scale on estimates of percent imperviousness, we estimated imperviousness in the cumulative drainage area tributary to each station.

We estimated percent imperviousness within the riparian corridor by intersecting in a GIS, the basemap of percent imperviousness with the riparian corridor area as defined by the City of San Jose (1994). 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 to because most municipalities in the Basin have policies or ordinances requiring at least 100-foot setbacks from riparian vegetation or top of stream bank. Multiple creek data sets were compiled to provide comprehensive coverage of creeks throughout the entire Basin (Buchan 1999b).

Projected imperviousness for the Coyote Creek watershed was estimated using economic and demographic forecast data to determine the amount of land available for development between 1995 and 2020 (ABAG 1998). This data included information from local government general plans, zoning, urban growth boundaries, and other policies specific to land development. Estimates of projected imperviousness were derived by taking the difference between existing and projected land use acreages for each watershed, assigning coefficients of imperviousness to the two 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 (Buchan 1999c). We did not estimate projected imperviousness by sampling station subwatersheds for this study, although it is feasible to do. Rather, the methodology was included here to demonstrate its utility.

3.3 Project Approach in the Walsh Avenue Catchment

To demonstrate the effectiveness of having implemented an industrial pollution prevention program for seven years we evaluated a suite of indicators (water quality indicators – Toxicity Testing and Non-point source loadings –, site indicators – Industrial/Commercial Pollution Prevention, and Industrial Site Compliance Monitoring – and a programmatic indicator – Number of BMPs Installed and Maintained.

3.3.1 Programmatic Indicators

Industrial/Commercial Pollution Prevention

BMPs Installed, Inspected and Maintained

Industrial Site Compliance Monitoring

To implement these indicators we reviewed the City of Santa Clara's inspection records, and asked business owners to respond to a questionnaire. We also accompanied a City of Santa Clara Fire Department inspector to visit 29 of the 32 (91%) businesses within the Catchment.

Surveys were sent to all the site managers of the businesses in the Walsh Avenue Catchment. The survey requested general information regarding the business, their prior knowledge of the Program, previous inspections, implemented BMPs and associated costs. Meetings were scheduled with site managers to collect and review the completed surveys. Of the 32 businesses in the Catchment, 29 were visited and 27 completed surveys were collected. The meetings with each individual site manager were followed by a 30 - 60 minute guided site visit.

The City of Santa Clara's NPS inspections are typically not announced. The NPS Inspector introduces himself and the Program to site managers and proceeds with the assessment. Comments and observations are documented on the City's *NPS Inspection Violation Notice* form. Upon completion, the NPS inspector and the site manager (or a representative) review the questions, findings and/or potential areas of violation. The NPS Inspector usually recommends actions and BMPs that may rectify the violation and promote compliance with the stormwater objectives. The City of Santa Clara does not track the number of BMPs already installed and maintained on-site. However, the operation and effectiveness of the existing BMP may be questioned. When applicable, the NPS Inspector may also ask to view management plans or regulatory documentation such as spill response plans, copy of NOI or stormwater pollution prevention plan.

3.3.2 Water Quality Indicators

For both of the water quality indictors we evaluated, we used toxicity monitoring and load calculations to detect water quality trends and their associations with BMP implementation.

Toxicity Testing

Trends in toxicity (and loads monitoring – see below) may be used to measure the success of storm water management efforts in decreasing pollutant concentrations. Much of the variability in urban runoff water quality is random, but some variability can be explained by the different hydrologic and antecedent conditions for each storm event. Seasonal effects may be more apparent in semi-arid climates such as those found in the Southwestern United States, which typically has dry summers and wet winters. Seasonal effects are often exacerbated by El Niño events or prolonged droughts, which can cause large variations in seasonal rainfall and runoff.

The existing Walsh Avenue catchment hydrology and water quality database was used to determine how much of the variability in loads was due to changes in water quality versus changes in total event flow. A large percentage of the variability due to changes in event flow would indicate that changes in loads might not be a sensitive indicator of BMP effectiveness.

Data Sources

Thirty eight storm events were monitored for water quality and stream flow at the catchment monitoring station (L2) between April 1988 and April 1995. Toxicity testing was conducted on 11 of these events. The monitoring station was also sampled for five storm events from October 1998 to April 1999. Rainfall has been measured continuously since 1948 in the watershed. Complete data (e.g., both flow, water quality, and rainfall) were only available for 27 of the 43 events.

Rainfall data from the San Jose Gage (Alert gage No. 1453, National Weather Service Gage (NWS) # 7821) were used to represent rainfall for each monitored storm event in the catchment. Flow data were collected at the water quality monitoring station using water depth sensors calibrated to theoretical pipe flow rates using a rating curve. A V-notched weir was installed in the pipe upstream from the manhole to improve the flow monitoring capabilities for low flows.

Water quality data were collected using flow-composite samplers programmed to collect a discrete sample after a given volume of flow (trigger volume) had passed the station. The trigger volume was adjusted prior to each event based on the forecasted rainfall amounts. The discrete samples were pumped into a large composite bottle contained within the sampler and transported to the laboratory for analysis. Results from the composite sample analysis are representative of the flow-weighted average concentration and are called event mean concentrations (EMC).

Data Analysis

We used simple time-trend linear regression analysis to determine if toxicity changed during the monitoring period. Linear trends were evaluated for concentrations and loads of total copper (Cu), total nickel (Ni), total lead (Pb), total zinc (Zn), and total suspended solids (TSS). Trends for total monitored event flow were also examined. We used Analysis of Variance to determine if the linear trend was significant.

Methods used to analyze hydrology data were the same as those described for the Exceedance Frequency of Water Quality Standards Indicator. Water quality data from Station L2 were recently summarized as a part of a regional effort to collect data from the San Francisco Bay Area into a single database (BASMAA 1996). 1998-1999 monitoring data were added to the database. Descriptive statistics were calculated for all the data.

Non-point Source Loadings

We used the same data and statistical analysis (trend analysis) to evaluate this indicator as were used to evaluate the Toxicity Testing Indicator (see above). The difficulty with using loads data in trend analysis is that loads can vary considerably from event to event and from year to year. Loads are often more variable than pollutant concentrations because they include variability in flow as well as variability in concentrations. Without being able to explain some of this variability it will be difficult to identify a trend in the data. In addition, variability in concentration increases the uncertainty in estimates of the mean (average) concentrations and loads.

Event runoff coefficients were estimated for each monitored event by dividing total rainfall volume by total flow volume. Data for events with runoff coefficients > 1.5 were examined to determine the potential cause of the lack of agreement between the monitored flow and rainfall data. Events with peak stages greater than the pipe diameter were assumed to be surcharging. Such events were excluded from the data analysis. Two additional events were excluded due to known programming errors in the sampling equipment.

Loads were estimated for each monitored event by multiplying the monitored total flow volume for each event by the event mean concentration (EMC) for each parameter.

3.4 Application of Indicators in the Program Area

3.4.1 Social Indicators

The geographic scope for evaluating the social indicators included the entire Program area, the portion of Santa Clara County that drains to San Francisco Bay (Figure 1-1).

Public Attitude Surveys

User Perception

To evaluate these indicators, the Program assessed and compared the results from two public opinion surveys. The first survey was conducted in April 1996, both to establish a baseline of attitudes and awareness of Santa Clara Valley residents on issues related to urban runoff pollution, and to gather information to guide the development of further public education efforts for the Program and its member agencies. A second survey was conducted in 1999 in order to determine the current levels of knowledge about urban runoff pollution, and to detect any changes in public awareness or behavior over the past three years as a result of the Program's public education efforts. The survey also included additional questions to determine the public's level of awareness of watershed issues to aid in focusing a future watershed education and outreach campaign.

A random digit dial telephone survey was conducted to sample approximately 850 residents, 16 years of age and older. The sample was drawn from zip codes representing the agencies of the Program. To ensure that a statistically significant number of interviews were conducted in the cities throughout the Program, a maximum quota of 285 interviews in the City of San Jose was established. Response data were then weighted to reflect the City of San Jose's actual percentage of the region's population. The survey required approximately 25 minutes for the average respondent to complete. A Spanish language version of the questionnaire was administered to those who preferred to respond in Spanish.

Results were analyzed for the County as a whole, by subregion of the County and by population subgroups. The margin of error for the sample as a whole was 3.4%. The margin of error for subgroups of the sample was larger depending upon the size of the subgroup.

As in 1996, several subgroups in the survey sample were formed based on responses to specific survey questions. These subgroups included:

⇒ respondents who said they had heard or seen something about the storm drain system; those who said they had not;

⇒ those who had seen the Program's storm drain stencil;

⇒ those who had witnessed someone dumping something down a storm drain; and those who had not.

⇒ "do-it-yourselfers"

⇒ respondents who said they engage in various kinds of behavior that avoid storm drain pollution and those who said they would be willing to change their behavior to keep pollution out of the storm drain system

⇒ people who visit the Bay, the ocean, the river, wetlands, creek trails, reservoirs, and nature centers;

⇒ and additional subgroups based on income, housing, education, age, gender, ethnic background, language preference, and city of residence.

Response data collected by the telephone interviews were analyzed to:

⇒ determine the extent to which attitudes and perceptions are associated with misinformation or lack of awareness

⇒ identify messages or motivations that might be effective in promoting behavioral change or participation in urban runoff pollution prevention programs

⇒ profile subgroups that appear to have the greatest levels of awareness in propensity to participate, and those that have the lowest levels to assist in developing strategies for targeting information to specific audiences.

Public Involvement and Monitoring

To evaluate public involvement and monitoring we compiled information about programs and projects implemented or funded independently or jointly by Program Co-permittees. These included urban runoff pollution prevention education, active resident participation (e.g. calling for information, assisting in a clean-up, attending a workshop), volunteer monitoring, or other "hands-on" activities (Program Annual Reports, Annual Workplans, summaries of Co-permittee Performance Reviews, and "PIP Updates" (monthly summaries of Public Involvement and Participation (PIP) activities) Coyote Creek Riparian Station's (CCRS) Integrated Community Involvement Program Report (June 1997), CCRS' Permanente Creek StreamWatch Program Report (February 1999), CCRS reports of StreamKeeper activities (August 1995 – June 1997), Santa Clara Valley Water District's (SCVWD's) Annual Reports). With few exceptions (some school education programs), the activities described included both an educational and hands-on component.

Specifically, we tabulated the following:

Program Activities (1995-98 fiscal years):

⇒ Number of calls to the Program's informational hotline (800 #).

⇒ Number of presentations/events by Program staff and amount of audience reached (where information was available).

⇒ Number of public involvement and monitoring organizations/projects funded by the Program, and number of participants in these projects (where information was available).

⇒ Number of participants attending Program-funded weekend activities at the Don Edwards San Francisco Bay National Wildlife Refuge Environmental Education Center at Alviso.

⇒ Number of activities of the StreamKeepers volunteer monitoring group funded by the Program, and number of participants involved in monitoring.

Co-permittee Activities (1997-98 fiscal year):

⇒ Number and effectiveness of school education programs.

⇒ Number of creek clean-up events organized and total number of participants (where available).

⇒ Number of creek segments adopted in the Santa Clara Valley Water District's (SCVWD) Adopt-a-Creek program.

⇒ Number of Co-permittees using volunteers to stencil storm drains and the amount of volunteer participation (where available).

⇒ Number of community events which included Program representation and numbers of residents reached (where available).

⇒ Number of workshops, classes, and presentations by Co-permittee staff which included urban runoff pollution prevention messages, and numbers of residents reached (where available).

⇒ Number of Household Hazardous Waste (HHW) drop off events organized and total resident participation (where available).

⇒ Number of other activities that included public participation and/or monitoring.

3.5 Project Data Overview

We compiled data from numerous sources to evaluate stormwater indicators in both the Coyote Creek watershed and the Walsh Avenue Catchment. Table 3-9 lists data collected and compiled for the SEIDP stormwater indicator evaluation, including the geographic area covered by each data set, and the format in which the data exist. Historical data that existed in electronic format prior to implementing the SEIDP and were used in the indicator evaluations are also listed in Table 3-9.

Table 3-9. Data collected, compiled, and used to evaluate the SEIDP stormwater indicators.

Data Set and (Indicator Number)	Description	Geographic Extent	Data Format
Physical & Biological Sampling *Locations*	18 locations (100 m reaches) on Coyote Creek where biological and physical data were collected during May, June, and July 1999.	Coyote	GIS
Fisheries (12)	Number, length, weight, and anomolies of individual fishes sampled by electroshocking 18 locations on Coyote Creek. Metrics calculated using these data (based on Barbour et al. 1997).	Coyote	Access[1]
Historical Fisheries (12)	A. Length, weight, and relative abundance of fishes sampled 1978 - 1979, grouped by urbanization category ; presence/absence of fishes by individual site (Pitt and Bozeman 1982).	Coyote	Access
	B. Number and length of individuals sampled 1992 - 1998; species ratings (Leidy 1999).	Bay Area	Access
	C. Presence/Absence of species 1858 – 1999 (Buchan et al. 1999).	Coyote, Alameda	Excel
	D. Number and weight of individuals sampled 1998; Salmonids were fin-clipped (Cressey 1998).	Coyote	Access
	E. Length and number of individuals sampled 1980 – 1981; 1987 (Smith et al. 1988).	Coyote	Excel
	F. Number of individuals sampled 1972 – 1977 (Scoppettone and Smith 1978)	Coyote	Excel
	G. Number and weight of individuals sampled 1990 – 1994 at six sites near percolation ponds (Habitat Restoration Group 1994).	Coyote	Excel
	H. Number of individuals sampled on lower Coyote Creek 1996 (Jones and Stokes 1996).	Coyote	Excel
Macroinvertebrates (13)	Number of individual invertebrates sampled at 9 locations on Coyote Creek. Metrics calculated using these data (based on Barbour et al. 1997).	Coyote	Access[1]
Historical Macroinvertebrates (13)	Relative abundance of individuals keyed to genus, and sampled 1978 - 1979 (Pitt and Bozeman 1982).	Coyote	Access
Physical Habitat (8)	Physical habitat at the 18 locations on Coyote Creek where biological sampling occurred.	Coyote	Access[1]
Creek Geomorphology (7)	Geomorphic classification of creek reaches based on geology, lithology, topography, ecoregions, channel width and type, urbanization extent, location of dams, diversions, stormdrain outfalls, percolation ponds, historic mining, and habitat.	Coyote	GIS, Excel
Sediment Characteristics (5)	Sediment size and metal concentrations at nine locations on Coyote Creek where biological sampling occurred.	Coyote	Access[1]
Flood Frequency (10)	Annual peak flows on Coyote and Penitencia Creeks, dates of historic flooding, extent of urbanization from 1895 – 1995, population growth from 1925 – 1995.	Coyote	GIS, Access
Imperviousness (24)	Subwatershed imperviousness (cumulative imperviousness estimated for subwatersheds below Anderson Dam).	Coyote	GIS
Illicit Connections, Illegal Discharges (21)	Location and type of illegal discharges to stormdrain network reported in the City of San Jose from 1993 - 1998. Only incidents reported from 1995 – 1998 were georeferenced.	City San Jose	GIS, Dbase
State NPDES Notice of Intent Filers (23)	Location of industries and construction sites that filed a notice of intent with the State Regional Water Quality Control Board and were included on the State's NPDES permit.	Coyote, Walsh	GIS, Dbase
Water Quality Monitoring *Locations*	5 locations on Coyote Creek where probes were deployed to continuously monitor selected water quality parameters (see below).	Coyote	GIS
Water Quality (11)	Continuous measurement (15 weeks, June – September at 15-minute intervals) for dissolved oxygen, temperature, pH, and conductivity	Coyote	Access[2]
Historical Water Quality (11)	Water quality and stream flow monitored in Coyote Creek during 38 storm-events between 4/88 and 4/95 using flow composite samplers. Walsh Catchment was monitored again for 5 storm-events from 10/98 to 4/99.	Coyote, Walsh	TBD
Rainfall (11)	Rainfall data from the San Jose Gage (#1453; National Weather Service Gage # 7821), continuously monitored since 1948.	Coyote, Walsh	TBD
Industrial Site Compliance (26)	Type and number of Best Management Practices implemented at industries in the Catchment, as well as record of compliance with NPDES permit requirements.	Walsh	Excel
Public Attitude; User Perception (17, 20)	Results of two public opinion surveys (conducted in 1996 and 1999) designed to assess changes in public awareness, perceptions, and behavior as a result of the Program's public education efforts.	County	? Word Tables
Public Involvement & Monitoring (19)	Level of public involvement in a variety of programs related to raising awareness of creek function and health, volunteer creek monitoring and cleanup, as well as pollution prevention.	County	Word Tables

Column 3 indicates the geographic extent covered by each data set (Coyote = Coyote Creek Watershed; Walsh = Walsh Avenue Catchment; Records noting City of San Jose include the urbanized area of the Coyote Creek Watershed but also extend beyond its boundaries; Alameda = Alameda Creek Watershed; Santa Clara County = sampled throughout the Program area; Bay Area = sampled throughout the San Francisco Bay Area). Column 4 indicates the data format of each data set (GIS = resides in a geographic information system, ESRI's ArcView and PC ARC/INFO; Access = resides in Microsoft Access relational database and can be linked to the associated GIS coverage; Excel = resides in a Microsoft Excel spreadsheet; Dbase = resides in a Dbase file that can be linked to the associated GIS coverage; Word = Microsoft Word Table). Associated GIS coverages are referenced by subscripts: [1] = physical and biological sampling locations; [2] = water quality sampling locations .

4. Results and Discussion

4.1 Results in the Coyote Creek Watershed

4.1.1 Physical and Hydrological Indicators

Stream Widening and Downcutting

Successful implementation of this indicator using the methods described in Claytor and Brown requires having historical data of sufficient quality for temporal comparisons of creek morphology. We could only identify a few repeated cross-sections along the creek, and these were inadequate due to variation in survey methods, sparse documentation of channel bed elevation, and inadequate location (e.g., located near channel structures such as bridges and culverts, or were built as modified channels after data were collected). Other potential data sources, including bankfull channel widths, bank-scour measurements, stream discharge measurements, and aerial photos, were also of insufficient quality for temporal comparison.

We implemented an alternative approach, developing a geomorphic stream classification based on natural (geology, lithology, elevation, hydrology, and creek planform), and anthropogenic (land use and modified channel characteristics) factors. The relative contribution of these factors varied according to position in the watershed. For example, gradient and planform was more important in the headwaters; geology, hydrology and channel width were most important in the reaches below Anderson Dam; and channel type and land use were most important in the lower creek reaches and the tidally influenced area.

Combining both natural and human-related geomorphic influences to Coyote Creek, we divided Coyote Creek into eight distinct geomorphic reach types (Figures 4-1 and 4-2, Table 4-1). The upper three reaches occur in rural areas of the watershed above Anderson Dam. The lower five reaches are characterized as low gradient streams that flow through a mixture of rural and urban lands.

A geomorphic creek classification can be used to:

- ⇒ Identify the geomorphic controls that influence channel response to changing flow regime;
- ⇒ Provide a means for communicating and predicting inherent stream processes;
- ⇒ Stratify data and reduce variance;
- ⇒ Provide a framework for monitoring channel change over time;
- ⇒ Organize data and extrapolate findings to reaches with similar geology, hydrology and land use conditions.

Reaches above Anderson Dam:

- ⇒ Reach 1 represents the headwaters of Coyote Creek downstream to an elevation 880 feet, located approximately one mile downstream of Gilroy Hot Springs. This reach is characterized as having narrow valleys, moderately steep slopes, low channel sinuosity, and moderate stream gradients. The tributaries to this reach are generally steep, flow over unstable rock formations and are capable of producing high levels of soil erosion (SCVWD 1978).
- ⇒ Reach 2 is the stream segment between Reach 1 and Coyote Reservoir. This reach is low gradient, maintains a wide flood plain, and has high sinuosity with a braided planform.
- ⇒ Reach 3 is the section of creek between Coyote Reservoir and Anderson Dam. This reach is characterized as having deep, slow moving water and high sediment deposition. All three uppermost reaches are susceptible to mass wasting and soil erosion, but a majority of the sediment is transported and then trapped behind either of the two dams.

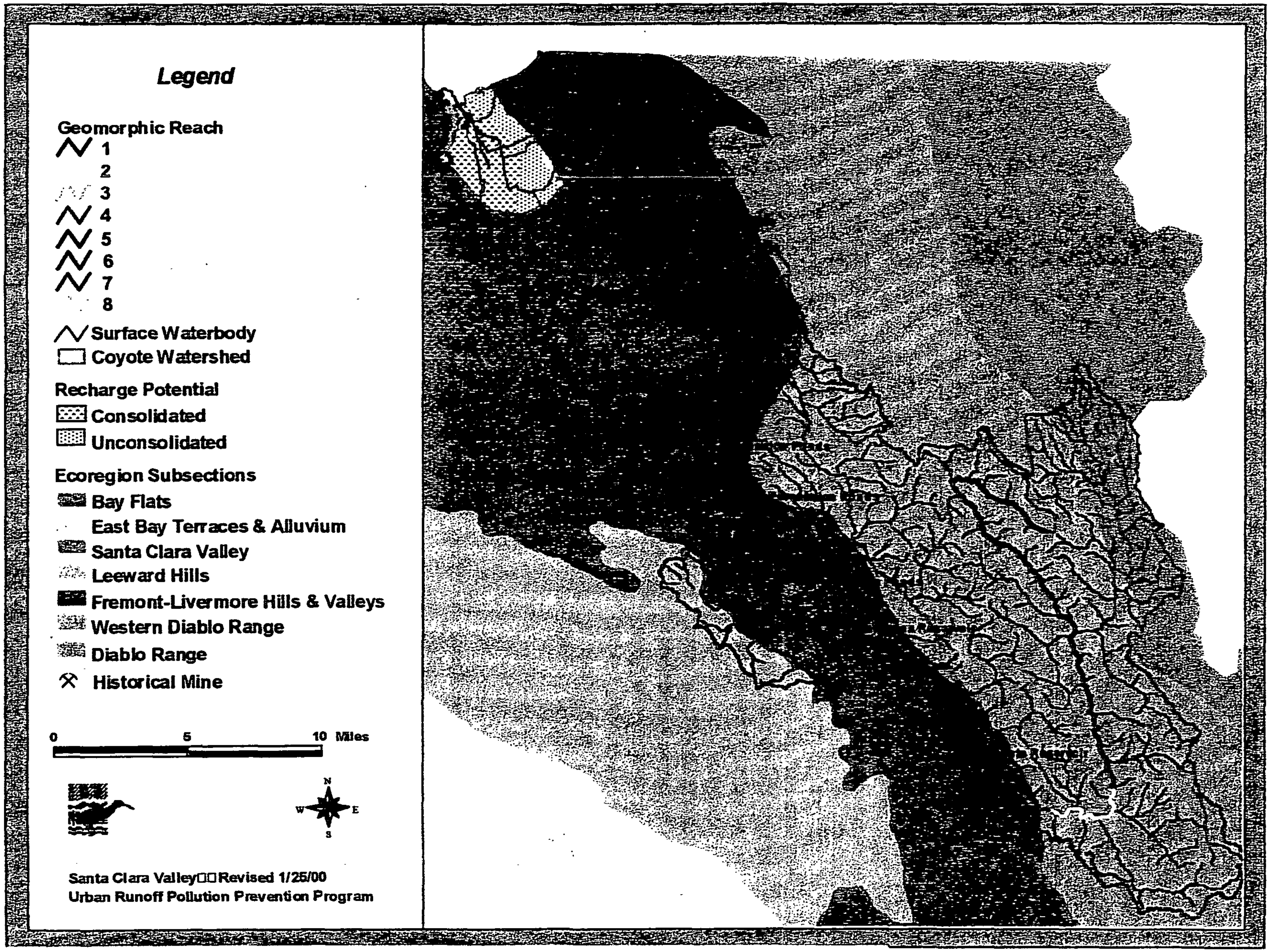


Figure 4-1. Stream classification and hydrological and geological features of Coyote Creek.

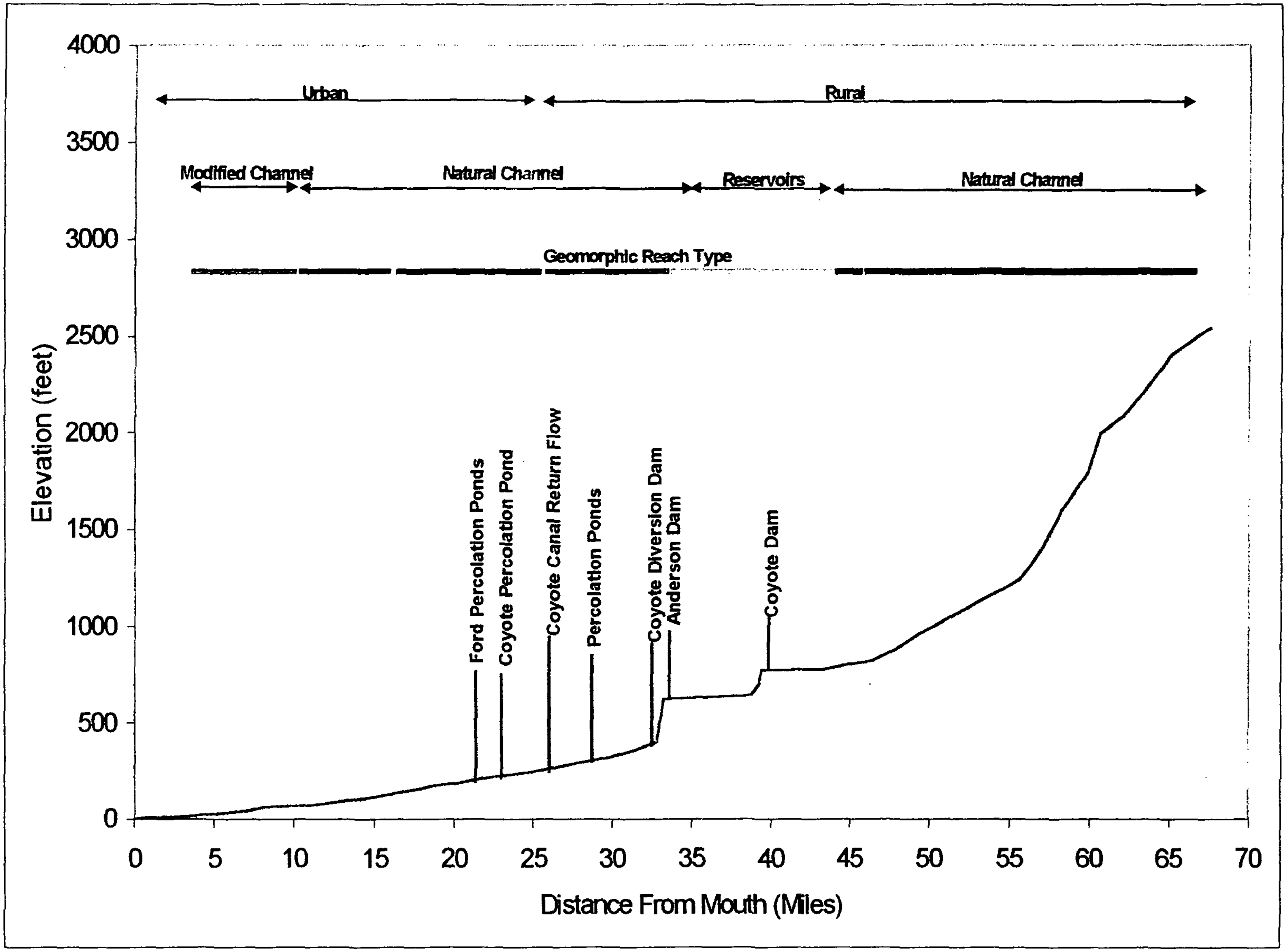


Figure 4-2. Longitudinal profile, hydrological controls, channel type and land use of Coyote Creek.

Table 4-1. Criteria used to create geomorphic classification of Coyote Creek.

Major Stream Process	River reach	Average gradient (percent slope)	Planform	Average stream width (ft)	Channel type	Substrate	Groundwater Recharge Potential	Lithology	Geomorphic Processes	Stream Flow Alteration
Sediment Supply	1	2-4	narrow	NA	Natural	Bedrock, boulder, cobble	NA	Franciscan sedimentary, volcanic, metamorphic	Mass wasting and fluvial erosion	NA
Sediment Transport	2	0.75-1	braided	NA	Natural	Cobble, gravel	NA	Franciscan sedimentary, volcanic, metamorphic	Mass wasting and fluvial erosion	NA
	3	0-2.0	NA	NA	Impounded	Silt	NA	Miocene marine sediments	Mass wasting and fluvial erosion	Permanent dams
Sediment Deposition	4	0.4	meandering	450	Natural	Lrg cobble, gravel	unconsolidated	Late Quaternary alluvium	Fluvial erosion and deposition	Diversion, spreader dams, stormdrains
	5	0.25	meandering	193	Natural	Sm cobble, gravel	unconsolidated	Late Quaternary alluvium	Fluvial erosion and deposition	Spreader dams, stormdrains
	6	0.23	meandering	107	Natural	silt,sand	consolidated	Late Quaternary alluvium	Fluvial erosion and deposition	Stormdrains
	7	0.17	channelized	133	Modified	silt, sand, gravel	consolidated	Late Quaternary alluvium	Fluvial erosion and deposition	Stormdrains
	8	0.08	meandering	33	Natural	Silt	consolidated	Quaternary bay-fill, silt and clay	Fluvial, coastal marine	Seasonal dam

Reaches below Anderson Dam:

⇒ Reach 4 is the section between Anderson Dam and a point 0.25 miles upstream of Metcalf Road, an area known as the Coyote Narrows. This 8.5-mile section of creek flows over the Coyote Valley subbasin, which is composed of a 10-40 foot layer of alluvial deposits. This reach is characterized as a wide, meandering, natural stream channel, with large cobble and gravel substrate. This reach is subjected to water diversion at the Coyote Canal inlet, and the creek is often de-watered for half the year (April – October). This reach is mostly rural, although it contains four stormwater outfalls that originate from the city of Morgan Hill.

⇒ Reach 5 is an 8.5-mile section of creek between the Coyote Narrows and the downstream edge of the unconsolidated region, which is the groundwater recharge area for the Santa Clara sub-basin. This reach is characterized as a moderately wide, meandering natural channel, with predominately small cobble and gravel substrate. This creek segment receives water inflow from Coyote Canal, Fisher Creek and 16 storm water outfalls. Reach 5 is urbanized on the western side of the creek, with predominately rural area to the east. The reach also contains past gravel mining sites.

⇒ Reach 6 is a 5.5-mile section of creek between the upstream edge of the consolidated region and the upstream edge of the modified channel portion of Coyote Creek. This reach is characterized as a moderately wide, meandering natural channel, with predominately silt and sand substrate. This section of creek receives additional flow from Upper Silver Creek and 20 storm outfalls. Reach 6 is surrounded by a wide band of riparian vegetation in an urban area. There are several abandoned gravel mining sites in this reach as well.

⇒ Reach 7 is a 7.9 mile length of modified channel that runs just upstream of East Santa Clara St down to 0.35 mile downstream of Hwy 237. This section of creek has been modified by earth excavation and setback levees for flood control. The channel is moderately wide with low sinuosity, relatively no flood plain and has a mixture of silt, sand and gravel substrate. This section is also highly urbanized and has a narrow band of riparian vegetation along its banks. Additional water inflow to this reach comes from Upper Penitencia and Lower Silver Creeks and 32 storm water outfalls.

⇒ Reach 8 is the lowest section of Coyote, which is characterized as a tidally influenced stream. The reach begins at the end of the modified reach and flows into the South Bay. This section of creek is narrow, sinuous and has predominately silt substrate. This section receives additional freshwater inflow from the Lower Penitencia Creek watershed.

Physical Habitat

Against the backdrop of stream geomorphology, measurements of physical habitat provided additional evidence of the complexity of the Coyote Creek watershed and factors affecting its habitat value. Coyote Creek benefits from a chain of parks that extends mostly through the urbanized area. This protection of land uses immediately adjacent to the creek buffers the creek from some urban influences; however, storm drain pipes traverse this buffer area and discharge directly to the creek.

The influence of dam releases and water diversions on flow was revealed during our implementation of this indicator. Although the summer of 1999 was mild compared to recent years, a warming trend in early July translated into little (1 cfs) to no flow at the three sites above the reservoirs (Table 4-2). Streamflow through the lower watershed varied from nearly 50 cfs just below the Dam to less than 5 cfs in the transition and upper urban stations, and 10 - 13 cfs in the lower, most urbanized stations. Flow reductions observed below the R-3 station were caused by diversion to old quarry gravel pits via a breached levee. Flow was augmented from several tributaries, resulting in flow increases observed at stations T-3 (from Fisher Creek), and the lowest three urban stations (from Lower Silver and Upper Penitencia Creeks). The decreases

Table 4-2: Gradient and stream flow for Coyote Creek sampling stations.

Reach ID	Date	Flow (cfs)	Gradient (% slope) Field	Gradient (% slope) GIS
U-1	6/30/99	12.88	0.23	0.17
U-2	7/1/99	12.30	0.23	
U-3	7/1/99	10.63	0.19	
U-4	7/2/99	4.00	0.02	0.23
U-5	7/6/99	4.06	0.15	
U-6	7/6/99	2.04*	0.38	
U-7	7/8/99	3.70	0.82	0.25
T-1	7/8/99	4.55	0.32	
T-2	7/7/99	21.84	0.23	
T-3	6/28/99	19.95	0.91	
R-1	7/7/99	9.12	0.16	0.40
R-2	7/12/99	26.71	0.39	
R-3	7/12/99	37.38	0.46	
R-4	7/13/99	38.81	0.08	
R-5	7/13/99	48.49	1.16	
R-6	7/16/99	0.83*	0.77	0.75 - 1.00
Ref-1	7/16/99	0.00	0.70	
Ref-2	7/16/99	0.083*	0.91	

*Accuracy unknown: below minimum velocity detection limits for flow meter

observed at urban sites correspond to a change in lithology; rural and most transition sites are dominated by porous, gravel substrate which changes at the urban sites to high clay-content substrate that precludes groundwater percolation. In addition, stream flow fluctuates daily due to the schedule of regulated flows from Anderson Dam.

Typically, each reach contained four habitat units, consisting mostly of pool habitat types (by occurrence), followed by flatwater types. Riffle habitats were the least common by occurrence and by length (Figure 4-3).

The distribution of pool, flatwater, and riffle habitat types was similar among station groups and more correlated with streamflow, gradient, and substrate than with increased urbanization.

With several exceptions, pool and flatwater habitat units were typically longer and wider than riffle units. The wetted width of the creek channel gradually increased in the upstream direction, narrowing in two sections before and after the reaches in the urban/non-urban transition zone. Mean habitat unit depth for flatwater and riffle units was typically < 1.0 ft. Maximum pool depth ranged from 1.8 to 4.6 ft. Pool tail crest depth was typically 1.0 ft. Maximum pool depth was similar in all reaches.

The percent of total instream shelter was the greatest (13 – 22%) in the middle section of Coyote Creek between T-2 and R-4, with the exception of R-1 (Figure 4-4). Sites further upstream (R-5, R-6, and Ref-1) had 3 - 4%

Figure 3: Percent of Level II Habitat Types by Length

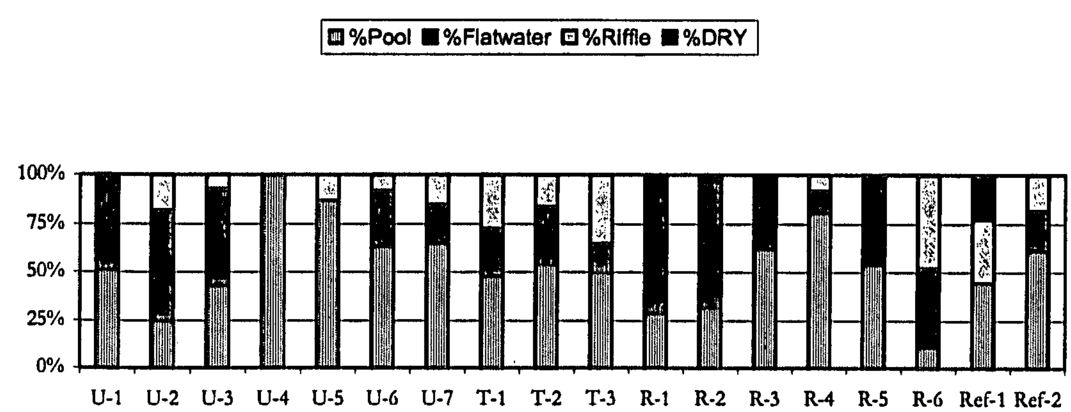
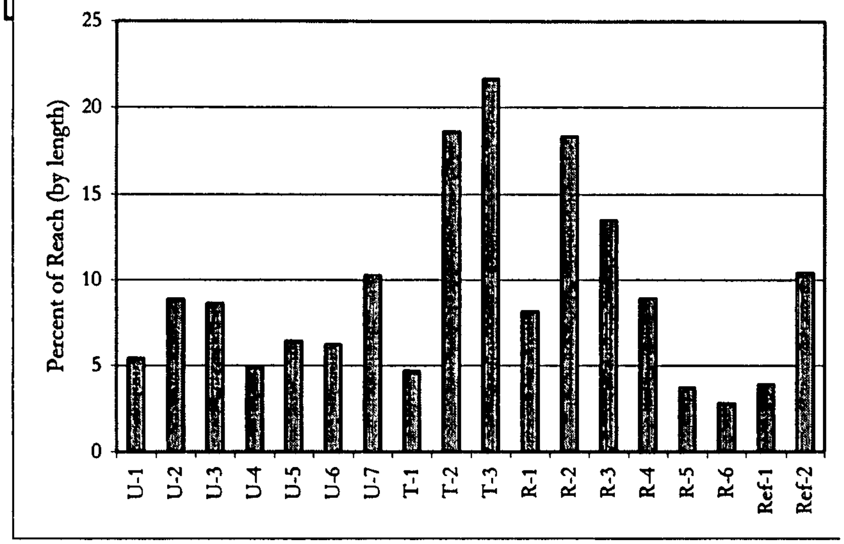


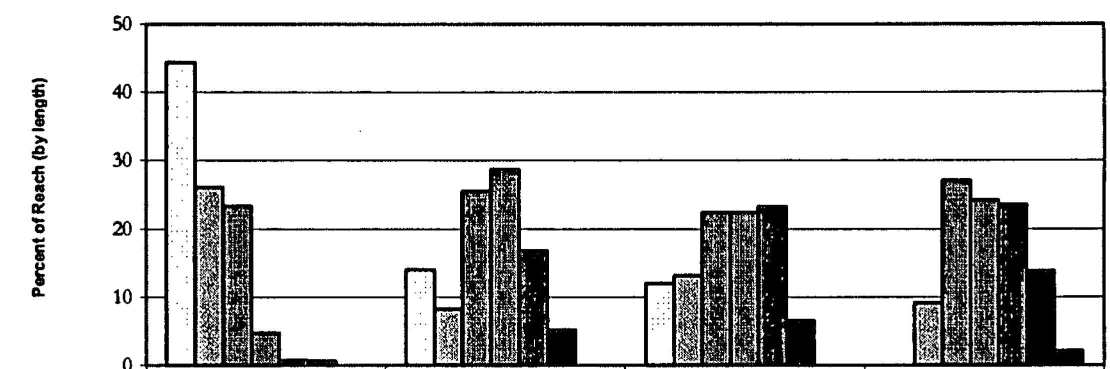
Figure 4-4: Percent of Reach with Available Instream Shelter



instream shelter, while the urban sites and the first transition site (T-1) had 5 – 10% instream shelter. In the urban reaches, small woody debris was the most prevalent type of shelter, followed by terrestrial vegetation and root masses. Artificial debris such as shopping carts, tires, and auto parts were much more common in the urban sites (especially in reach U-3) than in the transition and rural reaches, and none were found in the two reference reaches.

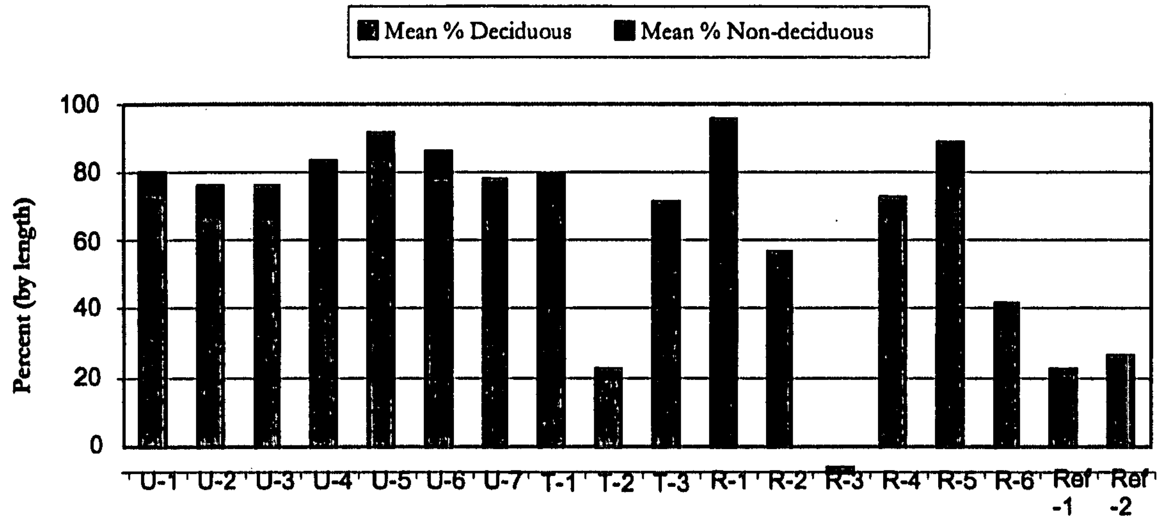
There was also a noticeable increase in turbidity in the downstream direction. This

Figure 4-5: Reach Substrate Averages by Urbanization Zone



	Urban	Transition	Rural	Reference
% Silt/Clay	44	14	12	0
% Sand	26	8	13	9
% Gravel	23	26	22	27
% Sm Cobble	5	29	22	24
% Lg Cobble	1	17	23	24
% Boulder	1	5	7	14
% Bedrock	0	0	0	2

Figure 4-6: Mean Percent Riparian Cover per Reach



observation correlates with the trend in dominant substrates (Figure 4-5). Substrate composition along the longitudinal creek profile changed from silt/clay dominant in the lower reaches, to a more equal distribution of intermediate-size substrate from approximately the transition sites through R-2. The proportion of larger substrate increased in the upper reaches.

Reflecting the protection afforded by the park chain, and possibly the encroachment of riparian vegetation because of the lack of scouring flows since Anderson Dam was constructed in 1950, the majority of reaches had total horizon canopy cover of $\geq$ 70% (Figure 4-6), most of which was deciduous (90 – 95%). Percent riparian canopy was high in the urban stations and tended to decrease at upstream sites with several exceptions (T3, R-1, R-4, and R-5).

The stations above the reservoirs showed a large and more consistent decrease in riparian cover compared to reaches below the reservoirs. Because these sites are located within different ecosubsections than sites below the reservoirs, differences in soil type, precipitation and land uses are influencing the distribution and species composition of riparian vegetation. In the urban and transition zones, 50% of streambank vegetation consisted of deciduous trees, 30 – 35% was brush, and the remainder grass/herb/forb. The proportion of deciduous trees comprising streambank vegetation in the rural and reference zones reflected the decrease in riparian canopy cover.

Increased Flood Frequency

Urban growth in the Coyote Creek watershed has occurred primarily along lower Coyote Creek, below Anderson reservoir and in the Upper Penitencia Creek watershed (Figure 4-7). As shown, population growth and urbanization increased dramatically in the Coyote Creek watershed starting in the 1950's. The accompanying increase in impervious area within the watershed

Flood frequency, location, and extent also has been highly modified by dam and levee construction (Figure 4-8). The construction of Anderson Dam (1950) greatly reduced the contribution of flows from the portion of the watershed above the Dam. Prior to construction, the median, annual peak flow (measured at the Edenvale gage) was 3,200 cfs. Post-construction, the median, annual peak flow was 149 cfs, reflecting a 95% decrease. Recorded flood events did not correlate with peak flows measured below the Dam, indicating that flooding incidence due to runoff from the watershed above the urbanized area was greatly reduced. In addition, the number of storm events with flow exceeding channel capacity in Coyote Creek decreased (Table 4-3).

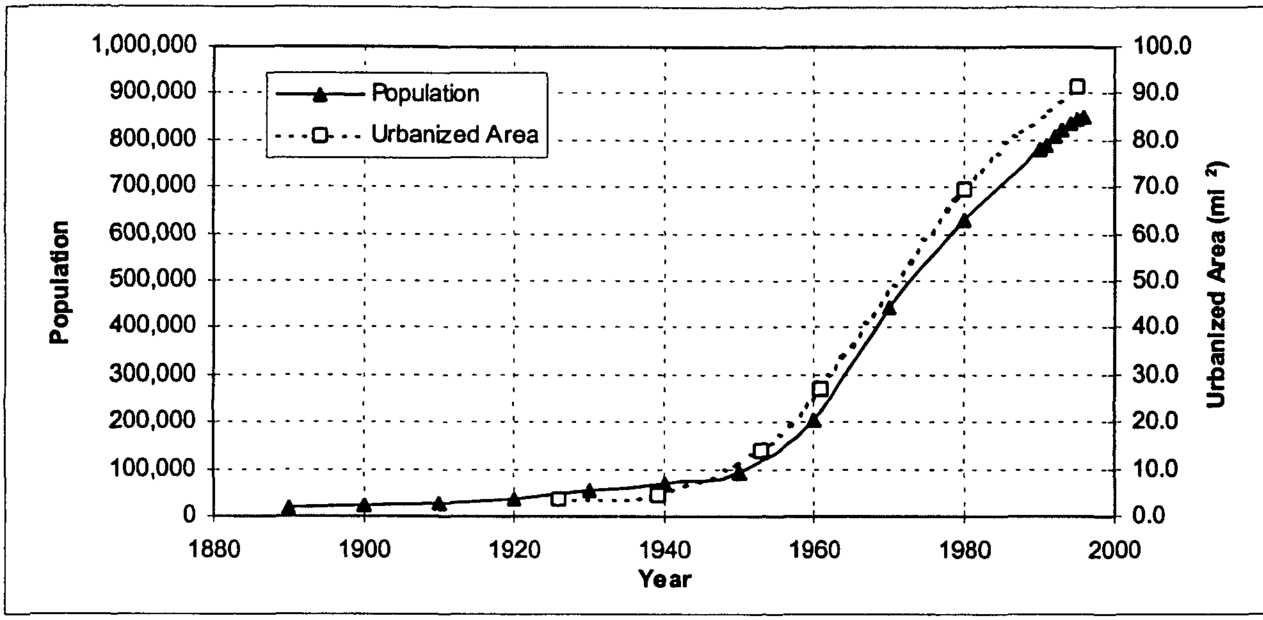


Figure 4-7: Growth in Population and Urbanization in the Coyote Creek Watershed
Sources: Urbanized Area, United States Geological Survey topographic maps, Population, ABAG 1996.

Figures 4-9 and 4-10 show the lower half of the Coyote Creek watershed on the 1980 USGS topographic map. Shaded areas in Figure 4-9 depict the general locations where flooding occurred between 1911 and 1973. This period was chosen to represent pre-urbanization because (1) accurate flood records were not available before this time, and (2) the population and developed area approximately doubled since then. Because the flood event locations were based on anecdotal evidence contained in old newspaper reports, the shaded areas represent only approximate flood locations. These records may better represent flooding that resulted in property damage and

Table 4-3: Number of Storms Exceeding Coyote Creek Channel Capacities based on Flow at the Edenvale Gage before and after Construction of Anderson Reservoir. Source: SCVWD 1999.

Reach	Reach Description	Approximate Reach Length (feet)	Existing Channel Capacity (cfs)	Storm Events Exceeding Channel Capacity	
				Before Anderson	After Anderson
1	Old Oakland Road to Penitencia Creek Confluence	4,400	4,500	5	0
2	Maybury Road to US 101	1,600	7,500	10	2
3	Yerba Buena Ave. to US 101	8,500	3,500	15	3

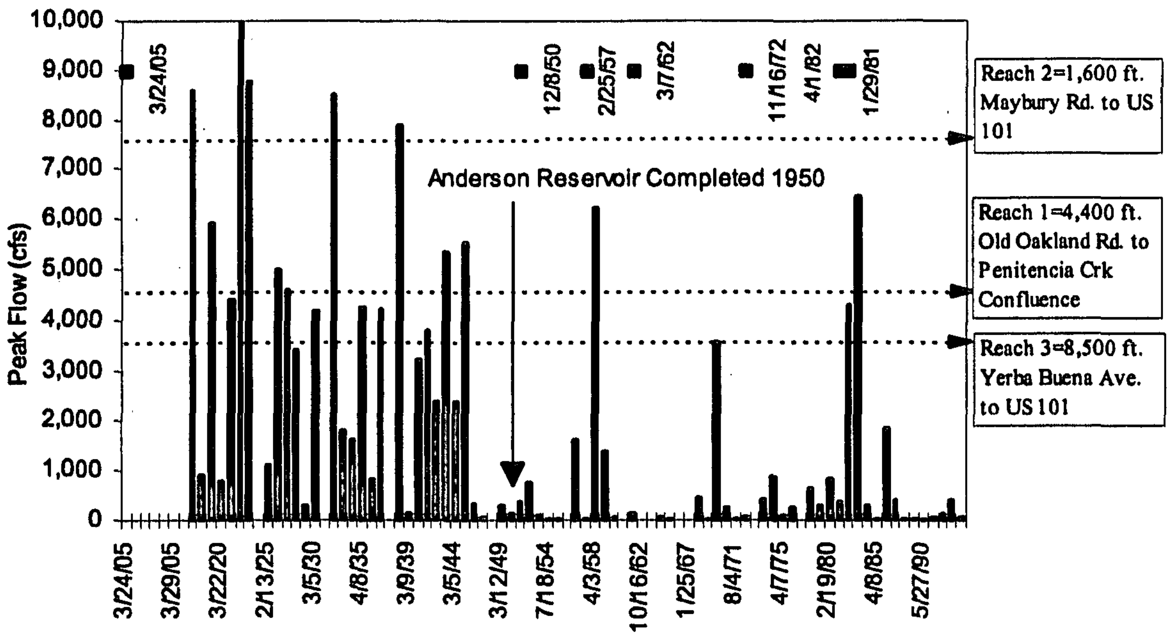


Figure 4-8: Annual Peak Flow in Coyote Creek at Edenvale Gage 1 (Dashed lines indicate existing channel capacity for the denoted reaches. Squares at the top of the figure indicate days when flooding occurred.)

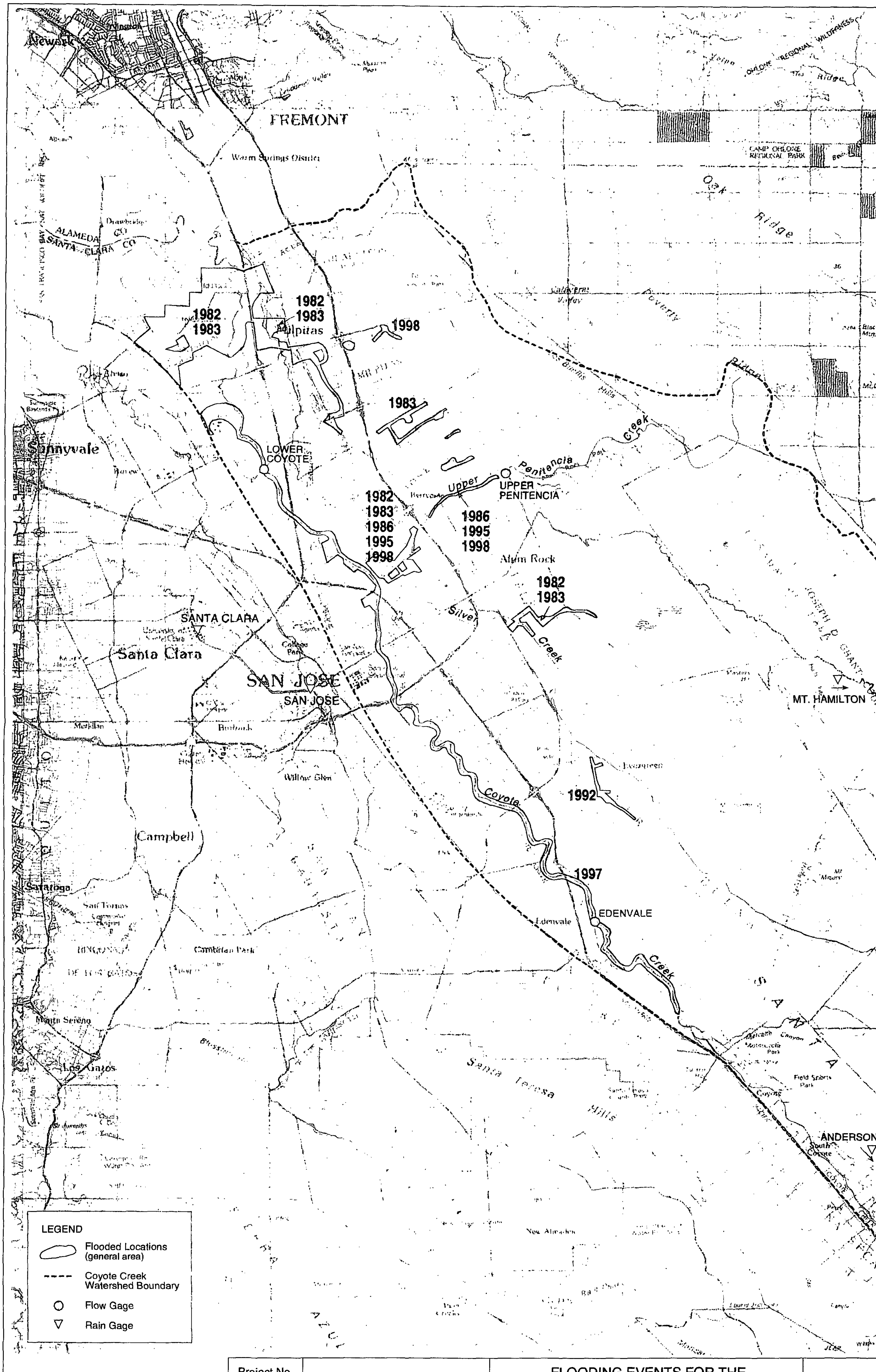
occurred in developed areas as well as more recent flooding. Flooding in undeveloped or agricultural areas may have been under-reported. Figure 4-10 identifies the locations where flooding has occurred from 1978 to 1998, during the period of increased urbanization. These flood locations represent a combination of large flood events and localized flooding events.

The lack of historic data and the effect of flood control facilities confounded our ability to ascertain how urbanization has affected flooding frequency along the Coyote Creek. The FEMA and SCVWD maps indicated that the Alviso and Evergreen neighborhoods flooded before and after the period of increased urbanization. The most perceptible correlation between urbanization and flooding was near the confluence of Penitencia and Coyote Creeks. The Penitencia Creek watershed was urbanized prior to the dramatic growth in urbanization of surrounding areas (Figure 4-11). Therefore, flood records, even those anecdotal, are likely to be relatively complete for this area. Flood events for this area included one in 1911 (Figure 4-12), and five from 1982 to 1998. Annual peak flows on Penitencia Creek closely correlated with the flood events of 1982, 1983, 1986, and 1995 (in contrast to the similar comparison for Coyote Creek below the Dam).

Relationship Between Flooding and Land Use Changes

As discussed above, the construction of Anderson Dam greatly reduced the flows into the urbanized area from the upper half of the Coyote Creek watershed and increased the capacity of the creek to accept increased flows from the urbanized area. Therefore, it is possible that even with increased flows from the urbanized areas that the flooding frequency of Coyote Creek has decreased from historic levels.

Comparison of the eight years of flow data available below the urbanized area of Coyote Creek to the flow data available for the relatively nonurbanized areas of Penitencia and Coyote Creeks showed that the urbanized area contributed more flow per unit area than the nonurbanized areas for four storms (about 62% of all flows of similar magnitude) during this period (Figure 4-13).



Project No. 51981183NA	Coyote Creek	FLOODING EVENTS FOR THE COYOTE CREEK WATERSHED: Locations where flooding has occurred from 1978 to 1998	Figure 4-10
URS Greiner Woodward Clyde			

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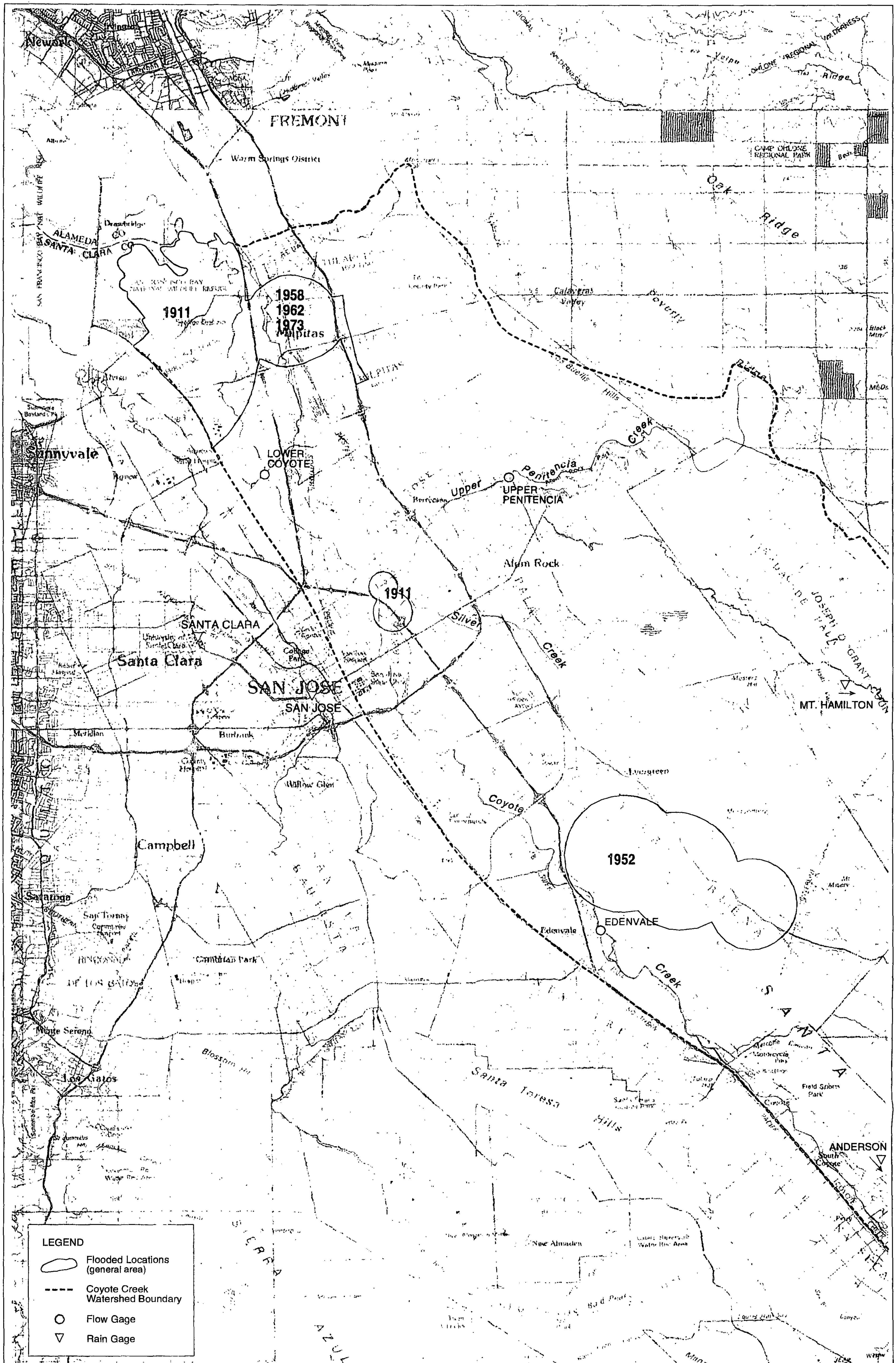

Project No. 51981183NA	Coyote Creek	FLOODING EVENTS FOR THE COYOTE CREEK WATERSHED: The general locations where flooding has occurred from 1911 to 1973	Figure 4-9
URS Greiner Woodward Clyde			

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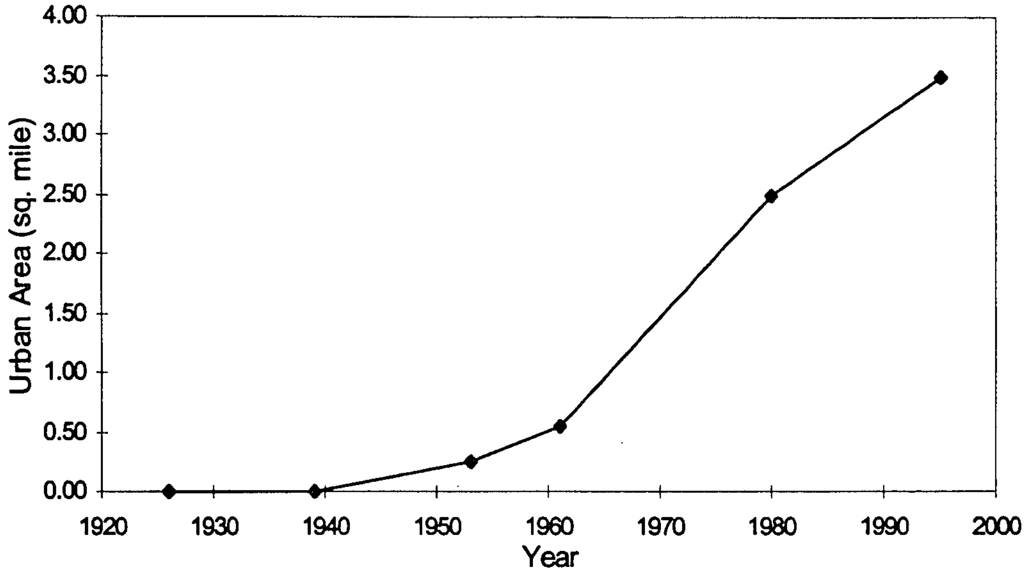


Figure 4-11: Urban Growth in Penitencia Creek Watershed

Temperature Monitoring

Spatial trends in daily temperatures reflected inter-station differences in surrounding land uses and environment (Figure 4-14). Daily mean temperatures at station R-5 were typically about 30 – 50% lower than at all other stations. Station R-5 is located in the rural region of the watershed just downstream of Anderson Dam (Figure 3-5) and is influenced by cool water that is routinely released during summer months from the bottom of the reservoir. This station is also well shaded. Stations R-5 and TS-5, located in the transition

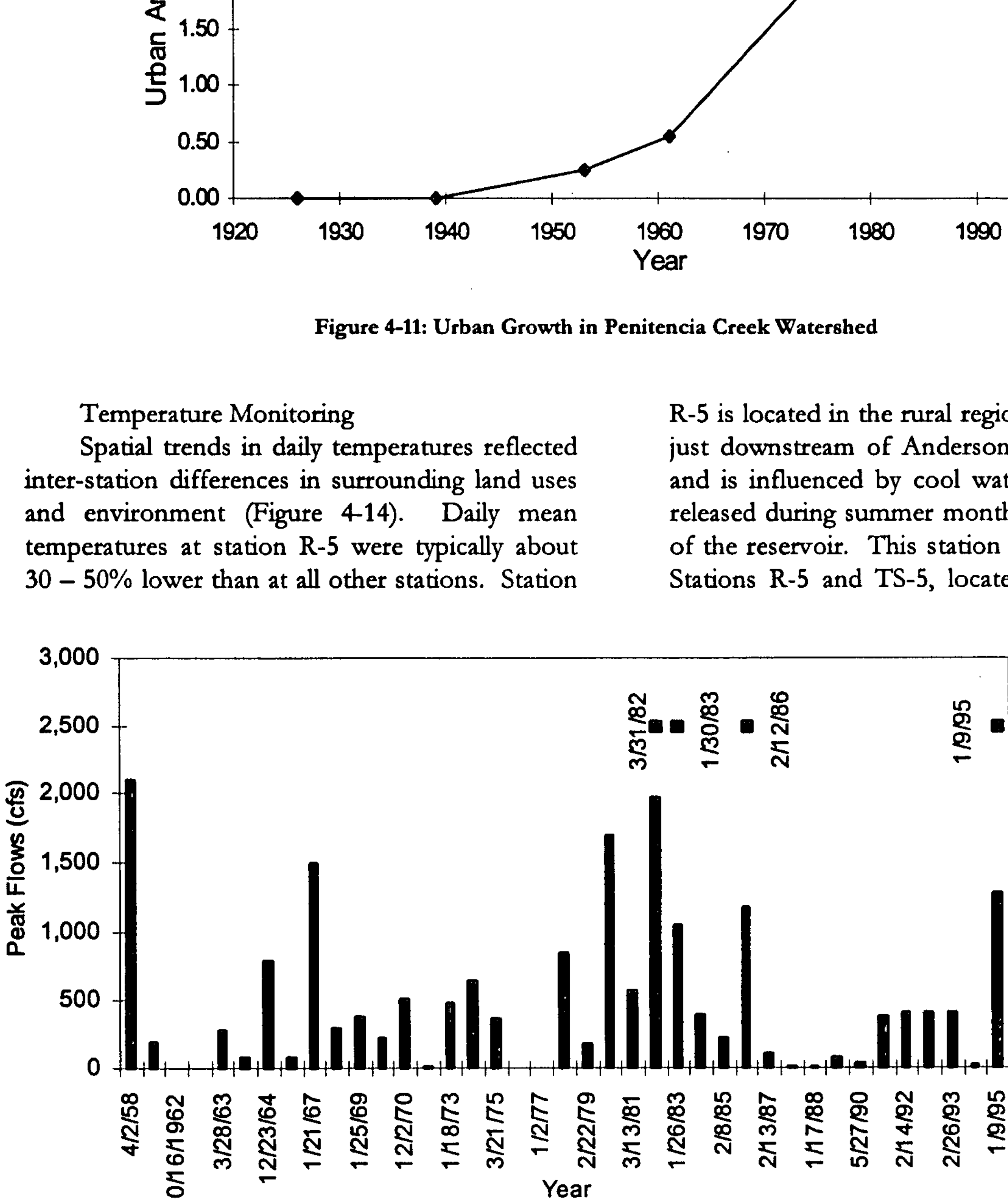


Figure 4-12: Annual Peak flows on Penitencia Creek at the Penitencia Gage and Dates of Flood Events (The squares at the top of the Figure indicate the days when flooding has occurred)

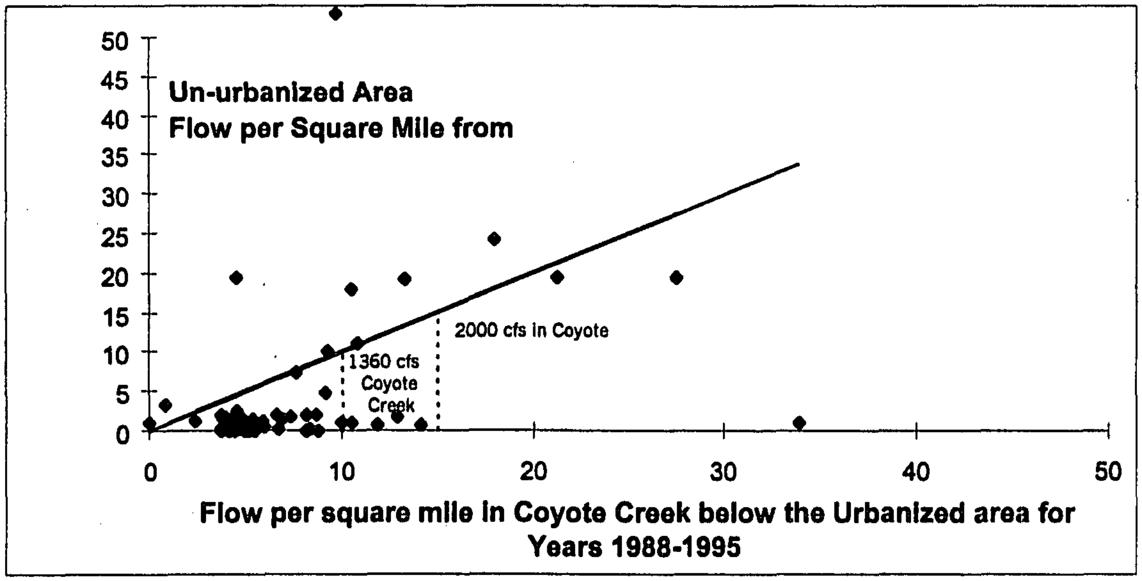


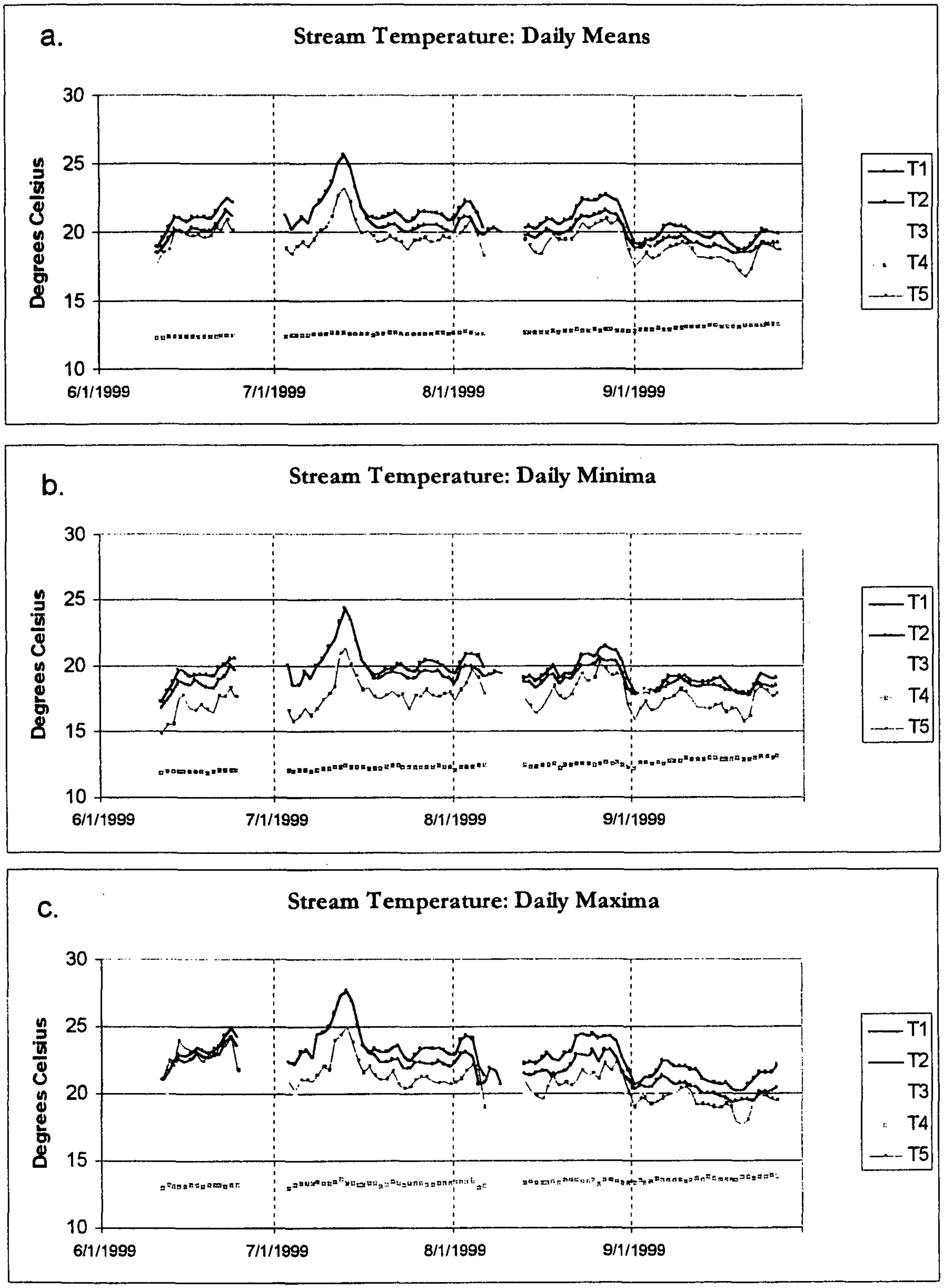
Figure 4-13. Annual peak flows > 500 cfs per unit area for urbanized and nonurbanized portions of the Coyote Creek Watershed. The 500 cfs flow threshold was chosen because it represented the smallest annual peak flow 1988 – 1995. The 45 degree line represents the point where the unit peak flow (in cubic feet per second per square mile) from the nonurbanized portion of the watershed is equal to the unit peak flow from the urbanized portion of the watershed. For storms > 1000 cfs, points on the graph below the line represent storms where the urbanized area contributed more flow per unit area than the nonurbanized areas.

and least-impacted reference regions of the watershed, respectively, exhibited slightly lower daily mean temperatures (1 – 2 °C) than stations 1 and 2 located within the urbanized region of the watershed. Temperature increased 5 - 7 °C over the approximately 8 river miles from station R-5 to T-3, the most dramatic change between any of the stations below the reservoirs. Such warming is likely caused by the paucity of riparian vegetation along most of this stream segment that increases exposure to solar radiation. Station TS-5, located in the hillslopes above the reservoirs is also less influenced by solar radiation due to the microclimate created by adjacent hillslope shading and entrapped fog, as well as the presence of riparian vegetation. Daily minimum temperatures were lower and occurred later during the day at Station TS-5 than all other stations, except Station R-5. The relatively higher temperatures at stations TS-1 and TS-2 may be attributed to attenuated flows and to increased exposure to solar radiation caused by increases in channel width. Despite the high shade-influence at and directly upstream of Station TS-2, it consistently exhibited the highest water temperatures and the largest range of diurnal temperature over the longest period of time. This is also partly caused by the upstream presence of several wide, minimally-shaded, in-channel percolation ponds (Habitat Restoration Group 1995). Slightly lower daily water temperatures at Station TS-1 may be attriibuted to augmented, cool flows from Silver Creek that are maintained by riparian cover in its upper reaches.

Stream temperatures were closely correlated with air temperatures recorded in the cities of Morgan Hill and San Jose. This is commonly found and has led to the use of air temperatures to predict stream temperatures (Pilgrim et al. 1998, Crisp 1990, Crisp and Howson 1982).

The quantity and quality of historical temperature data for Coyote Creek precluded quantitative comparison with our data. Of seven historical data sets identified (Aceituno et al. 1973, Pitt and Bozeman 1982, Sylvester 1986, Leidy 1981, Habitat Restoration Group 1995, H.T. Harvey et al. 1995, SCVWD 1999), only three reported adequate information to determine data collection methods, and most included few locations. Sylvester (1986) reported data (1979 - 1981) for two sampling locations, one of which was, like station R-5, highly influenced by reservoir releases. The Habitat Restoration

Figure 4-14. Daily stream temperature recorded at 5 stations along Coyote Creek



section (~4 river miles) of Coyote Creek. Leidy (1981) covered the greatest geographic extent, but measured temperature as single, spot values using a handheld thermometer.

Despite these limitations, Sylvester (1986) and Habitat Restoration Group (1995) supported the downstream warming trend we observed for sites below the reservoirs and range of temperatures we observed at stations T-3 and R-5. Our baseline study (Pitt and Bozeman 1982) reported diurnal temperature ranges similar to those we observed. Because they reported stream temperatures as single values, they likely measured using spot sampling. As their methods could not be confirmed from the report, no further site-specific comparisons were made.

4.1.2 Water Quality Indicators

Water Quality Constituent Monitoring

During storm events, more than 80% of total metal concentrations in Coyote Creek are associated with particulates; i.e., concentrations of total metals vary with concentrations of total suspended solids (TSS).

Total copper and zinc concentrations decreased during the monitoring period, but these trends were significant only at the 69% and 87% confidence levels, respectively (Figure 4-15). Particulate copper and zinc concentrations were more significant than total metal concentrations (96% and 90% confidence level, respectively). The relationship between time and particulate metal concentrations explained 18% and 14% of the variations in concentration for the two metals, respectively.

Strong positive and negative correlations (r > 0.5, i.e., or 25% of the variability is explained by the parameter) between total and dissolved copper, lead, nickel, zinc, total suspended solids and hydrology and rainfall were observed for several parameters (Tables 4-4 and 4-5). In general, positive correlations were found for total concentrations and negative correlations for dissolved and particulate concentrations. This dichotomy could be explained by the sorption of dissolved constituents by TSS. Total suspended solids were positively correlated with indicators

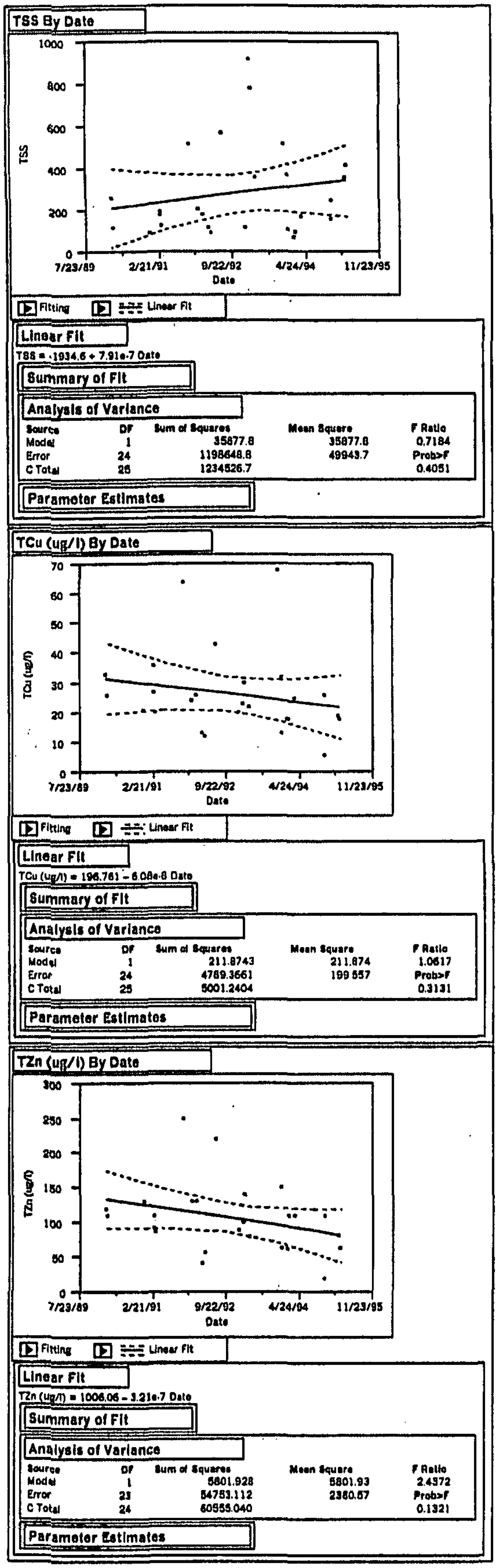


Figure 4-15. Time Trend Of Total Suspended Solids, Total Copper, and Total Zinc in Coyote Creek.

Table 4-4. Positive Pearson Correlations Water Quality and Hydrology

Water Quality Parameter	Hydrology Parameter	Correlation Coefficient
TSS	Total Rain to Date	0.552
TSS	Total Event Flow	0.581
TSS	Previous Two Week Flow	0.647
TSS	Previous Four Week Flow	0.5009
Total Copper	Average Intensity (in/hour)	0.740
Total Copper	Peak Intensity (in/hour)	0.549
Total Lead	Previous Two Week Flow	0.660
Total Lead	Previous Four Week Flow	0.621
Total Lead	Total Seasonal Flow to Date	0.549
Total Nickel	Total Event Flow	0.6044

Table 4-5. Negative Pearson Correlations Water Quality and Hydrology

Water Quality Parameter	Hydrology Parameter	Correlation Coefficient
Dissolved Copper	Peak Event Flow	-0.648
Dissolved Copper	Average Event Flow	-0.586
Dissolved Copper	Total Event Flow	-0.5568
Particulate Copper	Total Rain to Date	-0.8645
Particulate Copper	Previous Two Week Flow	-0.5645
Particulate Copper	Previous Four Week Flow	-0.5682
Particulate Copper	Total Seasonal Flow to Date	-0.6798
Particulate Lead	Peak Event Flow	-0.5025
Particulate Lead	Total Event Flow	-0.6428
Dissolved Zinc	Previous Two Week Flow	-0.647
Particulate Zinc	Total Rain to Date	-0.8262
Particulate Zinc	Total Seasonal Flow to Date	-0.6361

four week flow, total rain to date) and with total event flow, suggesting that large or wet events cause conditions that increased sediment transport or erosion. Total copper was positively correlated with average and peak rainfall intensity suggesting larger more energetic storms cause more copper to be flushed from urban surfaces. On the other hand, dissolved copper and dissolved zinc showed strong negative correlations with peak, average and total event flow, suggesting either dilution or increased sorption of dissolved copper due to the higher concentration of suspended solids during large flow events.

Particulate copper and particulate zinc were negatively correlated with indicators of the amount of flushing (total rain and flow to date, previous two and four week flow) indicating copper is seasonally flushed from urban surfaces and diluted by background concentrations found in soils and sediments.

Including flow volume in our analyses of water quality constituents was important for interpreting monitoring results. The TSS-flow regression showed that 95% of variation in TSS was explained by changes in flow volume in the antecedent 2 – 4 weeks, by peak and average flow rates, and by the number of dry period days prior to the event (Figure 4-16). Because TSS was highly correlated with flow parameters it was used as a substitute for flow indicators and included as an additional factor in the rainfall regression. The best stepwise regression model for total metals explained 57%, 45%, 95%, and 58% of the variations in copper, lead, nickel, and zinc, respectively. Total nickel variations are explained by the same variables used to explain the variations in TSS, providing strong evidence that total nickel concentrations are driven by erosion. For particulate metals the best model explained 66%, 23%, 59% of the variations in copper, lead, and zinc, respectively. Model relationships for dissolved metals explained 38%, 15%, and 49% of the variations in copper, lead, and zinc, respectively.

Results from ANOVAs demonstrated that mean total copper concentrations in dry winters were not significantly different than total copper concentrations in wet winters. Mean total copper concentrations differed by less than ten percent. The lack of apparent differences may be explained

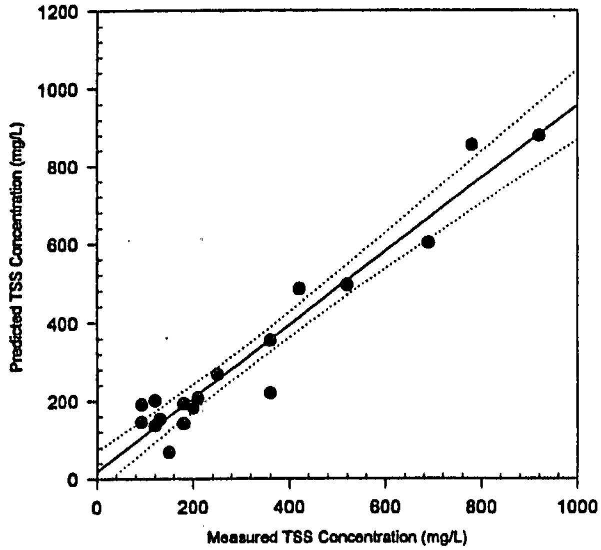


Figure 4-16. Predicted verses Measured TSS

by the lack of differences in hydrologic variables determined to be important through the step-wise regression model between the monitored events in the wet and dry winters.

Results from the comparison between wet and dry winters were used to determine how much of a difference between monitoring periods could be reliably detected for a given number of monitored events. Adding a hydrology factor to the water quality model increased the statistical power of the test and resulted in requiring fewer sampling events (30 storm events, 15 per monitoring period versus 50 monitoring events, 25 per period without the hydrology factor) to detect a 40% difference in metal concentrations (demonstrated using copper) (Figures 4-17 and 4-18).

Exceedance Frequencies of Water Quality Standards

Coyote Creek monitoring data are compared to total and dissolved water quality criteria in Table 4-6. The table shows the number of exceedances versus the total number of sampled events. Few parameters exceeded chronic water quality criteria and even fewer exceeded acute criteria. The highlighted cells in the table are those showing at least one exceedance of the criterion.

Results from the SYNOP analysis indicate

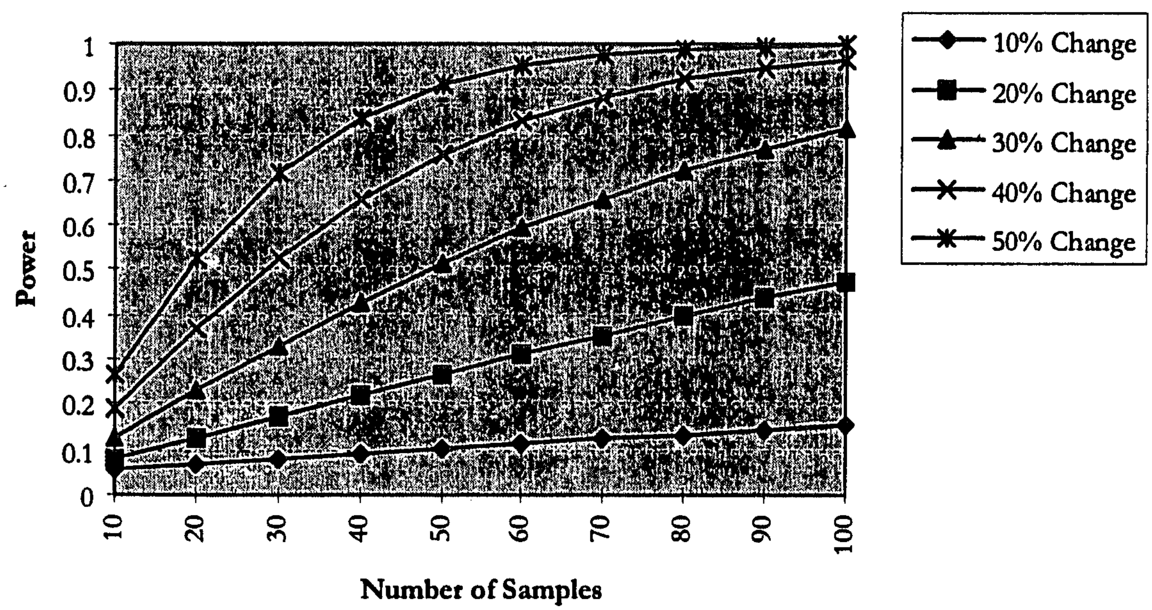


Figure 4-17. Power Analysis Results For Total Copper Changes Using ANOVA Analysis

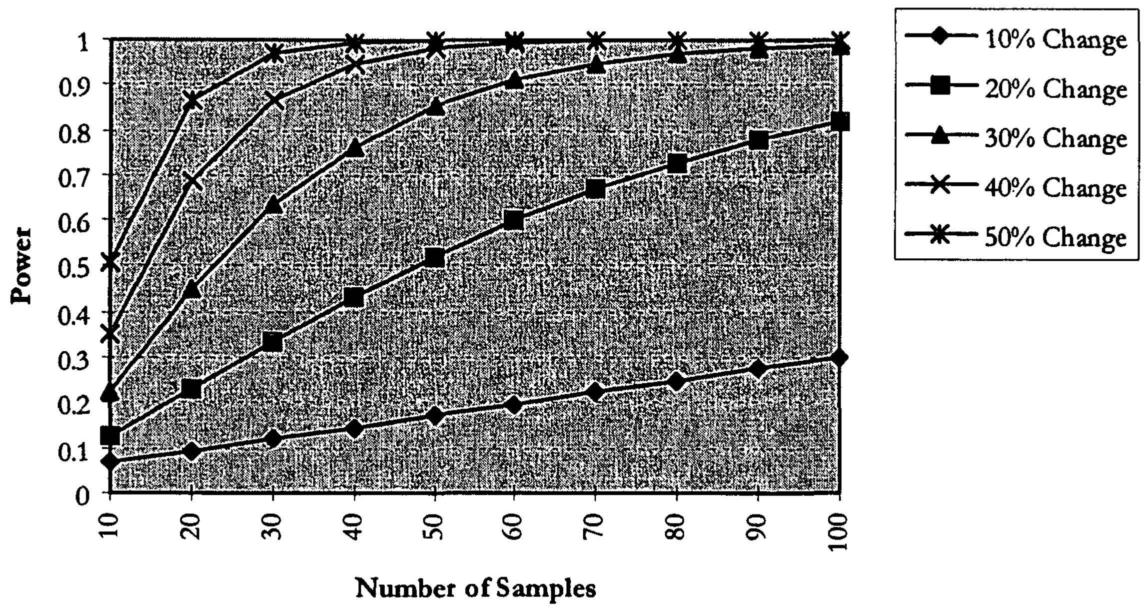


Figure 4-18. Power Analysis Results For Total Copper Changes Using ANCOVA Analysis with Hydrology Factors

median storm duration of about 19 hours with 75% of the storms less than about 35 hours in duration. This implies that acute criteria would be most applicable. However, chronic criteria might also be relevant for the larger storms.

An overall decrease in the number of exceedances year-to-year suggests an improvement in water quality, especially for particulate metals concentrations in suspended solids. Apparent changes in water quality could be

Table 4-6. Summary of Exceedance of Water Quality Standards in Coyote Creek Runoff

Total Criteria

Total Arsenic		Total Cadmium		Total Copper		Total Chromium		Total Lead		Total Mercury		Total Nickel		Total Selenium		Total Silver		Total Zinc	
Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic*	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
0/27	0/27	0/28	5/28	14/27	23/27	0/24	0/24	1/27	25/27	1/27	5/5	0/27	1/27	0/29	0/29	0/27	0/27		

Dissolved Criteria

Dissolved Arsenic		Dissolved Cadmium		Dissolved Copper		Dissolved Chromium		Dissolved Lead		Dissolved Mercury		Dissolved Nickel		Dissolved Selenium		Dissolved Silver		Dissolved Zinc	
Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
0/27	0/27	0/23	0/23	0/20	0/21	0/3	0/3	0/22	3/22	0/6	5/5	0/2	0/2	0/27	0/27	0/27	0/27		

Notes: Total Water Quality Objectives are in California's Water Quality Control Plan for the San Francisco Bay Basin, and reference EPA Federal Register 40 CFR Part 131 (d)(10)(ii), December, 1992. Dissolved Water Quality Criteria are from EPA Federal Register 40 CFR Part 131 (d)(10)(ii), May 4, 1995.
0/5: Number of exceedances/Total Number of Sampled Events Shading indicates an exceedance. * The chronic WQO for total mercury is based on preventing fish from accumulating levels of mercury concentrations that could be hazardous to human health. However, it is not certain whether concentrations in waterways during storm events persist long enough to allow accumulation in fish.

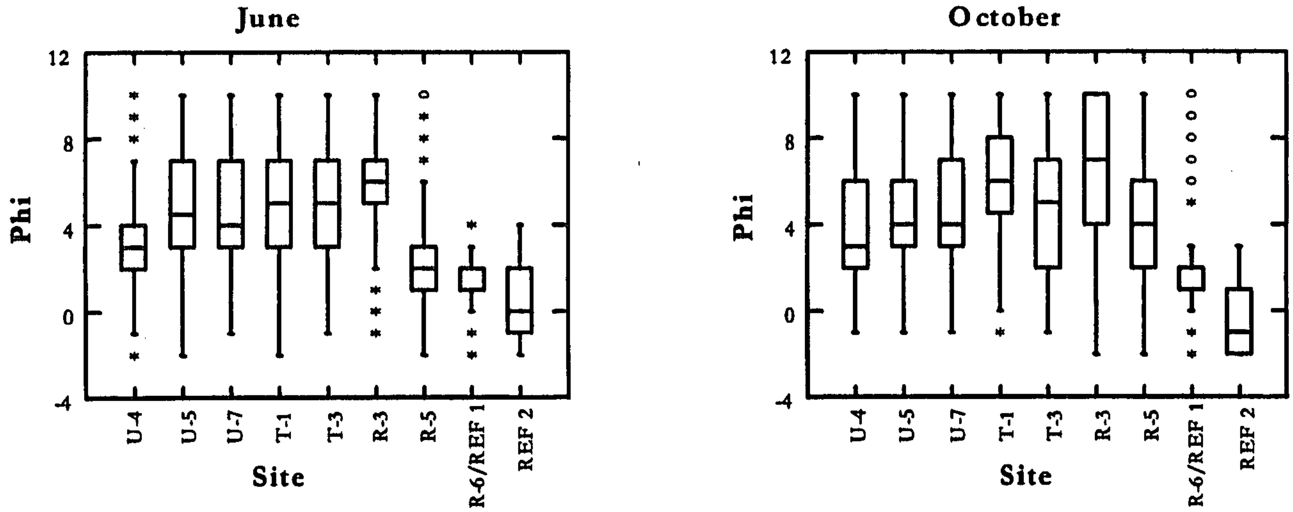


Figure 4-19. Sediment Particle Size Distributions at each Site. (Horizontal Bar=Median, Upper Box Hinge=Third Quartile, Lower Box Hinge=First Quartile, Upper Whisker=Upper Hinge-(1.5*(Median-Upper Hinge), Lower Whisker=Lower Hinge-(1.5*(Median-Lower Hinge), *=Outside Value, o=Very Outside Value)

due to return to average wet annual rainfall patterns that could have decreased metals concentrations in runoff and local streams.

Sediment Characteristics and Contamination

Two spatial differences in sediment characteristics and pollutant concentrations were apparent. First, particle size differed along the urbanization gradient, with coarser sediment found in the upstream reaches, and finer sediment found in the downstream reaches (with the exception of R5 Cochran, which had the highest variance between surveys, and R3 Miramonte, which had the finest sediments of all sites). See Figure 4-19. Second, distribution of metals concentrations for cadmium and lead indicated that concentrations increased with urbanization. See Figure 4-20 Lowest concentrations at reference sites were partly attributed to coarser particle size found at these sites.

However, there were no seasonal differences observed between metals concentrations, and few temporal differences; most concentrations did not change over the 20-year period between sampling. Mercury was an exception; sediment concentrations apparently decreased substantially over this period. Figure 4-21 compares the median and range of concentrations of the contemporary and historical data sets for each of the six trace metals.

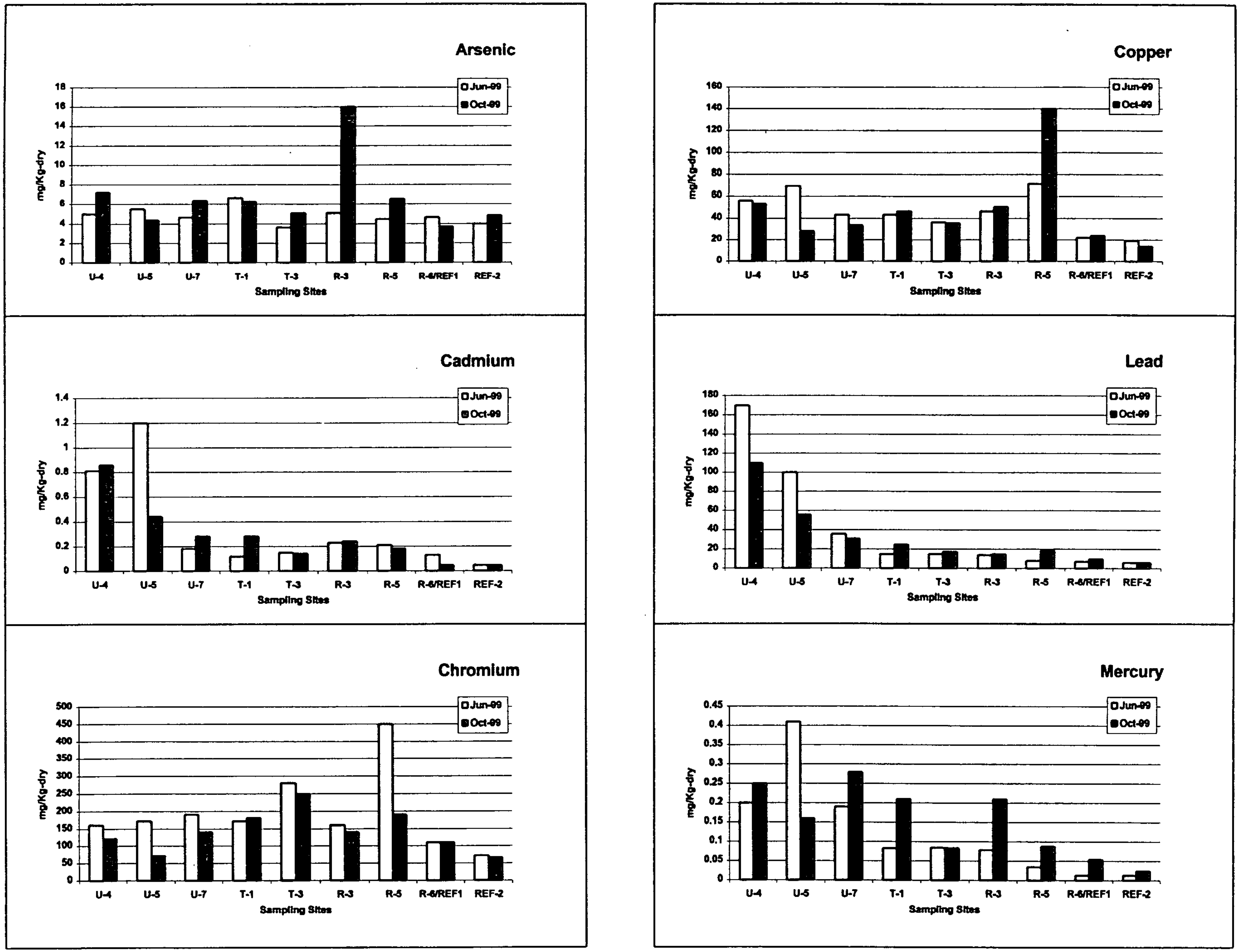


Figure 4-20. Seasonal and Spatial Comparison of Trace Metal Concentrations in Coyote Creek along a Gradient from Downstream Urban Sites to Upstream Reference Sites.

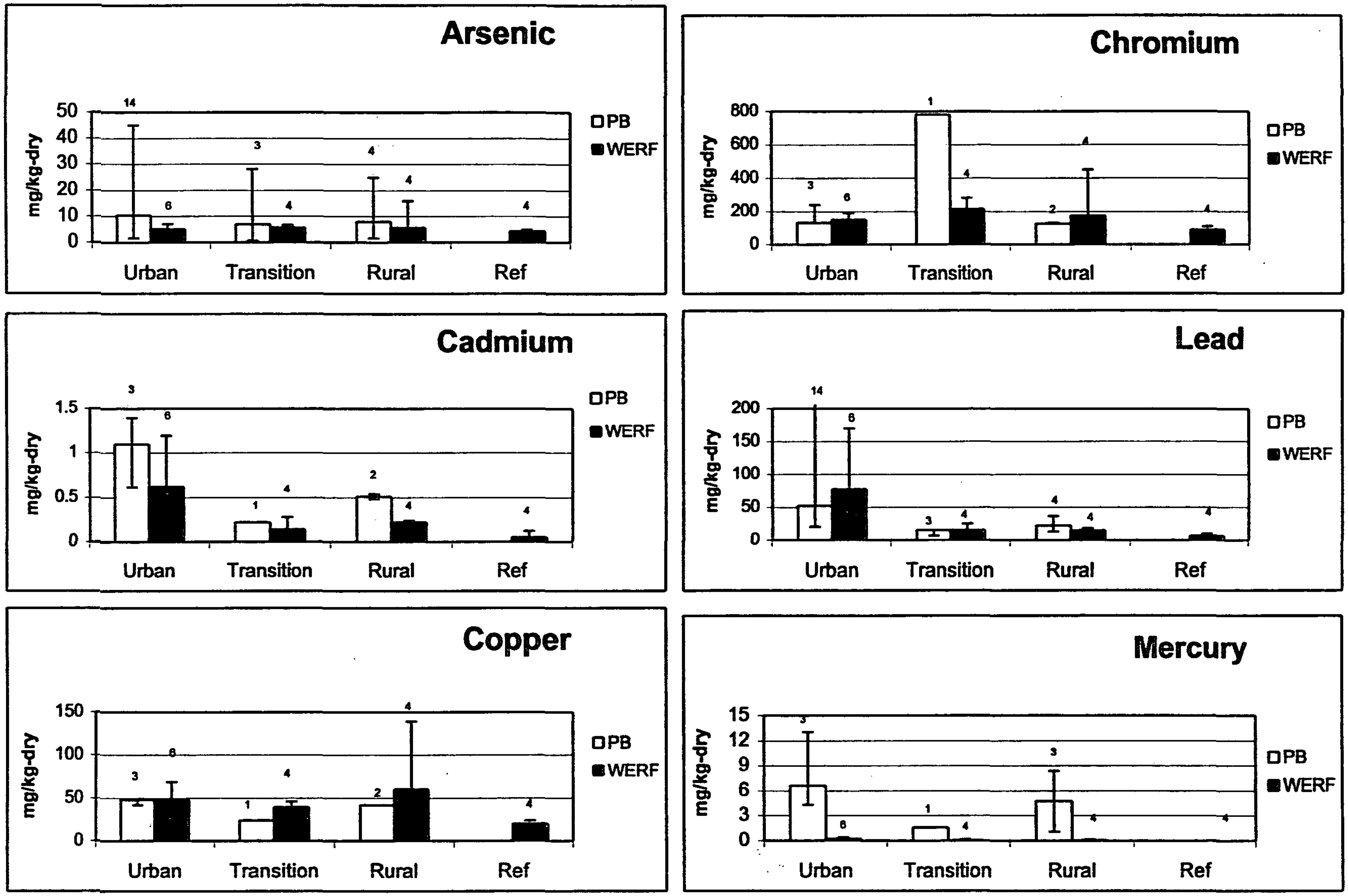
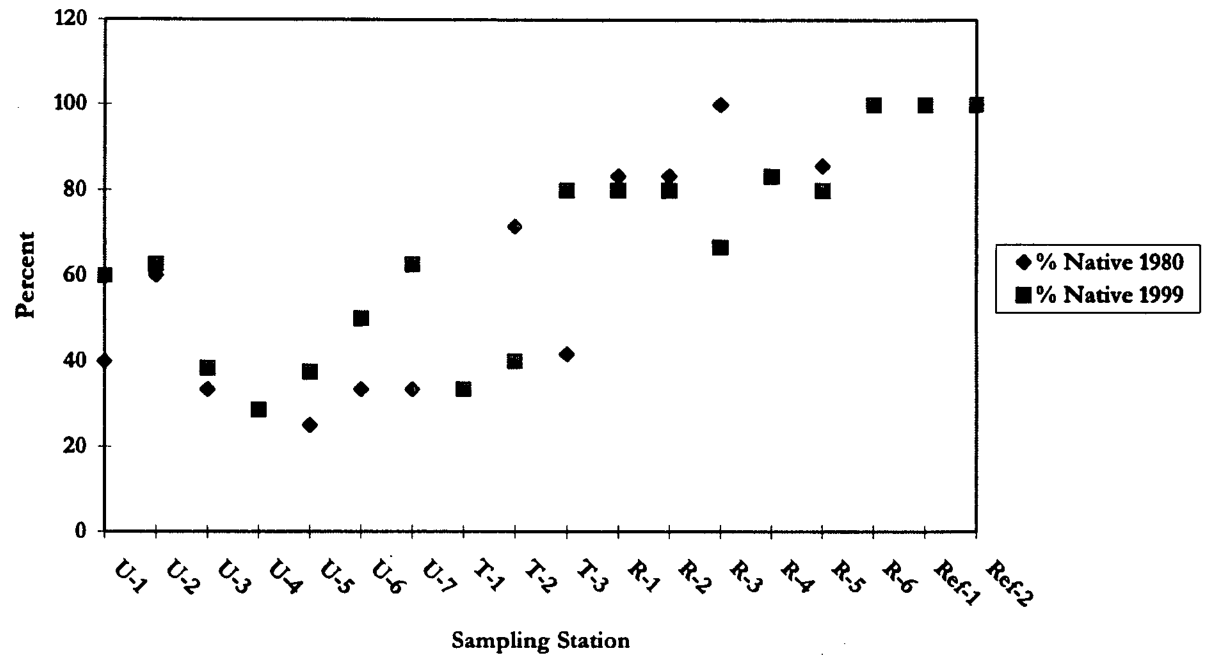


Figure 4-21. Comparison of Sediment Trace Metal Concentration Measured in the Present Study (WERF) with Baseline Concentrations Reported by Pitt and Bozeman (PB). Bars represent the median concentrations, error bars indicate the range of concentrations reported at each site and the numbers indicate the numbers of measurements in each study.

Figure 4-22. Percent of Native Fish Species in Coyote Creek 1980 and 1999



Biological Indicators

Fish Assemblages

We identified a total of 21 fish species, ten of which were native. Comparison of fisheries metrics indicated that urban influence extended farther upstream from where it had been when the baseline study (Pitt and Bozeman 1982) was conducted. Statistical comparisons were more significant when the two downstream transition stations were grouped with the urban stations, and the upstream transition station was grouped with the rural stations (Figure 4-22). This result correlates with the increase in the number of stormdrain outfalls in the transition zone since the late 1970s. Metrics for number of native species, number of native individuals, percent of cyprinid and centrarchid species, percent of cyprinid and centrarchid individuals, and total biomass were found to have statistically significant differences[5] (α = 0.05) among the urban, rural, and reference station groupings (Table 4-7).

Fish assemblages did not differ among station groups by sampling period in 1999 (Figure 4-23). The total number of rainbow trout sampled, however, declined with subsequent sampling periods, suggesting that individuals may move to other creek reaches or be harder to catch. Some individuals had par marks, indicating that they may be steelhead (i.e. anadromous). Thus, the decline in the number of fish captured between spring and late-summer may also reflect seasonal migration to San Francisco Bay.

Rainbow trout were found at 50% of SEIDP sampling stations (Table 4-8), including urban, rural, and reference stations. Pitt and Bozeman (1982) found them only at the most upstream reference station. These results could indicate an improvement in water and/or habitat quality, and could also reflect the influence of interannual

[5] The statistical significance of a result is the probability that the observed relationship (e.g., between variables) or a difference (e.g., between means) in a sample occurred by pure chance. Specifically, the p-value represents the probability of error that is involved in accepting our observed result as valid, that is, is "representative of the population." For example, a p-value of .05 (i.e.,1/20) indicates that there is a 5% probability that the relation between the variables found in our sample is due to chance alone (StatSoft, Inc. 1999).

Table 4-7. Comparison of Metrics in Grouped Stations

Metric	Title	Results	p value (α=0.05)
1a	Number of Native Species	reference > urban	0.0032
		reference>rural	0.0151
1b	Number of Native Individuals	reference>rural	0.0127
		reference>urban	0.0001
		rural > urban	0.0001
3a	Percent of Cyprinid and Centrarchid Species	urban > reference	0.0025
		urban > rural	0.0001
3b	Percent of Cyprinid and Centrarchid Individuals	urban > rural	0.0001
		urban > reference	0.0001
8b	Number of Insectivore and Invertivore Individuals	rural > reference	0.0001
		urban > reference	0.0001
13	Biomass	1999 < introduced fish in rural	0.0039
		1999 > native biomass in urban	0.0137

precipitation and flow on community assemblage structure and composition (see below).

As shown in Figure 3-5, Pitt and Bozeman (1982) placed the "Urban Boundary" between the stations we have designated as U-7 and T-1. Figure 4-23 suggests that the upstream movement of this urban boundary between 1980 and 1999 may be reflected in the proportion of native species.

Analysis of the entire record of historical fisheries assemblages within Coyote Creek (Buchan et al. 1999) indicated that the assemblages identified in 1999 were similar to those observed since the construction of Anderson Dam in 1950 (Figure 4-24). Species found at SEIDP urban and transition sites included similar native species but had three fewer nonnative species than most studies found after 1950. Species found at SEIDP rural sites below Anderson Dam included three fewer of the commonly found, native species (Hitch, *Lavinia symmetricus*; Sacramento pikeminnow, *Ptychocheilus grandis*; Sacramento blackfish, *Orthodon microlepidotus*), one additional native species that had not been observed in these reaches since 1925 (Tule perch, *Hysterocarpus traskii*), five fewer nonnative species (Common carp, *Cyprinis carpio*; Goldfish, *Carassius auratus*, Mosquitofish, *Gambusia affinis*; Bluegill sunfish, *Lepomis macrochirus*; Green sunfish, *L. cyanellus*), and one nonnative species that had not been observed by any previous study (Fathead minnow, *Pimephales promelas*).

It is likely that natural hydrologic fluctuation has had a considerable influence on the differences observed in fisheries assemblages

Figure 4-23. 1999 Coyote Creek Native and Non-native Fish Species

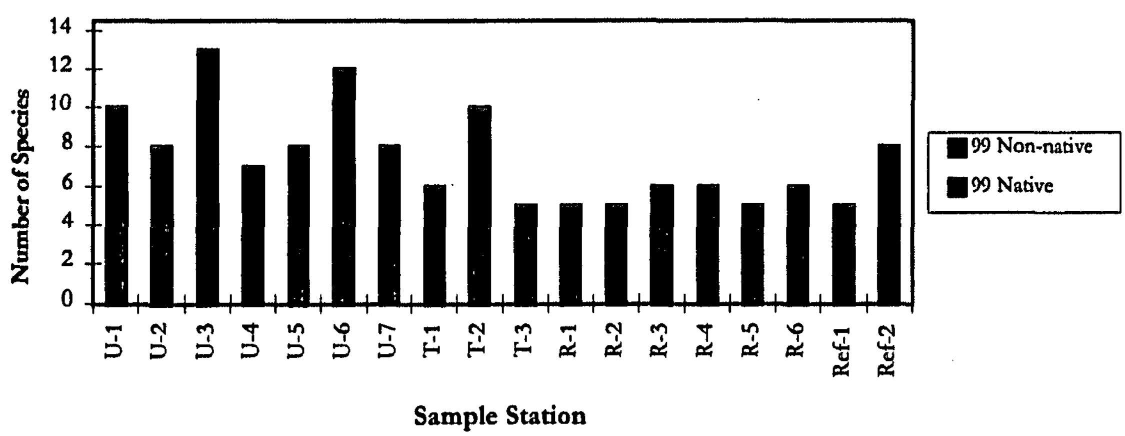
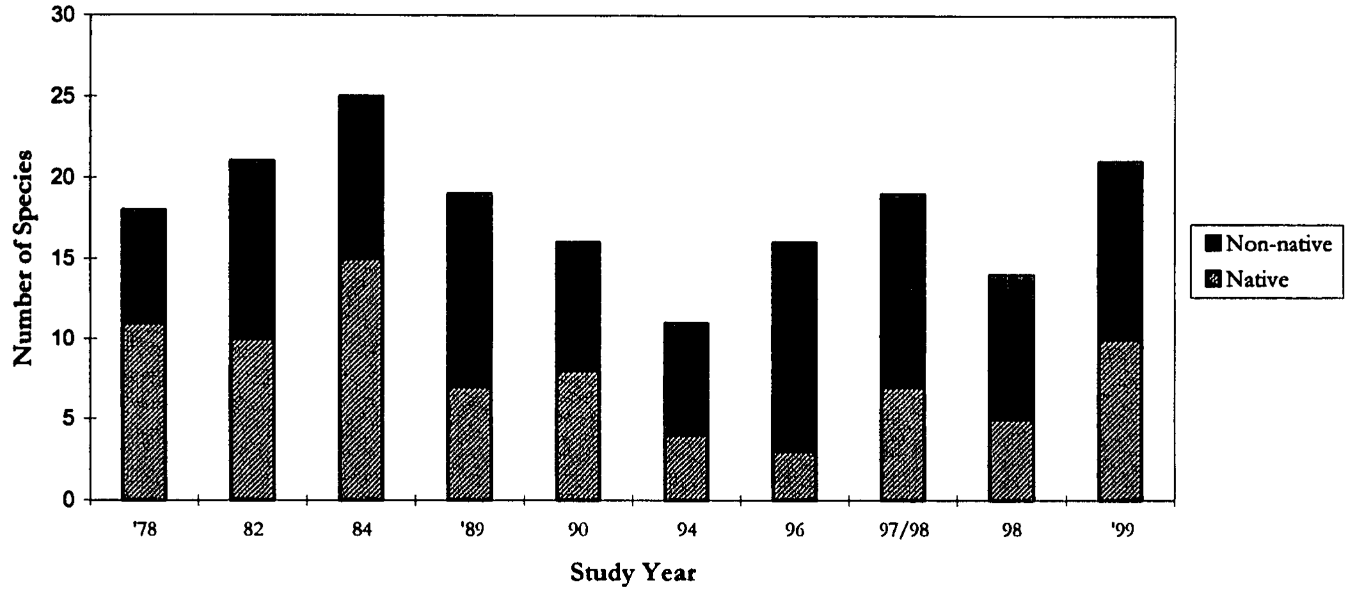


Table 4-8. Rainbow Trout Captured in 1999 Sampling Events

Month	U-1	U-2	U-3	U-6	T-2	R-4	R-6	Ref-1	Ref-2	Total
May	1	2	1	1	1	2	3	2	11	23
June	2		1			2	4		9	19
Sept.			2				2			4

Figure 4-24. Native and Non-native Fish Species from 10 Studies



between the baseline and the 1999 study. Comparison of SEIDP and the baseline fisheries assemblages with the three antecedent years of streamflow data indicated that peak flows prior to the 1998-1999 sampling were 10 – 50 times greater than peak flows prior to the 1978-1979 sampling (Figure 4-25). High magnitude flows influence biological community composition and may be responsible for reducing the relative proportion of nonnative species which, unlike native species, are not adapted to such dramatic hydrologic fluctuation (R. Leidy, pers. Comm.). Thus, it is likely that natural hydrologic fluctuation had a considerable influence on the differences observed in fisheries assemblages between the two sampling periods.

Several fisheries metrics were significantly associated with cumulative percent imperviousness both at the subwatershed and riparian corridor scale (Table 4-9). Metrics based on species, rather than individual counts, were most strongly associated with cumulative percent

Table 4-9. Significant (alpha = 0.05) associations between percent imperviousness (cumulative for subwatershed scale, and non-cumulative for riparian corridor scale) and metrics calculated for fisheries data sampled in May, June, and September, 2000 in Coyote Creek from stations U1 – Ref2. Associations were tested using simple linear regression; an asterisk indicates associations tested using logistic regression. Results are sorted in descending order based on the coefficient of determination, r^2, at the subwatershed scale. Blank cells indicate non-significant results.

Metrics	*r2* Subwatershed	P-value	*r2* Riparian Corridor	P-value
# Tolerant Species	.65	<0.0001	.38	0.0069
% Tolerant Species*	.59	0.0002		
# Nonnative Species	.50	0.0009	.33	0.0124
% Native Species*	.43	0.0029		
# Diseased Individuals	.33	0.0127		
Total # Species	.31	0.0166	.33	0.0121
# Native Individuals	.26	0.0327		

imperviousness. The response to percent imperviousness measured by the four species-level metrics that were strongly associated[6] ($0.43 \geq r^2 \leq 0.65$) with cumulative percent imperviousness was continuous; however, the response rate was highest between 8 and 11% (Figure 4-26). A similar, but less clear pattern existed for the other three fisheries metrics that were significantly associated with cumulative percent imperviousness (Figure 4-26). In general, as the cumulative percent subwatershed imperviousness increased, the proportions of nonnative species, total number of species, and diseased individuals increased, and the proportion of tolerant species decreased.

Dissolved oxygen (DO) concentrations at all five continuous monitoring station locations were greater than five milligrams per liter except at the water quality monitoring location TS-1 (Figure 3-5) just upstream of station U-5. At this site, DO repeatedly dropped below 5 mg/L (Figure 4-27). Between September 9 and 16, 1999 the DO remained below 5 mg/L and nearly dropped to zero. This may have caused a fish kill, evidenced by observations during the September sampling event at station U-1 of 26 dead carp and one dead catfish.

Macroinvertebrate Assemblages

We identified a total of 44 taxa, identified to the tribe, subfamily, or genus, of which nine were classified as tolerant and 35 as intolerant (Ode 1999 Seasonal comparisons for taxa sampled within 1999 did not identify significant differences among station groups. However, spatial comparisons among station groupings revealed significant differences for several metrics. The total number of taxa (Figure 4-28) and the total number of EPT taxa were greater at the reference stations than at the rural and urban stations. The percent of individual EPT insects was similar at the reference and rural stations, but higher than at the urban stations (Figure 4-29). Therefore, the total number of taxa was useful for describing macroinvertebrate diversity, but not population composition.

The reference stations had the greatest number and percent of low tolerance taxa (Figure 4-30), as well as the greatest percent of low tolerance individuals. The rural stations had more low tolerance taxa and individuals than the urban stations. Evaluating low tolerance taxa appeared to be a more discriminating measure than evaluating high tolerance taxa because low-tolerance taxa only exist where the water quality is suitable but high-tolerance taxa are ubiquitous (albeit in varying densities). Since the tolerance metric directly relates to water quality it should be included in future macroinvertebrate assemblage analyses.

Comparison to the baseline study revealed that the mean total number of taxa per station more than doubled (29 per station grouping vs. 12) since 1978-1979. Several differences between these studies may account for some of this: the 1999 data were identified to a higher taxonomic level, taxonomy has changed since the baseline study, and differences also could have resulted from different interpretations by different taxonomists. In addition, sampling methods were different between the two studies, and documentation from the baseline study was incomplete; only pooled data from multiple sampling events were reported.

We found that the percentage of EPT taxa was a more robust metric than total number of taxa because it is less susceptible to differences in taxonomic interpretation. This metric indicated that the mean percentage of EPT taxa in the rural stations had not changed since the baseline study. In contrast, there was a significant decrease in the percentage of EPT taxa at the transition stations (from 20.5% to 13.5%, p=0.0131) while the mean percentage of EPT taxa at the urban stations nearly doubled to 6.8% from 3.5% (p=0.0554).

These results may indicate that since the baseline study, water quality and/or habitat have improved in the urban reaches of Coyote Creek, and decreased in the transition reaches where urbanization has since encroached. We did not find evidence that water quality parameters, such as dissolved oxygen, were limiting the 1999

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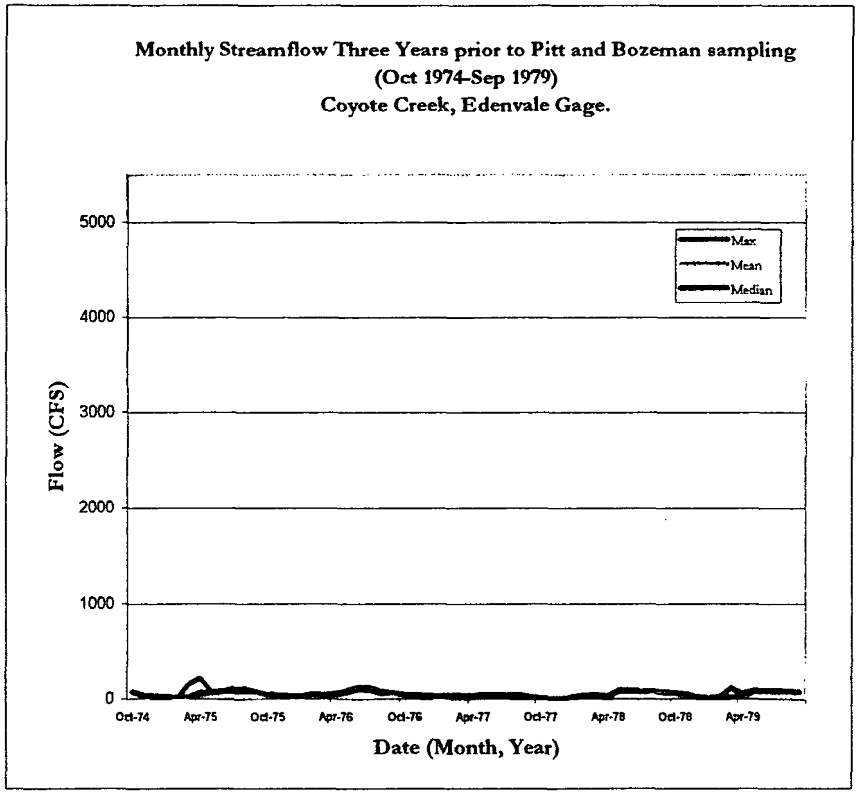
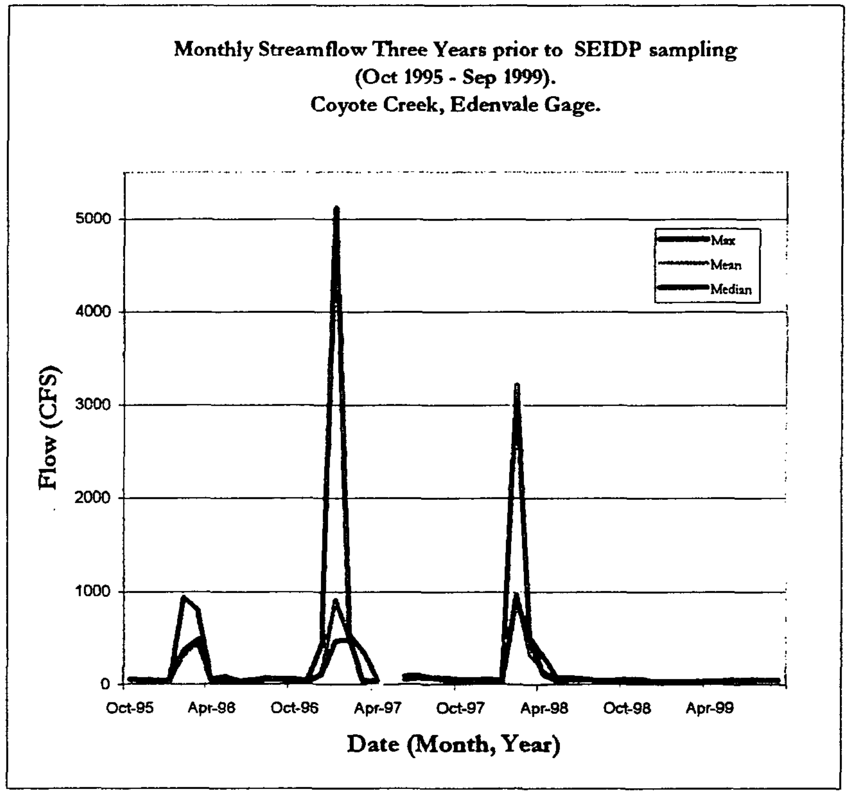
[6] The R-square value is an indicator of how well the model fits the data, i.e., the "strength" or "magnitude" of the relationship. An R-square value close to 1.0 indicates that we have accounted for almost all of the variability with the variables specified in the model.

Figure 4-25. Monthly streamflow three years prior to Pitt and Bozeman (1982) and SEIDP (1999) sampling.





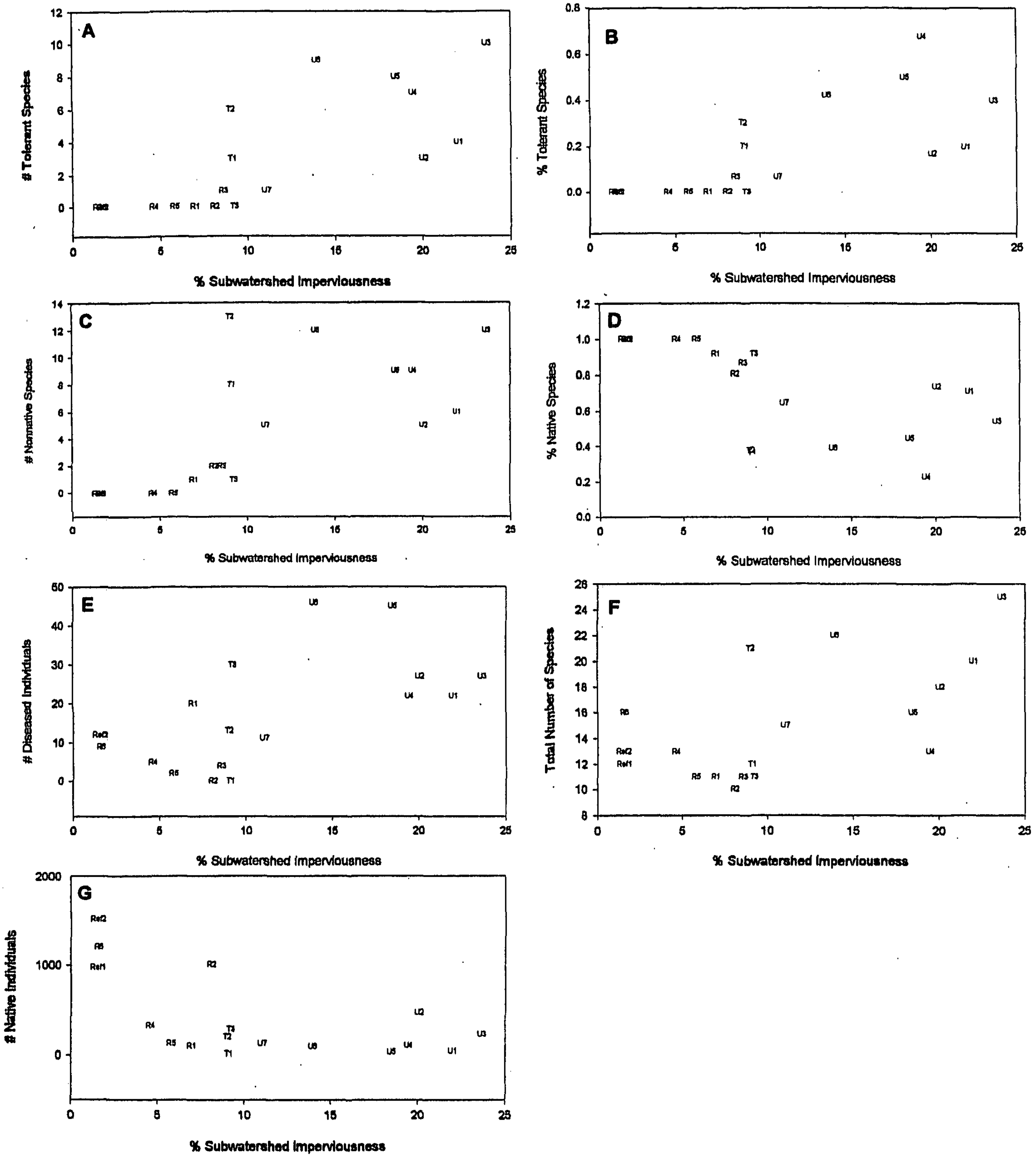


Figure 4-26. Percent cumulative imperviousness in Coyote Creek subwatersheds versus fisheries metrics that were significantly associated. Data points are labeled by sampling station (R6, Ref1, and Ref2 often overlapped (panels A – E).

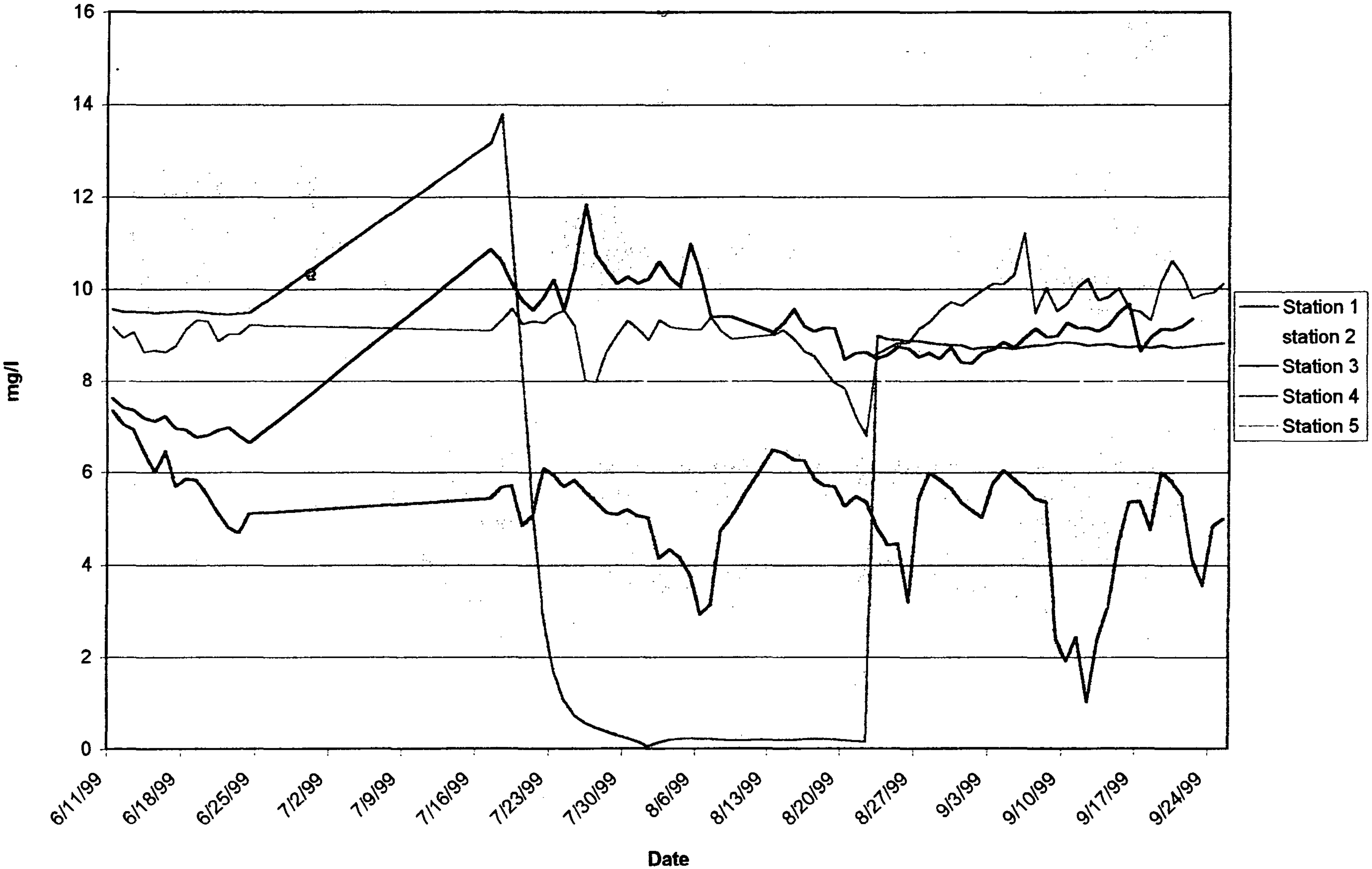
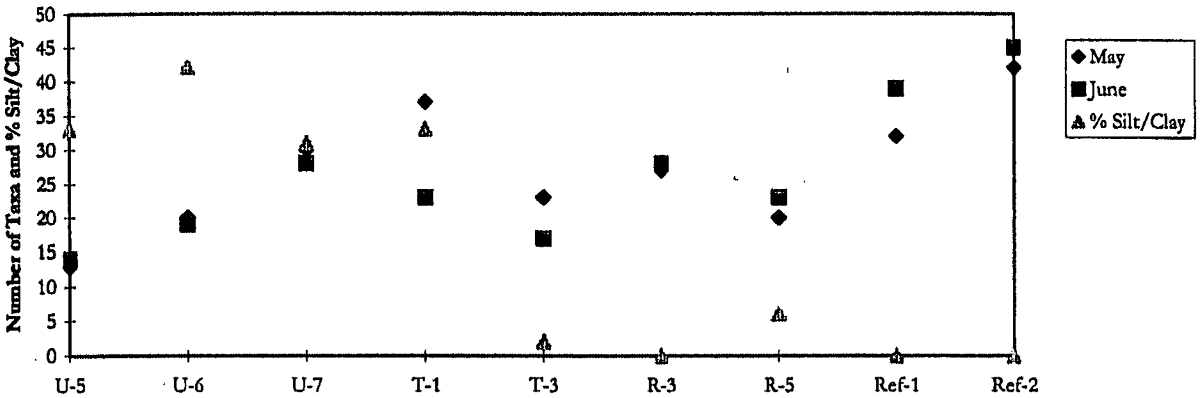


Figure 4-27. Mean Dissolved Oxygen Concentration at the Five Water Quality Monitoring Stations.

Figure 4-28. Total Number of Macroinvertebrate Taxa, Coyote Creek, May & June 1999, Plotted with Percent Clay/Silt



macroinvertebrate community composition but did not have similar data from the baseline study to compare to. We did find the influence of substrate composition reflected in the 1999 distribution of macroinvertebrate assemblages. Mean substrate size was greater at stations upstream from U6, favoring EPT taxa as seen, and indicating greater habitat complexity and stability, both factors that contribute to increased macroinvertebrate diversity and abundance (Merrit and Cummins 1984): sand, the poorest substrate for macroinvertebrates, comprised 26% of samples collected from stations U1 – U6; silt/clay content was at least three times greater than at upstream stations. Lacking similar data from the baseline study, we were unable to draw conclusions regarding the relative influence of substrate over this period of time. Hydrologic fluctuations can dramatically impact macroinvertebrate assemblages. Because Coyote

Figure 4-29. Percent of EPT, Chironomid, Oligochaete and Other Taxa, Coyote Creek, 1999

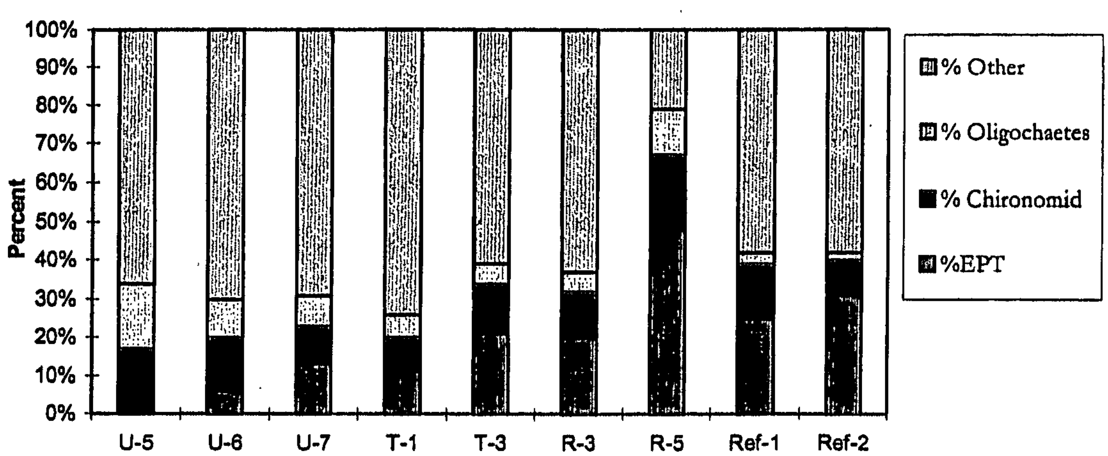
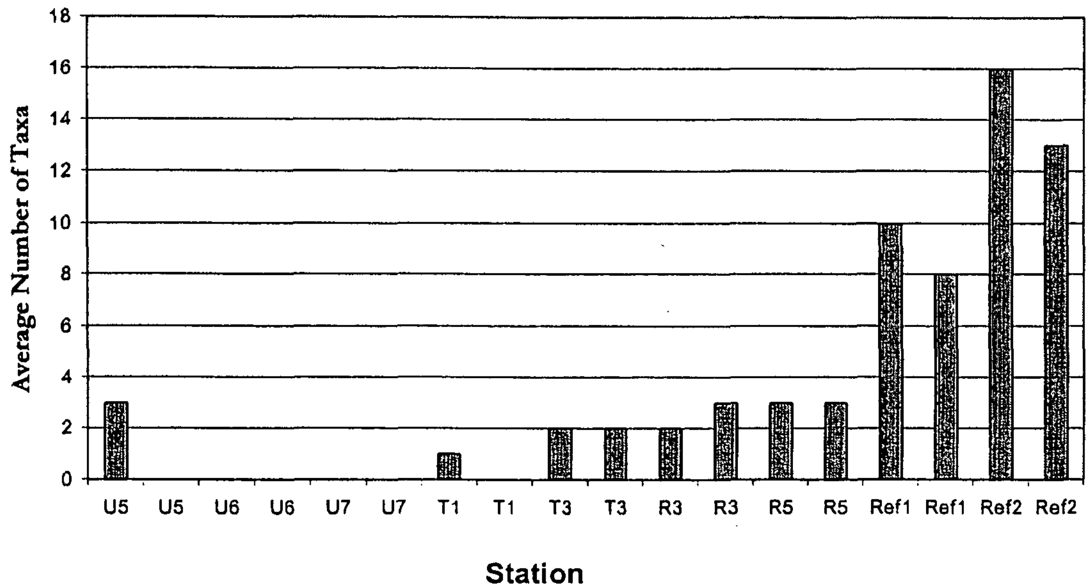


Figure 4-30. Average Number of Low Tolerance MacroinvertebrateTaxa



Creek flows have been highly regulated during both studies (annually from April 15 – October 15), only large fluctuations causing droughts or floods are likely to have contributed to observed changes in assemblages, through impacts on erosion, bedload movement, and distribution of instream habitat units.

While numerous factors can modify habitat and potentially confound interpretation of results, including effects of factors related to hydrology, sediment transport, and taxonomy and sampling, it appears likely that factors related to urbanization have influenced the distribution and abundance of macroinvertebrate assemblages in this system. Identifying specific causes and their relative contributions is difficult, particularly in complex urbanized systems such as Coyote Creek.*Programmatic Indicators*

Growth and Development

Estimating percent imperviousness using different data sources (1995 ABAG data versus a compilation based primarily on 1999 County Assessor data) resulted in large differences for sampling station subwatersheds (Table 4-10). Urban sites were characterized by the 1995 ABAG data as having higher percent imperviousness (5 –

Table 4-10. Subwatershed percent imperviousness estimated using different data sources with different spatial resolution and currentness. Primary data sources were 1999 Santa Clara County Assessor land use data (ownership parcel as spatial resolution), and 1995 Association for Bay Area Government's land use data (1-hectare spatial resolution) (ABAG 1996). Additional data sources used to develop the estimates of imperviousness for the Assessor's land use data are described in Chapter 3.

	Percent Imperviousness for Sampling Station Subwatersheds																	
Land Use Basemap	1	2	3	4	5	6	7	1	T 2	3	1	2	3	4	5	6	ef1	R ef2
Assessor's Land Use Data	6.5	9.6	3.9	7.4	1.2	0.2	7.6	6.7	1 .7	0.7	.9	.2	0.6	.5	.8	.9	.6	2 .7
ABAG's Land Use Data	1.4	2.9	7.5	6.9	2.7	2.2	7.3	2.0	1 .7	.4	.0	.1	.1	.0	.9	.0	.0	1 .0

24%). Non-urban sites (e.g., transition, rural, and reference) exhibited a lesser difference in percent imperviousness (1 – 5%, 1 – 4%, and < 2%, respectively) based on the disparate data sources. Differences in percent subwatershed imperviousness for all sites resulted from similar land use categories. Industrial, residential, and commercial land uses accounted for more impervious acreage in the ABAG-based estimates than in those based on

Assessor's data; transportation and vacant/undeveloped land uses accounted for more impervious acreage using the Assessor's data, as compared to the ABAG-based estimates. We attribute these differences to the finer spatial resolution of the Assessor's data and our use of multiple data sources and groundtruthing to improve land use classifications. We found exceptions to these patterns in subwatersheds with recent development (R2 – R4). Here, industrial, residential, and/or commercial land uses accounted for slightly higher (0. 5 – 1.5%) estimates of percent imperviousness in the more recent Assessor's 1999 data than in the 1995 ABAG data.

Cumulative percent subwatershed imperviousness increased slightly (.05%) between sites above Anderson Dam (Ref2 to R6) and more substantially (16.21%) between sites below Anderson Dam (R-5 to U-1) (Table 4-11, Figure 4-31).

Selected Components of Subwatershed Imperviousness

The relative contributions of different land uses to percent imperviousness varied by subwatershed (Table 4-12).

Percent imperviousness within the riparian corridor

The percent of riparian corridor imperviousness was highest in lower urban subwatersheds (U1–U5). Percent imperviousness within riparian corridors differed from the respective subwatersheds (Table 4-13). In all but three subwatersheds, percent imperviousness was lower in the riparian corridor than in the entire subwatershed (Table 4-13). Road-right-of-way comprised the greatest proportion of imperviousness within the riparian corridor of the mainstem Coyote Creek (1.88%) (Table 4-14).

Projected imperviousness

Percent imperviousness for the Coyote Creek watershed was projected to increase by 1.7% from 1995 – 2020. About two-thirds (72%) of this increase was due to increased residential development; about one-third (28%) was due to increased industrial/commercial development.

Permitting and Compliance

The SWRCB database identified 378 NOI filers in the Coyote Creek watershed (Table 4-15, Figure 4-32).

Industrial activities covered under the statewide stormwater NPDES permit for industrial activities included the 17 industrial

Table 4-11. Cumulative percent imperviousness influencing sampling stations was estimated using the County Assessor land use data for Coyote Creek drainage area. The numbers in bold reflect where the cumulative imperviousness estimates at each sample station in the Coyote Mainstem also includes drainage area of major tributary and its corresponding imperviousness.

Sampling Station	Cumulative Area		Cumulative Percent Imperviousness
	Impervious Area (Miles^2)	Watershed Area (Miles^2)	
Ref2	1.27	80.58	1.57
Ref1	1.29	81.51	1.58
R6	1.70	105.17	1.62
Anderson Dam			
R5	0.05	0.79	5.8
R4	0.08	1.66	4.61
R3	0.44	5.10	8.58
R2	0.64	7.85	8.1
R1	0.86	12.37	6.95
T3	2.53	27.35	**9.24**
T2	2.87	31.79	9.03
T1	3.01	33.04	9.11
U7	4.09	36.96	11.07
U6	6.40	45.91	**13.94**
U5	9.39	50.79	18.48
U4	10.14	52.11	19.47
U3	22.77	96.17	**23.67**
U2	25.12	120.78	**20.08**
U1	27.30	124.06	22.01

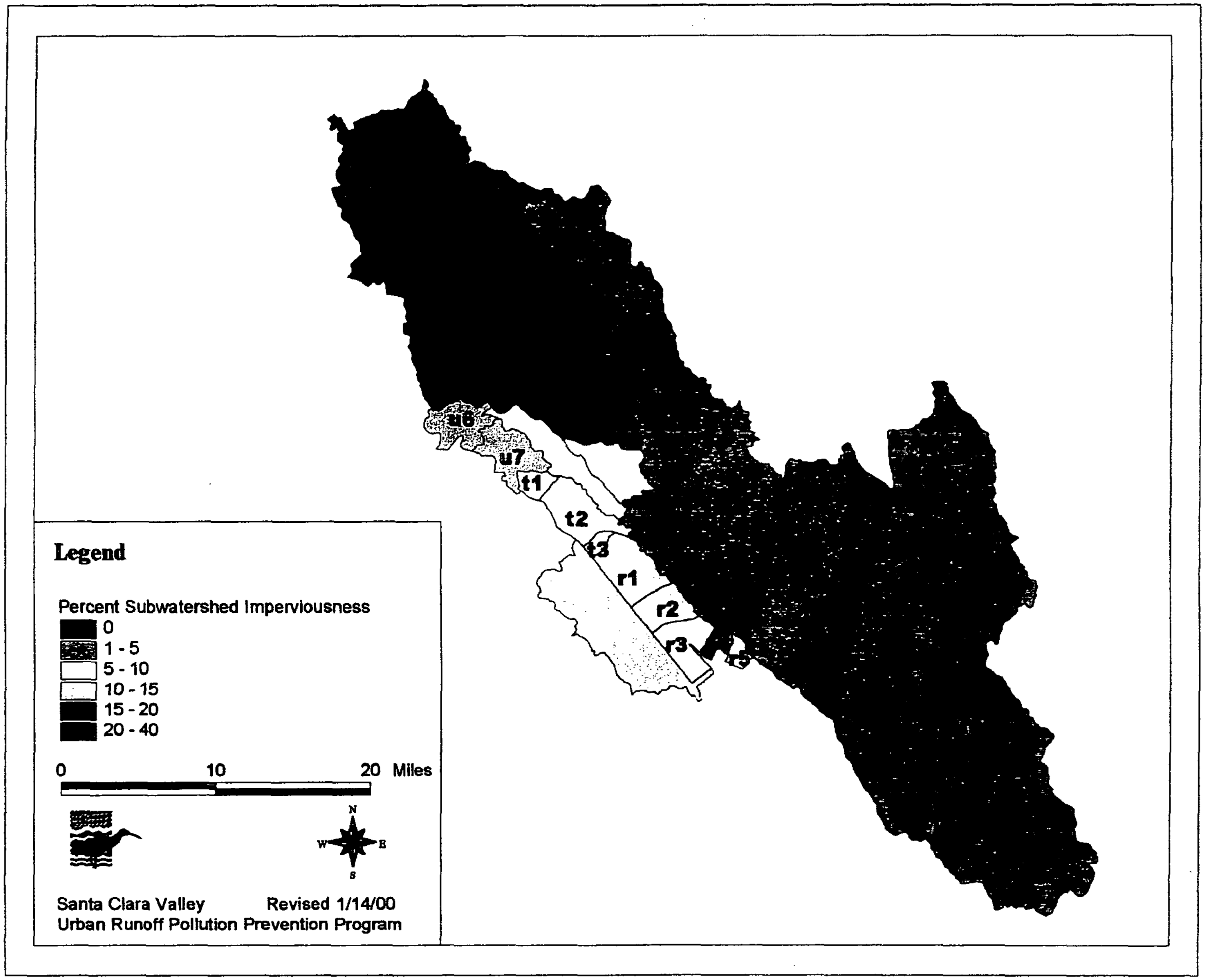


Figure 4-31. Estimated percent imperviousness in Coyote Creek subwatersheds. Estimates for subwatersheds along the Coyote Creek main channel reflect cumulative percent imperviousness (U1-R5 include upstream drainage area below Anderson Reservoir; R6 – Ref2 include all upstream drainage area).

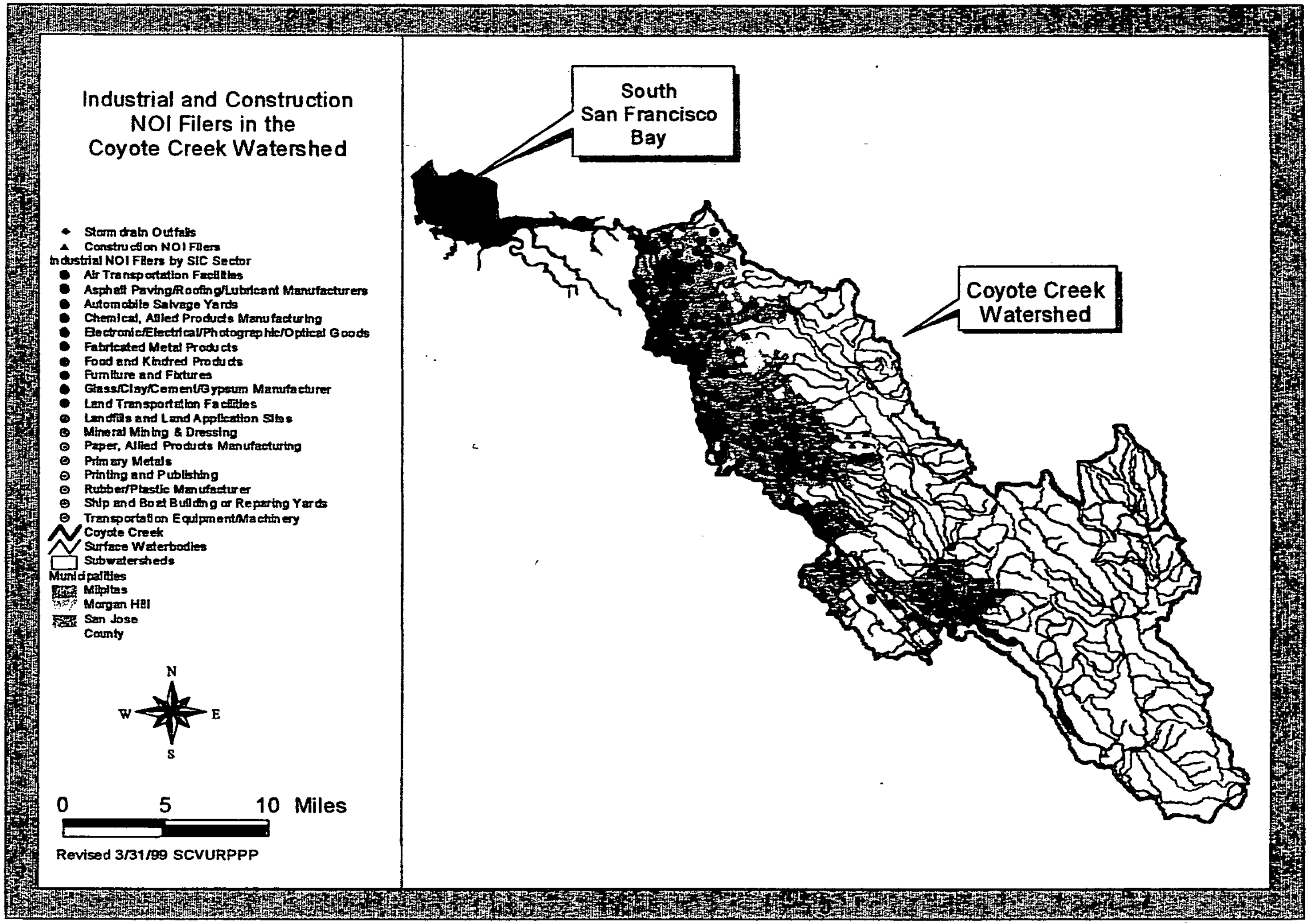


Figure 4-32. Industrial and construction sites filed under the California National Pollutant Discharge Elimination System permit in the Coyote Creek watershed by standard industrial classification sector.

Table 4-12 . Relative contribution of selected land uses to percent sampling station subwatershed imperviousness.

Sampling Station	Percent Imperviousness for Selected Land Uses				Total
	Commercial	Industrial	Residential	Road Right-of-Way	
U1	9.3	25.29	12.04	16.46	63.09
U2	7.38	43.33	0.38	15.3	66.39
U3	5.45	1.13	23.72	18.87	49.17
U4	3.58	12.34	16.07	18.79	50.78
U5	7.96	10.01	19.24	16.63	53.84
U6	4.17	5.96	20.76	14.07	44.96
U7	0.46	1.46	10.99	12.29	25.2
T1	0	2.43	0.39	6.08	8.9
T2	0.36	0.46	1.15	3.51	5.48
T3	0	0	0	4.68	4.68
R1	0.05	0.05	0.05	2.81	2.96
R2	0.01	1.53	0.05	3.38	4.97
R3	1.34	0.5	2.19	4.41	8.44
R4	0.05	0	0.6	0.51	1.16
R5	1.49	0	0.36	1.92	3.77
R6	0	0	0	0.82	0.82
REF1	0	0	0	0.98	0.98
REF2	0	0	0	0.12	0.12

categories listed in Table 4-16.

We georeferenced industrial and construction filer site locations (Figure 4-33) and cross-referenced potential pollutants that may exist in runoff from these sites (Figure 4-34) by associating site SIC codes with pollutants monitored as a permit requirement (SWRCB 1995). We did not estimate the proportion of non-filers in this watershed due to the difficulty in identifying reliable data sources for such a large area.

In the Walsh Avenue Catchment we were able to assess the status of non-filers because we developed a reliable data source by conducting our site surveys and inspections. We did not identify any non-filers within the catchment; however, because the catchment was the subject of a pilot inspection program in 1992, facility operators may be more aware of filing requirements than is typical. From the SWRCB NOI database we identified two active NOI filers and three businesses that were terminated from the Permit during its initial year (Table 2, Figure 4-35). Of these three, two closed their operations;

Table 4-13. Percent imperviousness of the riparian corridor within each sampling station subwatershed and of each entire sampling station subwatershed. Estimates based on Santa Clara County Assessor 1999 land use data.

	Percent Imperviousness for each Sampling Station Subwatershed																	
Land Use Area	U1	U2	U3	U4	U5	U6	U7	T1	T2	T3	R1	R2	R3	R4	R5	R6	Ref1	Ref2
Riparian Corridor	34.1	54.3	39.3	14.2	16.6	6.7	6.0	5.8	7.7	5.7	5.1	6.1	7.8	6.1	3.8	1.0	1.0	1.9
Entire Watershed	66.5	69.6	53.9	57.4	61.2	50.2	27.6	16.7	9.7	10.7	4.9	7.2	10.6	3.5	5.8	1.9	2.6	1.7

Table 4-14. Percent imperviousness within the riparian corridor of the Coyote Creek mainstem from its mouth (downstream of U1) through the most upstream sampling station subwatershed (Ref2). Estimate of imperviousness based on Santa Clara County Assessor 1999 land use data, and sorted in descending order.

Land Uses	Impervious Area (Acres)	Percent Impervious Riparian Corridor
Road Right-of-Way	301.35	1.88
Residential	236.24	1.47
Urban Recreation	127.00	0.79
Industrial	101.45	0.63
Agriculture	92.58	0.58
Commercial	79.80	0.50
Public, Quasi-Public	58.15	0.36
Non Urban Recreation	43.17	0.27
Vacant, Undeveloped	19.09	0.12
Transptn/Commtn/Utilities	16.48	0.10
Sanitary Landfill	0.05	< 0.01

the third altered its drainage so that runoff from the work area discharges to the sanitary sewer.

Of ten annual reports required from the two active NOI-filing businesses over the 5-year history of the statewide permit, four reports were actually submitted (40% compliance). Of ten required monitoring reports, three were submitted (30% compliance). There was a trend toward more consistent submittal of reports over the past three years than in the earlier years of the permit. This could be attributed to the increased effort associated with the local stormwater programs and regional public infor mation effort. However, by this measure, compliance in the Walsh Avenue catchment was poor when compared to average compliance found for industries in this county and the Bay Area region (Table 4-17).

One of the two active facilities developed and implemented a SWPPP. This facility's SWPPP had not been updated since it was prepared in 1996. For the two active NOI facilities in the Catchment, we found that general housekeeping and employee training BMPs were being implemented.

Illicit Connections Identified/Corrected

Illegal Dumping Incidents

The locations of illegal dumping incidents reported in the Coyote Creek watershed (1995 – 1999) are shown in Figures 4-36 and 4-37. The most commonly reported types of dumping incidents in San Jose and Milpitas, respectively, were residential auto (30.3%; 37.0%), commercial auto (9.8%; 8.8%), construction (7.0%; 9.2%), and illegal dumping (15.8%; 11.3%). Several residential incident types (gray water, irrigation, sediment) each contributed an additional 5.2% of all illegal dumping incidents reported in the Coyote Creek watershed. Equipment cleaning, restaurants, and sewage spills each accounted for approximately 4% of total incidents reported in the two-city area but a smaller proportion of the total incidents in the Coyote Creek watershed.

Incidents reported in the following categories declined consistently in the two-city area (1993–1998): automobile related activities (commercial car washing and wastewater discharge, residential radiator fluid dumping, oil dripping, and dumping associated with multiple family residences), residential cement washing, industrial cooling water discharge and equipment cleaning, paint spills and dumping, and sewage spills. The 1995-1998 trends in Coyote Creek watershed were

Table 4-15. Industrial and Construction site operators in the Coyote Creek Watershed and the Walsh Avenue Catchment that filed NOIs under the 1995 California National Pollutant Discharge Elimination System (NPDES) permit

Study Area	Industrial NOIs		Construction NOIs	
	Total	Active (% of Total)	Total	Active (% of Total)
Coyote Creek Watershed	227	162 (71%)	151	80 (53%)
Walsh Avenue Catchment	5	2 (40%)	0	0
Total	232	164 (70%)	151	80 (53%)

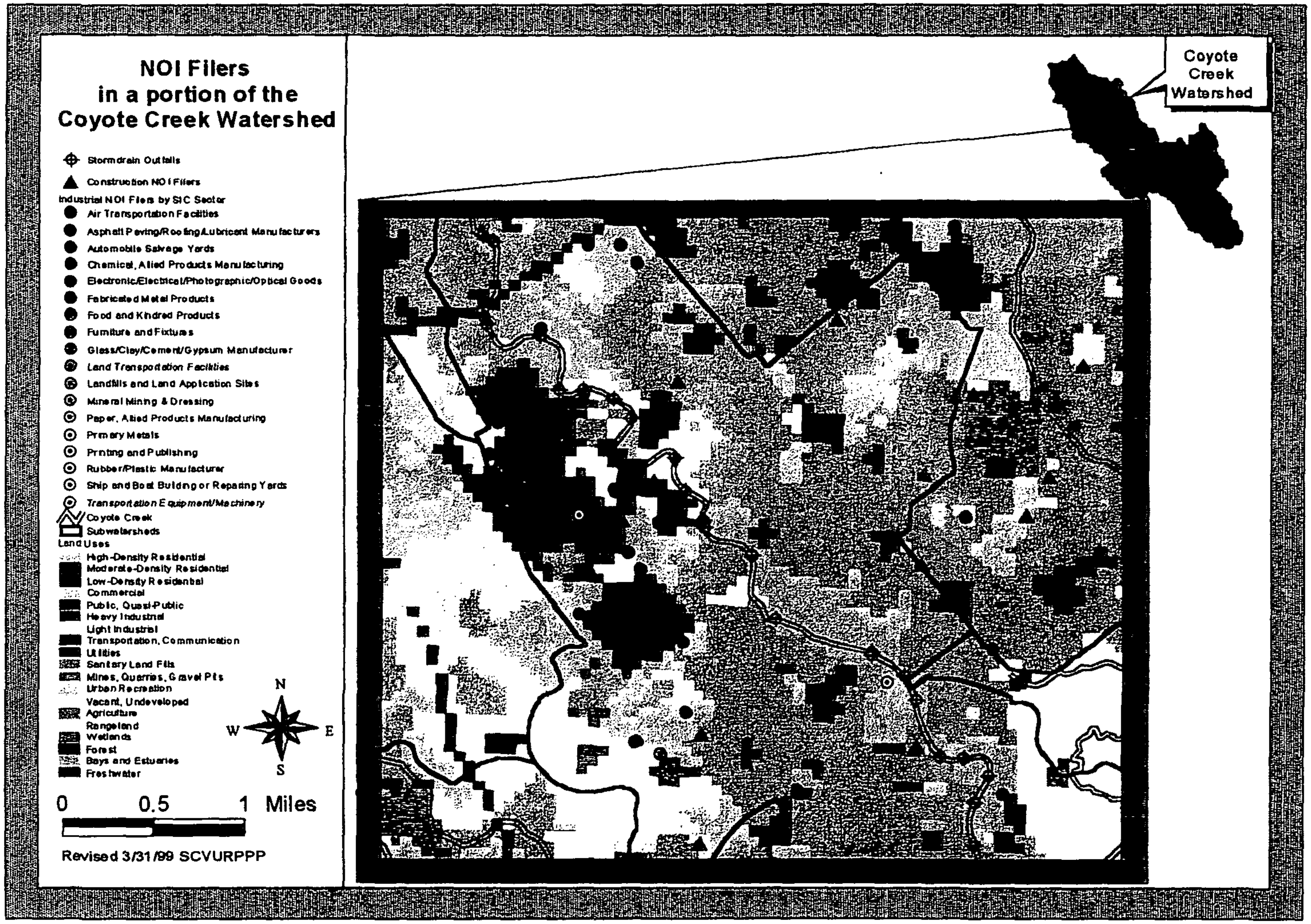


Figure 4-33. Industrial and construction sites filed (1998) under the California National Pollutant Discharge Elimination System permit in the Coyote Creek watershed and associated land uses.

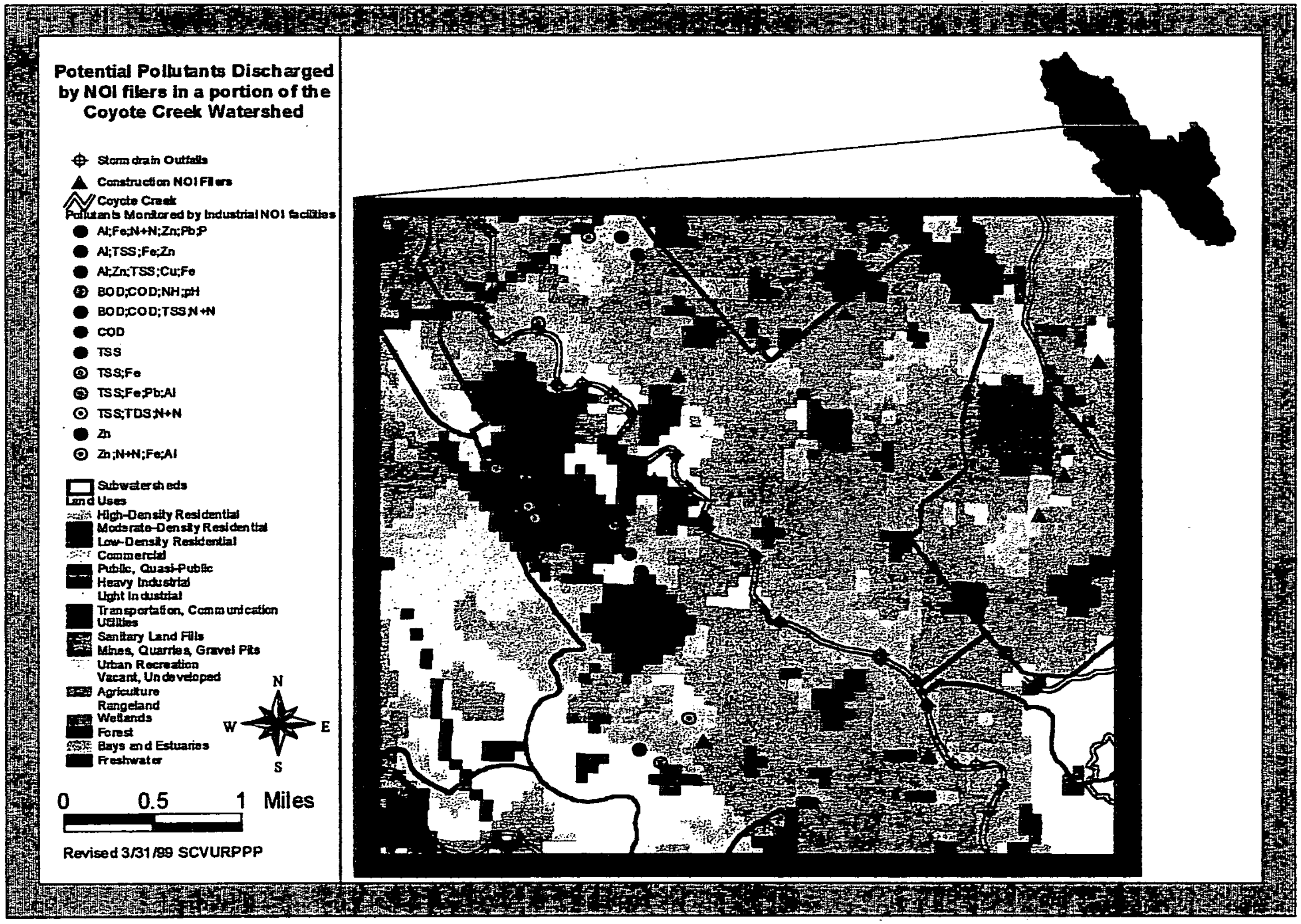


Figure 4-34. Pollutants monitored by NOI industrial facilities in the Coyote Creek watershed, as a requirement of the National Pollutant Discharge Elimination System permit (SWRCB 1995), and pollutants likely discharged by construction NOI sites.

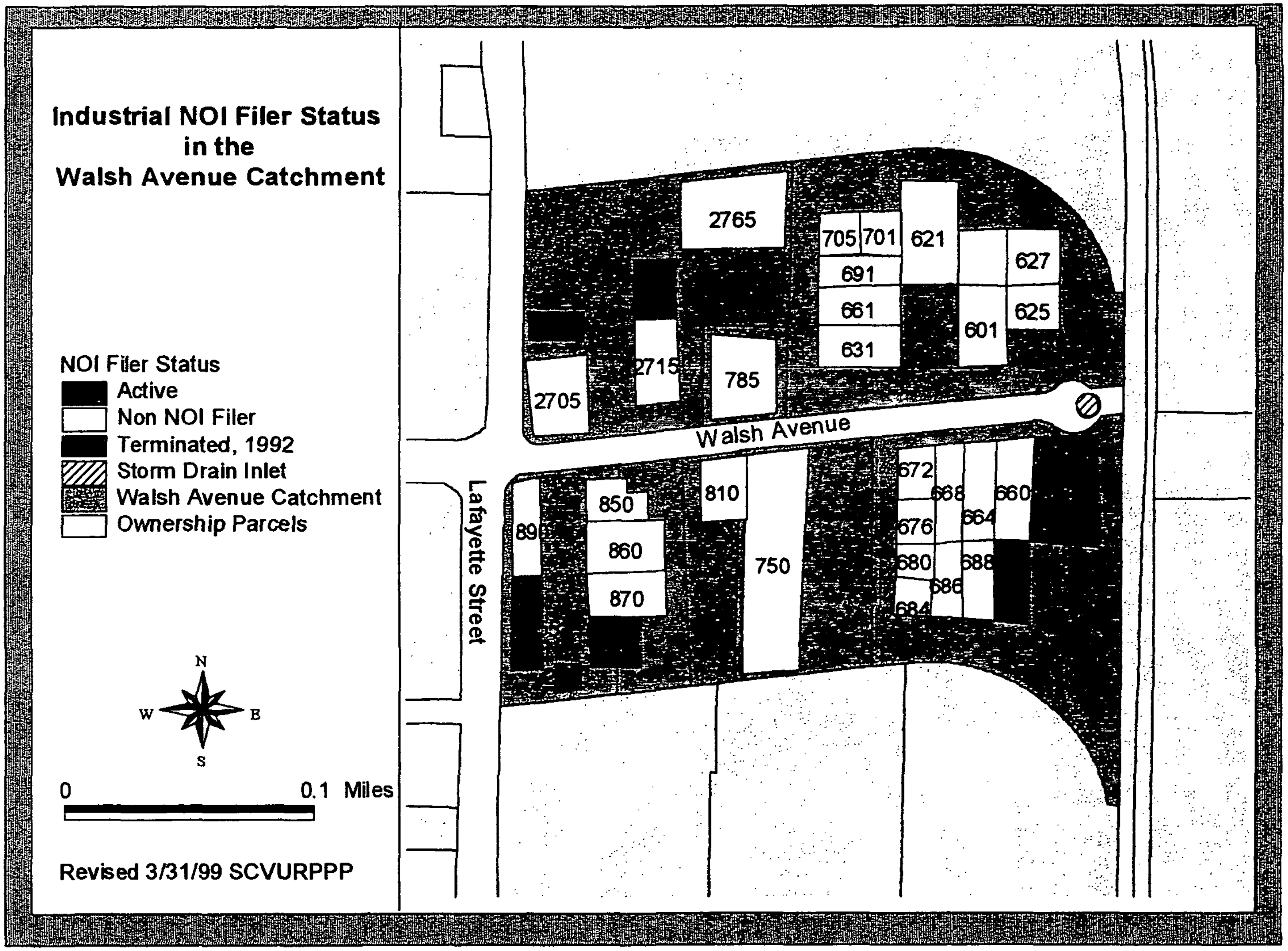


Figure 4-35. Industrial facilities within the Walsh Avenue catchment illustrated by NOI filer status.

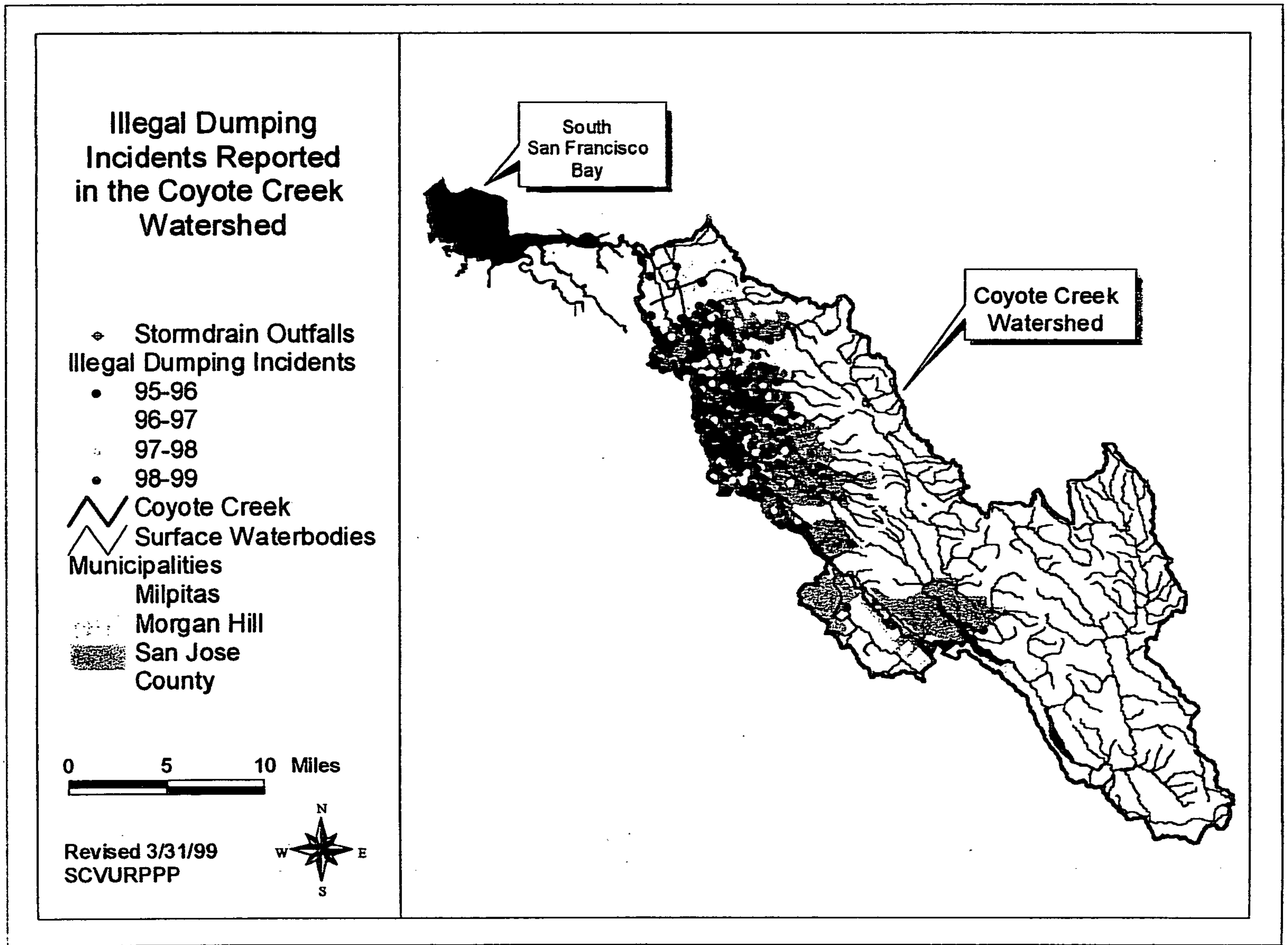


Figure 4-36. Recent (1995 – 1998) illegal dumping incidents reported in the Coyote Creek watershed.

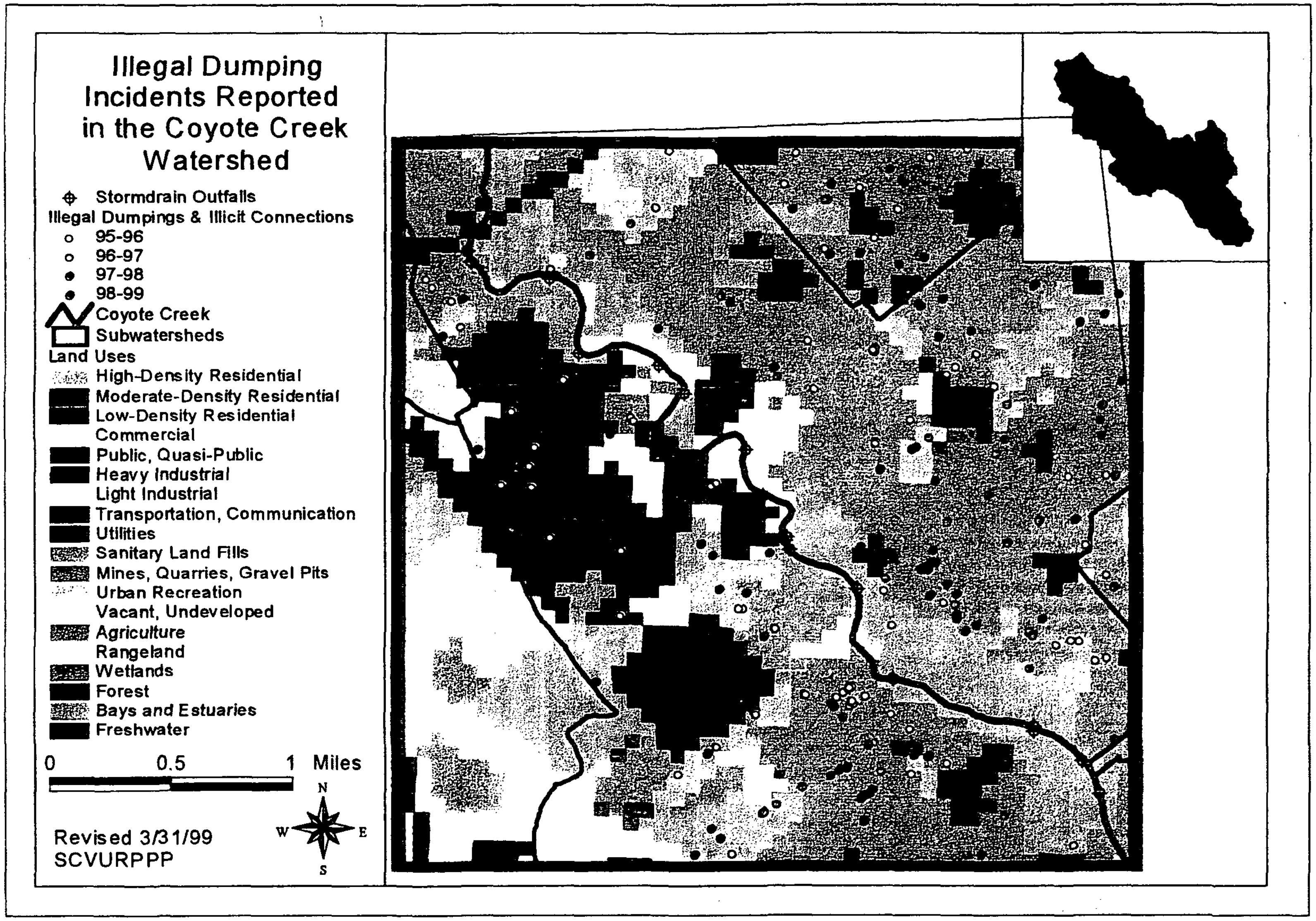


Figure 4-37. Enlarged area of Coyote Creek Watershed illustrating recent illegal dumping Incidents in the City of San Jose and their association with land uses.

Table 4-16. Pollutants monitored by NOI industrial facilities in the Coyote Creek watershed, as a requirement of the National Pollutant Discharge Elimination System permit (SWRCB 1995). Monitoring parameters are listed by standard industrial classification (SIC) sector (digit places designated as "X" indicate that subsectors exist, in which cases only a subset of monitoring parameters may apply).

Sector	Industrial Activity	SIC Code	Monitoring Parameters
B	Paper, Allied Products Manufacturing	26XX	COD
C	Chemical, Allied Products Manufacturing	28XX	Al;Fe;N+N;Zn;Pb;P
D	Asphalt Paving/Roofing/Lubricant Manufacturers	295X	TSS
E	Glass/Clay/Cement/Gypsum Manufacturer	32XX	Al;TSS;Fe;Zn
F	Primary Metals	33XX	Al;Zn;TSS;Cu;Fe
J	Mineral Mining & Dressing	14XX	TSS;TDS;N+N
L	Landfills and Land Application Sites	4953	TSS;Fe
M	Automobile Salvage Yards	50XX	TSS;Fe;Pb;Al
P	Land Transportation Facilities	41XX;42XX	none listed
R	Ship and Boat Building or Repairing Yards	373X	none listed
S	Air Transportation Facilities	45XX	BOD;COD;NH;pH
U	Food and Kindred Products	20XX	BOD;COD;TSS;N+N
W	Furniture and Fixtures	25XX;2434	none listed
X	Printing and Publishing	27XX	none listed
Y	Rubber/Plastic Manufacturer	30XX	Zn
AA	Fabricated Metal Products	34XX	Zn;N+N;Fe;Al
AC	Electronic/Electrical/Photographic/Optical Goods	36XX	none listed

Legend:

Al	Aluminum	NH	Ammonia
BOD	Biological Oxygen Demand	P	Phosphorus
COD	Chemical Oxygen Demand	Pb	Lead
Cu	Copper	TSS	Total Suspended Solids
Fe	Iron	Zn	Zinc
N+N	Nitrate + Nitrite		

Table 4-17. NOI filer compliance with the California NPDES Permit requirement for annual report submittal) within Bay Area counties during fiscal year 1997-1998 (Source: Region 2 Water Quality Control Board).

County	Number of Active Sites	Annual Report Submitted	Percent Compliance
Solano	62	39	63%
Alameda	532	325	61%
San Mateo	138	83	60%
Contra Costa	186	107	58%
Santa Clara	**517**	**300**	**58%**
Marin	37	20	54%
Sonoma	59	28	47%
Napa	109	45	41%
San Francisco	27	7	26%
Total	**1667**	**954**	**57%**

Table 4-18. New building development completed or under construction from 1995 – 1998 in planning areas (Edenvale, Evergreen, and Berryessa) within Coyote Creek Watershed

Development Category	Developed Area
Major Residential	5,781 DU
Major Commercial	28.6 ac
Major Industrial	66.6 ac

Source: City of San Jose Planning Department, http://www.ci.sanjose.ca.us/planning/siplan/devrep03.htm

"Major" defined as follows: residential = projects ≥ 100+ dwelling units (DU); commercial = projects ≥ 25,000 ft^2 (.57 ac); industrial = projects ≥ 75,000 ft^2 (1.72 ac).

involving residential radiator fluid remained relatively constant and those involving residential cement washing fluctuated.

Incidents reported 1993 – 1998 increased consistently for the following categories: residential oil dripping, construction activities, and residential gray water and sediment. Pollutants associated with auto-related activities (e.g., oil, antifreeze, solvents, and fuel) accounted for 40.8% of incidents reported as "hazardous illegal dumping," 5% of those reported as "non-hazardous illegal dumping", 25.7% of those reported as "parking lot" incidents, and 50.9% of those reported as "spills."

Illicit Connections

The number of illicit connections identified and resolved decreased 70-fold between 1993 and 1998. Most (79%) of the illicit connections reported in FY 93-94 resulted from a single condominium development that had plumbed washing machines and/or water softener drain lines into surface storm drain inlets.

Changes in Population and Program Practices

Evaluating stormwater program effectiveness requires considering co-occurring factors that can affect the rate and spatial pattern of reported ICID incidents. In the last decade (the period in which the Program was initiated) the Silicon Valley, and particularly its eastern watersheds, including Coyote Creek, have experienced rapid growth in population, industrial, commercial, and residential development, and transportation volume.

From 1990 to 1998, Milpitas and San Jose increased in population by 14% and 23% respectively (Santa Clara County Planning Office 1998). The number of jobs in these cities grew 13.5% from 1985 to 1995. Employment is projected to increase an additional 20.8% from 1995 to 2000. Increased employment and the high cost of housing have increased commuting distances and volumes. ABAG (1998) projected an increase in Santa Clara County from 40,000 daily commuters in 1980 to 116,000 daily commuters in 2000. Development continues in both San Jose and Milpitas, including development of the City of San Jose portion of the Coyote Creek watershed (Table 4-18). Analysis of land use projections showed that an additional 1% of the Coyote Creek watershed will be developed between 1995 and 2000 for residential, commercial and industrial uses (Buchan 1999).

Co-permittees have increased and allocated inspection staff to meet Program requirements and to focus inspection effort on incident types and/or industries they considered to be high priorities. Since 1990 the City of San Jose's inspection staff increased from 5 to 9 full-time equivalent (FTE) positions. Staff allocations to ICID inspection efforts increased from 1 FTE (1990) to 3.4 FTE positions in 1999. Inspection staff also was effectively increased by conducting cross-training sessions for city personnel in the City's public works, streets and parks, hazardous incidents, and fire departments. The smaller City of Milpitas increased their staff from 2 FTEs in 1990 to 3FTEs by 1996.

Decreases in the number of incidents reported in some incident categories may have resulted from the Co-permittees' outreach efforts, which included advertising to encourage used oil recycling, workshops, public relations events, and routine inspections of industrial and commercial facilities. The City of San Jose prioritized inspections for construction sites, auto repair shops, auto dismantlers, and restaurants by analyzing their illegal dumping database, evaluating response from industrial/commercial owner/ operators during inspections, and by evaluating growth trends. Inspectors reported difficulty in responding quickly to incidents due to limited ability to communicate from the field and due to limited site access. To improve response time the City of San Jose obtained two four-wheel drive vehicles and cell phones. City inspectors also reported the lack of outreach materials in multiple languages as an obstacle for field inspectors to address residential ICID incidents. Outreach materials have now been produced in these languages.

Increases in the number of ICID incidents reported in other incident categories do not necessarily indicate lack of stormwater program effectiveness. Indeed, increases should be expected given continued urbanization, and the anticipated lag time before public education and regulations will affect behavior. Increases in the number of illegal dumping incidents reported were observed for construction and auto-related maintenance activities (particularly residential). Such increases corroborate with the increased urbanization in the region, and with attendant increased inspection efforts focused on these types of activities and specific areas where they commonly occur.

Apparent fluctuations in the number of ICID incidents reported in some categories during 1993 – 1998 may be an artifact of how categories are defined. For example, categories such as hazardous dumping, non-hazardous dumping, and spills, are associated with a variety of pollutants, and do not describe a specific activity that could be targeted by inspectors. More descriptive definitions of these categories would improve a reporter's ability to associate pollutant types with the incidents. Fluctuations in the number of reported illegal dumping incidents could also result from variable reporting and inspection effort, or from increases in the type of discharge corresponding to localized urbanization.

Discharge of pollutants associated with automobile washing and repair (e.g. ethylene glycol, polyaromatic hydrocarbons (PAHs), surfactants, phosphates, and organic solvents) decreased for some residential categories, particularly for multiple dwelling residences. Discharge of sediment, organic solvents, selected metals, and pathogens may also have diminished due to decreases in cement washing, commercial equipment cleaning, and paint and sewage spills, respectively. Such improvements, however, may have been countered by discharges of similar pollutants associated with some categories of residential auto repair and construction activities.

The significance of the results obtained from applying the ICID Indicator to the Program are limited because:

⇒ Co-permittee efforts to investigate and eliminate ICID vary (over time and from Co-permittee to Co-permittee).

⇒ ICID reports may not accurately characterize incidents or pollutants involved.

⇒ Co-permittees reporting summaries have inconsistent formats, and some data is not available.

4.2 Results in the Walsh Avenue Catchment

4.2.1 Programmatic Indicators

Industrial/Commercial Pollution Prevention

Forty-five percent of the site managers interviewed were unfamiliar with the City of Santa Clara's stormwater pollution prevention program. However, most of these site managers understood that stormwater can carry pollutants to nearby creeks and water bodies, were receptive to the need to prevent stormwater pollution, and reported that they were implementing pollution-prevention measures such as proper material storage, dry sweeping, good housekeeping, and safety. In general, they accepted these requirements as common-sense practices.

Few respondents were familiar with the different Program components or with the environmental and legal consequences of stormwater violations. Few were familiar with the term "best management practices" — but most of the sites were implementing BMPs. Cost, work effort, and site manager attitudes were not significant barriers to implementation of runoff pollution control measures.

Since the 1993 pilot project, businesses had increased their implementation of pollution-prevention BMPs, and more businesses were in compliance with pollution-prevention requirements. However, lack of detail in the City's inspection record made it difficult to distinguish which BMPs were implemented as a result of efforts specifically related to stormwater pollution prevention outreach.

Businesses' costs for stormwater pollution prevention include construction and maintenance of BMPs, training of staff and labor costs to implement "operational" BMPs. Managers considered costs associated with operational and structural BMPs to be minimal and did not track them. For most facilities in the Walsh Avenue catchment, staff training is informal, and is part of day-to-day interaction between supervisor and employee. Where site managers did identify costs related to stormwater pollution prevention, these tended to be one-time costs (for example, the cost to purchase a piece of equipment or to install a "structural" BMP). Although the BMPs are implemented, most managers are not consciously motivated by the need to prevent stormwater pollution.

In general, the tendency of respondents to not associate specific training and operational activities with stormwater pollution prevention seemed related to their general unfamiliarity with the City's pollution-prevention program.

Number of BMPs Installed, Inspected, and Maintained

Respondents were asked to indicate, from a list, which BMPs were typically associated with their site. The most commonly reported BMPs included:

⇒ Perform daily cleanup and sweeping of indoor and outdoor work areas (21 responses);

⇒ Regularly remove trash and debris from outdoor areas (parking lots) (19 responses)

⇒ Properly dispose of process residues (sawdust, metal scraps, fluids) (18 responses)

⇒ Properly store raw materials, products and by-products (15 responses)

⇒ Minimize the use of wash water when cleaning equipment and vehicles (14 responses

⇒ Properly store paints, chemicals and solvents (12 responses).

Discussion of the survey with the site managers resulted in a more detailed list of BMPs applied and agreement on additional BMPs that should be applied based on observations made during the site visit. Most of the sites in the Catchment were indoor operations, minimizing the potential impact to storm water and the need for BMP implementation. However, some BMP applications were applicable. Existing (and recommended) BMPs were related to general housekeeping in the area surrounding the business and debris bins, staff training and material storage.

Many of the sites in the Catchment implemented BMPs but did not associate this implementation with the City's outreach and inspections. For example, many managers of commercial and light industrial sites cited organization and efficiency as the reason for storing materials properly. Similarly, parking lots and entranceways were swept to maintain a pleasing appearance. BMPs at the more industrial sites were implemented to comply with other environmental regulations, safety codes, and local fire codes, and not necessarily to protect storm drains.

Most BMPs implemented in the Catchment were non-structural with the exception of the plating facilities. Most of the commercial and light industrial businesses were implementing some appropriate housekeeping and material and waste storage BMPs. Additional BMPs, however, were recommended for many of the businesses.

Industrial Site Compliance Monitoring

Of 23 businesses in the Walsh Avenue Catchment that were inspected by the City of Santa Clara September 1998 – March 1999, 16 (70%) were found to be in compliance with all various stormwater pollution-prevention measures. The remaining 7 facilities had violations relating to general housekeeping, outside storage of equipment or raw material storage and the washwater disposal. Additional or follow-up reinspections were conducted as needed, in response to conditions observed at the scheduled site visits. In follow-up reinspections, two previously non-complying businesses remained in non-compliance. New violations were identified at two businesses that had been in compliance during the previous inspection.

Of the 32 businesses currently in the Catchment, 18 participated in the 1993 Pilot Study. A comparison of the inspection data for these sites for the two periods indicated a marked increase in the proportion of sites in compliance with the City's stormwater regulations. In two cases, some have never achieved compliance and demonstrated repeat violations in the same areas.

The two metal plating/finishing facilities in the Catchment are subject to the State's General Industrial Permit and must submit a Notice of Intent (NOI). As a part of the General Permit process, proof of the NOI, an Annual Report and a Stormwater Pollution Prevention Plan should be available. One of the facilities maintained a 1998 NOI, but their Annual Report and SWPPP were from 1995-1996. The other facility provided Annual Reports for the previous two years.

These two facilities also operate on-site industrial waste treatment systems and maintain permits from the San Jose/Santa Clara Water Pollution Control Plant to discharge treated effluent into the sanitary system. Staff based at the WPCP inspect the treatment equipment and require monitoring of effluent quality discharges.

4.2.2 Water-Quality Indicators

Toxicity Testing (Indicator #2)

All 15 samples were toxic, resulting in mortality within 24 hours of exposure to 100% runoff. Lack of apparent trends in toxicity is due, in part, to the use of the screening test design where organisms are exposed to 100% runoff rather than a dilution series used in the definitive test. If the definitive test was used it may have been possible to observe changes in the percentage of dilution of the runoff that was required to allow partial mortality of the test organisms.

The disadvantage with the definitive test is that the costs are greatly increased (3-4 fold) over the screening test. An alternative approach is to monitor changes in concentration of the causative toxic agents. In the case of Walsh Ave the causative agents were previously identified through a TIE as dissolved metals. The toxicity monitoring results are consistent with the results of the zinc monitoring where dissolved concentrations stayed high throughout the monitoring period.

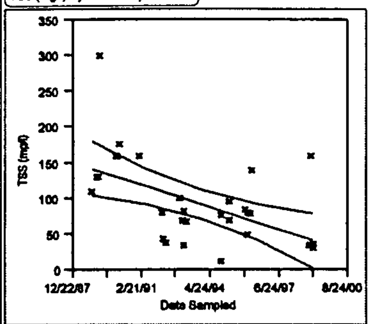
Non-Point Source Loading (Indicator #3)

Figures 4-38 and 4-39 show the results of the time-trend analysis for the total metals and solids. Time trends are presented for both pollutant concentration and pollutant load. Significant time-trends were found for both concentrations and event loads of TSS, lead, and nickel ($p < 0.05$), which decreased with time. In general, the trends were more significant for the pollutant concentrations than for the pollutant event loads. The load time trends explained 33% of the data variability for solids and lead and 51% of the data variability for nickel. Time-trends for zinc concentrations and event loads were not significant. Zinc concentrations were elevated as compared to most urban runoff with the highest concentration measured during the last year of monitoring. No significant trends were found for total copper concentration. However, weak trends in copper event load were significant at the 92% confidence level ($p = 0.078$). The time-trend in copper event load was highly influenced by two events that occurred early in the monitoring program. When these two data points are omitted from the analysis the trend becomes insignificant.

The results of time trend regressions for particulate copper, particulate lead, and particulate zinc are shown in Figure 4-40. The results of the analysis show none of the particulate metals had significant time trends. Particulate lead showed visually decreasing concentrations with time, while particulate copper and zinc concentrations were essentially unchanged over time.

Table 4-19 shows a statistical summary of concentrations of TSS, Copper, Nickel, Lead, and Zinc for runoff from the Walsh Avenue Catchment. Data are shown for three metal species: total, dissolved, and particulate. Dissolved concentration data were available for nickel only for the last season of monitoring. Particulate concentrations were calculated from the total, dissolved and TSS values using the following relationship: Particulate (μg/g) = {[Total (μg/l) - Diss (μg/l)]/ TSS (mg/l)} * 1000 μg/mg.

TSS (mg/l) By Date Sampled



Linear Fit

Linear Fit

TSS (mg/l) = 976.895 0 3.12e-7 Date Sampled

Summary of Fit

RSquare	0.28228
RSquare Adj	0.255698
Root Mean Square Error	52.40966
Mean of Response	91.44828
Observations (or Sum Wgts)	29

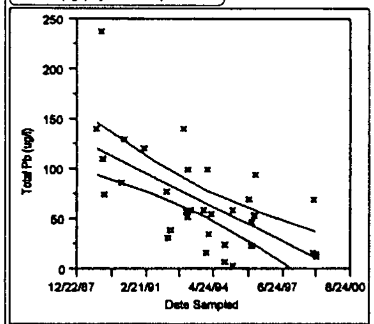
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	29168.32	29168.3	10.6191
Error	27	74162.85	2746.6	Prob>F
C Total	28	103331.17		0.0030

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	976.89548	271.8922	3.59	0.0013
Date Sampled	-3.118e-7	9.569e-8	-3.26	0.0030

Total Pb (ug/l) By Date Sampled



Linear Fit

Linear Fit

Total Pb (ug/l) = 1026.46 0 3.38e-7 Date Sampled

Summary of Fit

RSquare	0.42446
RSquare Adj	0.406474
Root Mean Square Error	38.1551
Mean of Response	65.53235
Observations (or Sum Wgts)	34

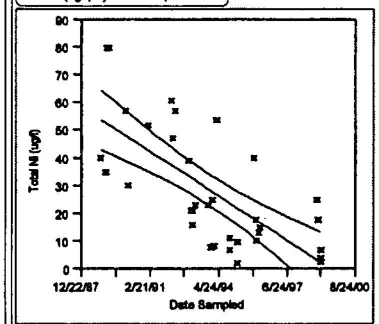
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	34357.039	34357.0	23.5999
Error	32	46585.975	1455.8	Prob>F
C Total	33	80943.014		<.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1026.4565	197.9116	5.19	<.0001
Date Sampled	-3.384e-7	6.965e-8	-4.86	<.0001

Total Ni (ug/l) By Date Sampled



Linear Fit

Linear Fit

Total Ni (ug/l) = 481.244 0 1.6e-7 Date Sampled

Summary of Fit

RSquare	0.486978
RSquare Adj	0.470946
Root Mean Square Error	15.8555
Mean of Response	28.21765
Observations (or Sum Wgts)	34

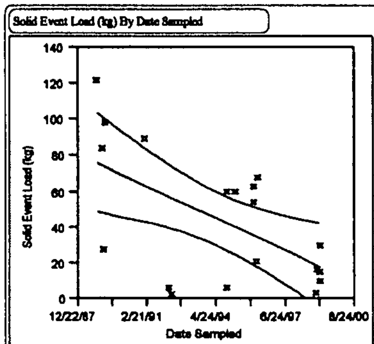
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	7636.309	7636.31	30.3755
Error	32	8044.700	251.40	Prob>F
C Total	33	15681.009		<.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	481.2435	82.24295	5.85	<.0001
Date Sampled	-1.595e-7	2.894e-8	-5.51	<.0001

Solid Event Load (kg) By Date Sampled



Linear Fit

Linear Fit

Solid Event Load (kg) = 559.221 0 1.8e-7 Date Sampled

Summary of Fit

RSquare	0.335757
RSquare Adj	0.296683
Root Mean Square Error	30.80909
Mean of Response	44.07107
Observations (or Sum Wgts)	19

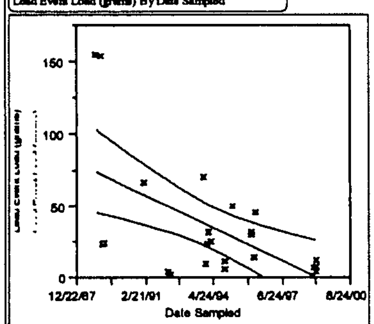
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	8156.503	8156.50	8.5930
Error	17	16136.404	949.20	Prob>F
C Total	18	24292.907		0.0093

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	559.22127	175.8781	3.18	0.0055
Date Sampled	-1.803e-7	6.149e-8	-2.93	0.0093

Lead Event Load (grams) By Date Sampled



Linear Fit

Linear Fit

Lead Event Load (grams) = 693.643 0 2.31e-7 Date Sampled

Summary of Fit

RSquare	0.333688
RSquare Adj	0.303401
Root Mean Square Error	34.96133
Mean of Response	33.96663
Observations (or Sum Wgts)	24

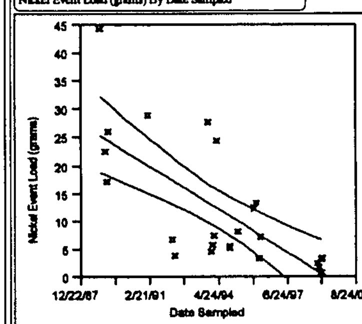
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	13466.700	13466.7	11.0178
Error	22	26890.484	1222.3	Prob>F
C Total	23	40357.184		0.0031

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	693.64252	198.6693	3.49	0.0021
Date Sampled	-2.311e-7	6.963e-8	-3.32	0.0031

Nickel Event Load (grams) By Date Sampled



Linear Fit

Linear Fit

Nickel Event Load (grams) = 233.048 0 7.74e-8 Date Sampled

Summary of Fit

RSquare	0.509688
RSquare Adj	0.487401
Root Mean Square Error	8.131501
Mean of Response	11.9945
Observations (or Sum Wgts)	24

Analysis of Variance

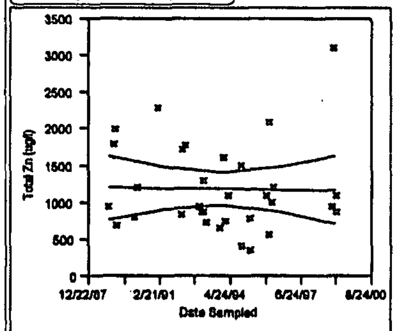
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1512.1527	1512.15	22.8694
Error	22	1454.6687	66.12	Prob>F
C Total	23	2966.8214		<.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	233.04823	46.25413	5.04	<.0001
Date Sampled	-7.744e-8	1.619e-8	-4.78	<.0001

Figure 4-38. Time Trend in TSS, Lead, and Nickel In Walsh Ave Catchment

Total Zn (ug/l) By Date Sampled



Linear Fit

Linear Fit

Total Zn (ug/l) = 1491.76 0 1.07e-7 Date Sampled

Summary of Fit

RSquare	0.00026
RSquare Adj	-0.03304
Root Mean Square Error	612.3274
Mean of Response	1187.344
Observations (or Sum Wgts)	32

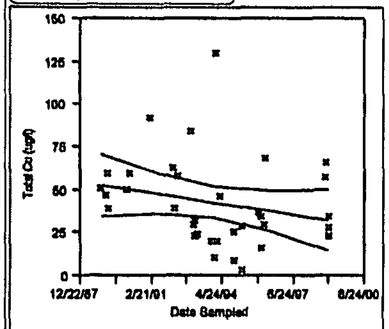
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	3156	3156	0.0084
Error	30	11248344	374945	Prob>F
C Total	31	11251499		0.9275

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1491.757	3320.005	0.45	0.6564
Date Sampled	-1.074e-7	0.000001	-0.09	0.9275

Total Cu (ug/l) By Date Sampled



Linear Fit

Linear Fit

Total Cu (ug/l) = 222.128 0 6.33e-8 Date Sampled

Summary of Fit

RSquare	0.053735
RSquare Adj	0.024164
Root Mean Square Error	25.72475
Mean of Response	42.35294
Observations (or Sum Wgts)	34

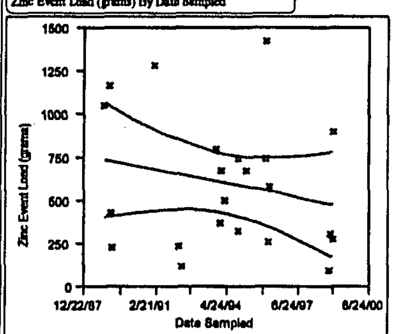
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1202.537	1202.54	1.8172
Error	32	21176.407	661.76	Prob>F
C Total	33	22378.945		0.1871

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	222.12845	133.435	1.66	0.1057
Date Sampled	-6.33e-8	4.696e-8	-1.35	0.1871

Zinc Event Load (grams) By Date Sampled



Linear Fit

Linear Fit

Zinc Event Load (grams) = 2871.55 0 7.97e-7 Date Sampled

Summary of Fit

RSquare	0.047642
RSquare Adj	0.000024
Root Mean Square Error	381.8436
Mean of Response	602.6322
Observations (or Sum Wgts)	22

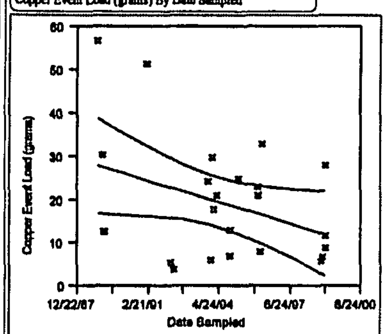
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	145878.1	145878	1.0005
Error	20	2916093.6	145805	Prob>F
C Total	21	3061971.7		0.3291

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2871.5518	2269.809	1.27	0.2204
Date Sampled	-7.965e-7	7.963e-7	-1.00	0.3291

Copper Event Load (grams) By Date Sampled



Linear Fit

Linear Fit

Copper Event Load (grams) = 158.676 0 4.88e-8 Date Sampled

Summary of Fit

RSquare	0.133914
RSquare Adj	0.094546
Root Mean Square Error	13.28785
Mean of Response	19.36081
Observations (or Sum Wgts)	24

Analysis of Variance

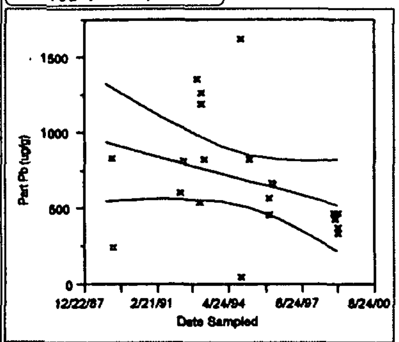
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	600.6147	600.615	3.4016
Error	22	3884.4726	176.567	Prob>F
C Total	23	4485.0873		0.0786

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	158.67585	76.68461	2.10	0.0475
Date Sampled	-4.881e-8	2.646e-8	-1.84	0.0786

Figure 4-39. Time Trend in Zinc and Copper in Walsh Ave Catchment

Part Pb (ug/g) By Date Sampled



Linear Fit

Linear Fit

Part Pb (ug/g) = 4446.05 0 1.31e-6 Date Sampled

Summary of Fit

RSquare	0.103026
RSquare Adj	0.055817
Root Mean Square Error	381.6127
Mean of Response	694.7143
Observations (or Sum Wgts)	21

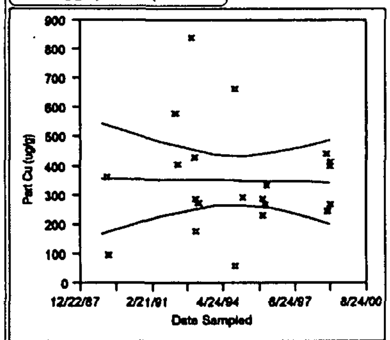
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	317810.2	317810	2.1823
Error	19	2766936.1	145628	Prob>F
C Total	20	3084746.3		0.1560

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4446.0464	2540.726	1.75	0.0963
Date Sampled	-0.000001	8.852e-7	-1.48	0.1560

Part Cu (ug/g) By Date Sampled



Linear Fit

Linear Fit

Part Cu (ug/g) = 461.728 0 3.88e-8 Date Sampled

Summary of Fit

RSquare	0.000427
RSquare Adj	-0.05218
Root Mean Square Error	185.4034
Mean of Response	350.5238
Observations (or Sum Wgts)	21

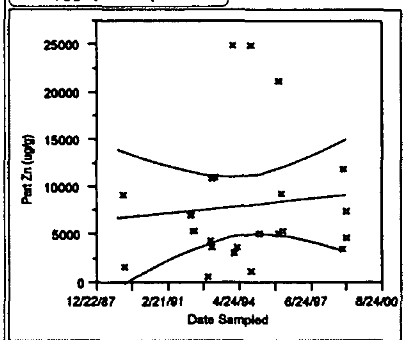
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	279.28	279.3	0.0081
Error	19	653113.96	34374.4	Prob>F
C Total	20	653393.24		0.9291

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	461.72802	1234.391	0.37	0.7125
Date Sampled	-3.877e-8	4.301e-7	-0.09	0.9291

Part Zn (ug/g) By Date Sampled



Linear Fit

Linear Fit

Part Zn (ug/g) = -13457 + 7.54e-6 Date Sampled

Summary of Fit

RSquare	0.008991
RSquare Adj	-0.0382
Root Mean Square Error	7087.854
Mean of Response	6091.652
Observations (or Sum Wgts)	23

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	9571169.11	9571169	0.1905
Error	21	1054991100	50237671	Prob>F
C Total	22	1064562269		0.6669

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-13457.05	49391.01	-0.27	0.7879
Date Sampled	0.0000075	0.000017	0.44	0.6669

Figure 4-40. Time Trends in Particulate Lead, Copper, and Zinc.

Table 4-19. Water Quality Summary Statistics for Walsh Ave

	TSS (mg/l)	Total Cu (µg/l)	Dissolved Cu (µg/l)	% Diss. Cu	Particulate Cu (µg/g)
Mean	92	44	16	43%	367
Median	78	37	13	36%	314
Standard Dev.	63	26	11	19%	194
CV	0.69	0.59	0.71	0.45	0.45
N	27	32	25	25	25

	TSS (mg/l)	Total Pb (µg/l)	Dissolved Pb (µg/l)	% Diss. Cu	Particulate Pb (µg/g)
Mean	29	67	4.5	10%	706
Median	22	58	3.1	8%	633
Standard Dev.	22	50	4.3	11%	387
CV	0.76	0.74	0.96	1.04	0.55
N	32	32	24	25	22

	TSS (mg/l)	Total Zn (µg/l)	Dissolved Zn (µg/l)	% Diss. Cu	Particulate Zn (µg/g)
Mean	10	1218	682	54%	8067
Median	7	975	660	51%	5453
Standard Dev.	9	602	381	28%	6804
CV	0.87	0.49	0.56	0.52	0.84
N	4	30	25	22	24

Factors Contributing to Variation in Event Loads

In contrast to results from large waterway stations, approximately half the copper, nickel, and zinc in the Walsh Ave catchment are found in the dissolved phase. Lead was mostly associated with the particulate fraction.

Results of ANOVA for copper, lead and zinc on the small storms are shown in Table 4-20.

For all parameters variations in both concentration and flow are important in determining event loads. The relative importance of each load component changes for each parameter. The results of the load component analysis indicate parameters with the most significant time trend in event load (solids, lead, and nickel) were also the most strongly influenced by pollutant concentrations.

Variations in lead event loads were the most strongly influenced by lead concentrations, probably as a result of decreasing lead concentrations related to the phase out of leaded gasoline. In contrast, concentrations of zinc had the least influence of any parameter on event loads and zinc had the highest unexplained variability of all the parameters. The large amount of unexplained variation indicates the importance of unexplained systematic or random factors that influence event loads.

When the high flow events were not excluded from the analysis, variations in flow accounted for much more of the load variability as

Table 4-20. Percentage of Load Variability Explained by Different Load Components (Based on ANOVA; storms less than 60,000 cubic feet total flow).

Parameter	Concentration	Flow	Unknown
Solids	44%	43%	13%
Copper	34%	41%	24%
Nickel	42%	34%	24%
Lead	68%	22%	10%
Zinc	22%	38%	30%

shown in Table 4-21.

Copper concentrations were not particularly elevated in most of the samples. Urban background concentrations are around 45 :g/l which was the overall average of the concentrations found in the entire dataset. Detecting changes in copper loads would require decreasing copper concentration below this urban background level.

Conversely, zinc concentrations remain elevated in runoff. Detecting changes in zinc concentration should be feasible; assuming the source of zinc could be located and eliminated.

Table 4-21. Percentage of Load Variability Explained by Different Load Components (Based on ANOVA, all storms).

Percentage of Load Variability Explained by:			
Parameter	**Concentration**	**Flow**	**Unknown**
Solids	4%	94%	2%
Copper	12%	42%	46%
Nickel	14%	43%	43%
Lead	32%	34%	34%
Zinc	7%	64%	29%

4.3 Results in the Program Area

4.3.1 Social Indicators

Public Involvement and Monitoring

Direct coordination by Program staff, and funding of additional projects which involved the public in urban runoff education and pollution prevention, constituted the main "public involvement and monitoring" activities that the SCVURPPP Co-permittees sponsored jointly and implemented through the Program. In addition, Co-permittees implemented activities independently under the auspices of the Program, as discussed below.

The Program maintained an "800" number for residents to request information regarding stormwater runoff and pollution prevention. During the 1997-98 fiscal year, Program staff fielded 210 calls. Program staff also:

1. Presented informational displays and distributed outreach material at approximately two community events per fiscal year (since 1995).
2. Made an average of two presentations concerning urban runoff pollution prevention per fiscal year to community and business groups.
3. Sponsored and assisted Co-permittees in organizing two countywide creek clean-up event.

Participation in creek clean-up events was well documented, but attendance at community events and presentations was seldom documented in the materials examined. Creek clean-up events have been successful as measured by increased participation each year (from 1 event and 600 volunteers in 1995-96 to 2 regular events and over 1800 volunteers in 1997-98), extensive media coverage, and positive feedback from Co-permittees and volunteers. Program staff also worked on regional level activities through the Bay Area Stormwater Management Agencies Association's (BASMAA) PIP Committee.

In addition, the Program involved the public in educational programs and monitoring activities by funding the following three PIP projects:

1. The Watershed Action Fund: designed to encourage and support pollution prevention and watershed awareness projects conducted by schools and community organizations has more than doubled the cash awards available since implementation in 1996-97.
2. Environmental Education Center: With Program support, the Center has been able to develop three new interactive programs focused on stormwater pollution, enhance its school education program to incorporate stormwater pollution prevention concepts, and increase the number of visitors to the Center each year.
3. Coyote Creek Riparian Station (CCRS): StreamKeeper volunteers were trained by CCRS staff to recognize and properly report incidents of runoff pollution and illegal dumping along their local creeks. Programs existed for nine creeks in the Santa Clara Basin and involved 73 members (as of June, 1997). From August 1995 until June 1997, StreamKeepers along Coyote, San

Francisquito, and Los Alamitos creeks reported and responded to 25 calls regarding pollution or potential creek problems.

In addition to the joint contributions to Program public involvement and monitoring activities, each Co-permittee was involved in a variety of activities related to: school education programs, volunteer storm drain stenciling, creek clean-up events, Adopt-a-Creek programs, community events, workshops/classes/presentations, household hazardous waste events, support of community groups, and a variety of other activities

One of the most successful and best documented were the school education programs. Seven of the twelve co-permittees reported coordinating and implementing School Education Programs. Five of the seven co-permittees documented the number of students and teachers that participated in their programs — combined, there were 20,283 participants. Co-permittees that did evaluate their school programs found the programs successful in involving a wide audience in thinking about urban runoff pollution prevention.

Public Attitude, User Perception

Fairbanks, Maslin, and Maullin (1999) details the results of the 1999 survey of 850 Program-area residents. The report also compares the 1999 results with a similar survey conducted in 1996. A summary of the measurements of awareness, perception, and behaviors from these two surveys follows.

Awareness

One in four residents remembered hearing or reading something about storm drain systems recently. Of these, a quarter remembered warnings against dumping substances in storm drains and an additional 20 percent retained that storm drains flow directly to the Bay. Twenty-two percent of those who had recalled something about storm drains remembered seeing the storm drain stencil (about six percent of all respondents). This number represents a slight decline from 1996, when 29 percent of those who had recalled something about storm drains remembered seeing the stencils (about 11 percent of respondents).

Many area residents continue to have misconceptions about how the storm drain system operates. Only two out of five residents understand that sanitary sewers and storm drains are separate systems, and only half realize that storm drain flows are not treated before they reach the Bay. These numbers did not differ substantially from the 1996 results.

Sixty-five percent of area residents correctly named the Bay or creeks as the place where storm drain flows end up; one in five (20 percent) incorrectly named the ocean. These proportions were virtually unchanged since the 1996 survey. Those who had seen storm drain stencils, or who said they had recalled something about storm drains recently, were significantly more likely to name the Bay or creeks as the final destination of storm drain flows.

Thirty-one percent of area residents have seen something dumped down a storm drain; in three out of four of those cases, it was either trash or oil. This represents an insignificant change from 1996, when 27 percent of residents had seen some form of storm drain dumping. In 1996, oil and trash were also by far the most commonly dumped substances.

Area residents generally understand that toxic chemicals pose a danger when poured into storm drains. However, many do not understand the harm that can be done by everyday items like leaves, grass clippings, swimming pool water, or water used to irrigate lawns or to wash a car. These results mirror the findings of the 1996 survey.

Eight out of ten survey respondents were most likely to label chemical and waste discharges from industry as the major source of water pollution, while a similar number pointed to hazardous wastes (75 percent). These percentages represented significant increases from 1996. In contrast, just 41 percent of respondents recognized discharge from storm drain systems as a major source of water pollution, a number virtually unchanged since 1996.

Santa Clara Valley residents were found to have a generally poor understanding of watersheds. While roughly one in four said they had seen or heard something about watersheds, only 42 percent of this group (or about eleven percent of all area residents) had any clear memory of what they had learned. When asked what the term "watershed" means, only one in four were able to define the term correctly, with an equal number identifying a watershed as a building used to store water.

Perceptions

Santa Clara Valley residents perceived traffic congestion as the area's most serious problem; 72 percent of survey respondents rated it as a very serious problem, up sharply from 59 percent in 1996. On the other hand, unemployment (18 percent) and crime (29 percent) were seen as very serious problems by far fewer respondents than three years ago. Forty-five percent of area residents perceived pollution of the environment as a very serious problem, a slightly smaller number than in 1996.

Water pollution remained as serious a concern for area residents as it was in 1996. Half of all respondents consider pollution of the Bay a very serious environmental problem, and nearly as many said the same for pollution of local creeks (43 percent), pollution of drinking water (42 percent) and pollution of wetlands (33 percent).

Residents believed that local reservoirs, rivers and creeks are best used for drinking water and as habitats for wildlife; four out of five respondents said such uses are very important. "Irrigation of crops or other agricultural uses" was the only other category labeled by a majority of respondents (65 percent) as a very important use of the area's water resources.

Area residents were inclined to fault large industrial or manufacturing companies for water pollution, and attributed far less responsibility to private residents. Sixty-eight percent said such companies were very responsible for water pollution, while just one in five said the same for private residents.

Seventy percent of the survey respondents indicated that the message "storm drain pollution destroys the environment for our children and future generations" would be very effective in getting people to change their behavior. The message that earned the next highest percentage (67 percent) was "storm drain pollution makes fish and seafood unhealthy for humans to eat." In third place was "storm drain pollution ruins our local creeks so fish, birds and wildlife can't live there" with 61 percent of those surveyed saying it would be very effective. These findings indicated no significant change from 1996.

When asked whether various natural features make "extremely important" contributions to the Valley's quality of life, 79 percent labeled the ocean extremely important. Seventy-two percent gave the same evaluation for the Bay, and 69 percent said the same for the region's air quality. These were the top three responses in both 1996 and 1999. Four out of ten respondents each labeled creeks and wetlands as extremely important to the quality of life in the Valley, figures virtually identical to those found in the 1996 survey.

Behavior

Valley residents continued to express great willingness to take a variety of actions to prevent water pollution (particularly supporting funding for public education, reporting illegal dumping, and using non-polluting brake pads). There were significant, though small, increases since 1996 in the proportion of residents proclaiming a willingness to use household hazardous waste collection centers, install non-polluting brake pads on their cars, and use non-toxic substances in place of pesticides and herbicides. However, the proportion of residents who actually engaged in such behaviors did not increased substantially since 1996.

Gardening and yard care continued to be the most common do-it-yourself activities in the Santa Clara Valley, with seven out of ten respondents responding they participate. Forty-five percent of respondents said they paint their houses, and 42 percent washed their cars at home. These results were almost identical to those obtained in 1996. Similarly, 30 percent of respondents said they change their own motor oil, an insignificant change from 31 percent in the 1996 survey.

Nine out of ten respondents visited ocean beaches at least occasionally, and roughly, four in five visited the Bay that often. Majorities made at least occasional visits to reservoirs, creeks and creek trails, and nature or interpretive centers along the Bay. None of these proportions have changed significantly since 1996. Local wetlands (41 percent) and the Guadalupe River (33 percent) were used by much smaller numbers of Valley residents.

When asked an open-ended question about what sources they would turn to if seeking information about ways to prevent pollution, the most frequently named responses were local government offices (33 percent), the phone book (13 percent), the garbage company or public works department (14 percent), the water company or water district (ten percent) and the Internet (nine percent). These percentages were roughly comparable to those obtained in the 1996 survey, though the proportion identifying the Internet increased substantially (from one percent in 1996 to nine percent in 1999).

When asked to evaluate different modes of communication, half of all respondents said they would definitely pay attention to classroom programs in schools (50 percent) and television commercials (50 percent). These were also the top two responses in 1996. In 1996, 44 percent of respondents said they would definitely pay attention to newspaper articles and that percentage remained roughly the same in the 1999 survey (40 percent). Generally, though, there appeared be to an across-the-board decline since 1996 in the proportion of respondents responding they would definitely pay attention to each of the modes of communication tested.

5. Application of Results to Watershed Management and Program Implementation in the Santa Clara Basin

This project included the application of 12 indicators in the Coyote Creek watershed, six indicators in the Walsh Avenue catchment, and three indicators in the SCVURPPP Program area as a whole.[7] The project objectives were to evaluate and refine the indicators, as well as to judge the usefulness of the 2-level indicator methodology.

The demonstration project tested whether systematic application of a group of indicators would assist the Santa Clara Valley Urban Runoff Pollution Prevention Program to characterize baseline conditions in the watershed (Level I in the Claytor and Brown methodology) and to assess and re-evaluate their management program (Level II).

As a first step to assess the general usefulness of the indicators (and the indicator methodology), we first review (in this chapter) how the indicator results are being used to improve watershed management and program implementation in the Santa Clara Basin.

In Chapter 6, we consider indicator benefits individually, i.e. compare our experience in the Santa Clara Basin with the specific useful characteristics Claytor and Brown ascribe to the indicators in their "Environmental Indicator Profile Sheets."

In Chapter 7, we review the usefulness of the collective results in the context of Claytor and Brown's proposed framework and methodology for using the indicators.

5.1 Application to Watershed Management

The results of applying physical, hydrological, water-quality, and biological indicators in Coyote Creek illustrate the complex natural history of this watershed. Quantitative results of these indicators are influenced by seasonal and year-to-year variation in rainfall and runoff and by natural variation in flow, gradient, geology, and vegetation along the stream corridor. These dynamic relationships also contribute to random variation in the parameters we measured.

However, spatial trends were evident along the urbanization gradient for most indicators that were field-sampled. Temporal trends were less evident, perhaps due to inadequate quality and documentation of historical data.

Our reference sites were located in undeveloped areas at higher elevation and with steeper slopes than the urban areas on the Valley floor. Over the past few decades the urban area has expanded beyond the region of consolidated soils and into an area of unconsolidated soils (and groundwater recharge) further up the alluvial plain (Fig. 3-5).

Downstream from Anderson Dam, Coyote Creek flows are controlled by releases and water diversions; the entire system is characterized by myriad influences of the region's history of development, including mining and agriculture. Figures 3-5, 4-1, and 4-2 partially illustrate the extent of damming, diversion, mining, and channel alteration within the watershed.

In many areas, the stream channel is still adjusting to the effects of past gravel mining, and riparian vegetation has not returned. In the urbanizing and urbanized reaches, the influence of watershed imperviousness, piped drainage and outfalls, and channelization are apparent, while an urban park chain has preserved riparian vegetation. Throughout lower Coyote Creek, habitat change, together with the introduction of exotic species of fish and other aquatic life, have created an ecosystem that — although it retains viable populations of native species — is fundamentally altered.

Riparian cover was consistently around 80% at the sites sampled in the urbanized area (Fig. 4-6), as a result of the City of San Jose's park chain along Coyote Creek, and was lower in the upstream reaches, where the creek is dry for much of the summer.

[7] The Permitting and Compliance Indicator (#23) was implemented in both the Coyote Creek watershed and the Walsh Avenue catchment. There were 20 indicators implemented in all.

Concentrations of arsenic, chromium and copper in Coyote Creek embedded sediments were similar to those found 20 years ago and did not appear to show any relationship to urban development. However, the spatial relationship of lead concentration to storm drain outfalls is readily apparent (Fig. 4-20). The elevated levels of lead in sediments from the urbanized portion of Coyote Creek most likely result from erosion of legacy deposits near major roadways. This may provide perspective on the behavior of other "legacy" pollutants, such as PCBs or chlorinated pesticides. A more complicated relationship is apparent for mercury (Figures 4-20), a pollutant of concern in San Francisco Bay. Here the pattern suggests other sources in the watershed, possibly including abandoned mercury mines in the watersheds of tributaries that enter Coyote Creek along its lower reaches. The significant apparent decline in sediment mercury concentrations over 20 years (Figure 4-21) may represent changes in a watershed source (e.g. "washing out" of legacy deposits from mining).

Coyote Creek continues to support significant native fish populations, including rainbow trout. Comparison with the project baseline study (Pitt and Bozeman, 1982) and other data suggests that fish assemblages are similar to what has been observed since 1950. However, there was significantly less biomass of introduced fish in rural reaches and significantly more native fish in urban reaches than in 1997-1980 (Table 4-7, Figure 4-23), suggesting that the population of native fish in the creek may have increased. This may be the result of increased summer streamflow from dam releases. Peak stream flow in antecedent years may also influence the relative incidence of native and non-native fish species.

Improvement in the urban reaches is also suggested by increases in the mean percentage of EPT taxa since 1977-1980 (Figure 4-29). However, there are still significantly more low tolerance macroinvertebrate taxa in the rural and reference reaches as compared to the urban reaches (Figure 4-30), indicating that water quality is still a concern in the lower reaches of the watershed. This may be confirmed by the depressed dissolved oxygen levels (Figure 4-27) at Station TS-1.

Despite the improvements in the urbanized reaches, the past 20 years' development at the urban fringe has apparently resulted in declining habitat or water quality, or both, in the affected reaches of Coyote Creek. This was shown by a significant decrease in the percentage of EPT taxa at these stations. Qualitative comparison of the number of native fish species and percentage of native fish species at stations sampled in 1999 and 1977-80 (Figure 4-23) suggests that the boundary between urban and rural reaches (as characterized by this indicator) has shifted upstream as a result of ongoing development.

Consistent with this latter finding, cumulative percent subwatershed imperviousness was strongly associated with several fisheries metrics at a species level (number and percent of tolerant species; number of nonnative species, and all species) and an individual level (number of native individuals, number of diseased individuals) (Table 4-8, Figure 4-26). The steepest response was noted between 8% and 11% imperviousness.

These results suggest that the Santa Clara Basin Watershed Management Initiative should focus on limiting the effects of future development on stream hydrology and riparian areas (particularly in the "transition" areas at the urban fringe). There is also apparent potential to obtain significant improvements in the habitat value of urban reaches, possibly by improving summertime flows and water quality. In addition, there may be opportunities to improve habitat through restoration of some in-stream characteristics.

5.2 Application to the Santa Clara Valley Urban Runoff Pollution Prevention Program

The biological indicators suggest that effects on beneficial uses are associated with the presence of stormwater outfalls. Stormwater outfalls correlate with increased sediment concentrations of cadmium and lead, but the concentrations found are not associated with measurable impacts on aquatic life or other beneficial uses. Results of the water-quality indicators were inconclusive regarding any specific relationship to long-term loadings of the measured pollutants.

Although dissolved oxygen monitoring is not one of Claytor and Brown's water-quality indicators, our use of continuous monitoring probes (performed to support interpretation of the fish assemblage and macroinvertebrate assemblage data) revealed that dissolved oxygen was repeatedly depressed at one urban station, and that a extreme and prolonged drop may have been associated with a fish kill at that location. This suggests that the most significant water-quality problem related to storm drain discharges may be acute and short term, rather than chronic, and related to conventional pollutants (biochemical oxygen demand) rather than toxic pollutants. This possibility deserves further investigation and could lead to significant changes in stormwater pollution prevention priorities.

From 1993 to 1998, the urban runoff pollution prevention program achieved 70-fold decrease in illicit connections reported; a concurrent trend toward fewer illegal dumping reports (for most categories) suggest that the Co-permittees' outreach, industrial/ commercial inspections, response to dumping incidents, and enforcement have had an effect. This is consistent with surveys in the Walsh Avenue catchment, which showed a heightened awareness, among facility managers, of the need to implement "good housekeeping" measures to avoid the entry of pollutants into storm drains. During this same period, many industrial facilities became subject to a statewide NPDES stormwater discharge permit; however, compliance (as measured by filing of applications and reports) is relatively low.

Zinc is the primary pollutant of concern in runoff from the Walsh Avenue Catchment. Total zinc concentrations remained at high levels throughout the monitoring period. This could be due to accumulated zinc in the storm drain system and in unpaved areas in the catchment or due to continued discharge from the facilities in the catchment.

Significant decreases in solids, lead, and nickel in runoff from may be the result of improvements in housekeeping at businesses within the catchment. Decreases in lead are probably due to elimination of tetraethyl lead from gasoline and decreases in solids loads in general (lead was highly associated with solids). Decreases in nickel concentrations may be due to improved management BMPs or changes in industry types located in the catchment.

Results of some programmatic indicators were immediately applicable (and many were immediately applied) to improving the stormwater pollution prevention program.

The primary value of tracking illegal discharges, illicit connections, industrial inspections, and BMPs is the use of the resulting data to target further inspection and enforcement efforts. Our results showed that this benefit depends on the completeness and accuracy of the data collected and the consistency with which it is recorded. In addition, the use of relational databases and georeferencing the data greatly enhance the targeting process.

We found that the methods used to collect and record data varied considerably between departments and between municipalities within the Program, and all departments could benefit from additional technical support. The recent development of internet-based tools for entering and storing data makes it feasible for staff from the various program municipalities to enter and update records in a centrally maintained database. Discussions with municipal staff led to a decision to investigate the feasibility of a consistent reporting system and centralized, internet-accessed database for recording illegal dumping incidents.

Two of the social indicators — the Public Involvement and Monitoring indicator and the Industrial/Commercial Pollution Prevention indicator — revealed the advantages of incorporating interviews and other feedback mechanisms into the Program's outreach efforts.

The surveys performed to implement the Public Attitude Surveys indicator and the User Perception indicator helped the Program gauge public awareness of watershed issues and allowed the Program to gauge how well a future campaign will be received. The survey results will serve as a basis for the development of the Program's upcoming five-year Watershed Education and Outreach Campaign.

6. Utility Of Individual Indicators And Recommended Refinements

Claytor and Brown (1996) describe a "utility of indicator to assess stormwater impacts" for each of their 26 proposed stormwater environmental indicators.

Based on these descriptions, for each of the 20 indicators we implemented and tested (Table 3-1), we developed specific questions applicable to our study (Table 6-1). We evaluated the utility of each indicator based on our ability to answer these questions using the data obtained from this study.

Consequently, our assessment of indicator utility is biased by the specific circumstances under which the indicator was applied. Factors that affected the utility of more than one of the indicators included:

⇒ Region and climate. Interpreting the results of many of the physical/hydrological, water-quality, and biological indicators requires consideration of intra-annual and inter-annual rainfall cycles characteristic of the semi-arid coastal climate.

⇒ Watershed scale. We implemented different indicators at the scale of a 310-square-mile watershed, a 28-acre catchment, and the 13-municipality program area.

We have attempted to identify where these factors affect the utility of specific indicators.

Each indicator we tested, and its usefulness, is discussed below. The numbering follows that of Claytor and Brown (1996).

Recommended refinements to each indicator are presented in Table 6-2.

6.1 Water Quality Pollutant Constituent Monitoring

Even with relatively large datasets, it may be impossible to detect changes in water quality constituents due to implementation of BMPs or changes in land use. The model we developed was able to account for a large percentage of the variability of many metal constituents (when measured as total recoverable metals). After applying the model, changes of 40% could be detected with reasonable sample sizes.

However, it is unlikely that such an extreme trend would actually occur in Coyote Creek. Total metals are often associated with suspended solids, and concentrations tend to reflect changes in the amount of erosion and sediment/bedload transport occurring in the stream channel. In Coyote Creek particulate copper concentrations in "wet" winters decreased by approximately 50% from particulate concentrations in "dry" winters (Dry Winter = 133 ug/g; Wet = 65 ug/g).

Monitoring during dry winters or selecting lower flow events may help overcome the influence of constituents in eroded soils.

It might be more feasible to detect trends in pollutant concentrations in storm drain discharges, rather than creek flows. (We did detect trends in pollutant concentrations from monitoring the storm drain in the Walsh Avenue catchment. See the discussion of Indicator #3, Nonpoint Source Loading, below.) However, measuring concentrations of pollutants in runoff still in storm drains is somewhat less relevant to the objective of protecting beneficial uses, since pollutants in storm drains may be diluted, settled out, or transformed upon reaching downstream water bodies.

The most significant effects of water-quality constituents on aquatic life in Coyote Creek may well be due to conventional pollutants (i.e., biochemical oxygen demand) rather than toxic pollutants, and may be short-term, rather than cumulative over time. Continuous monitoring of stream pools for dissolved oxygen (and temperature, pH, and conductivity) in summertime, coupled with targeted surveillance of dry-weather flows, may be more useful than monitoring storm flows for toxic pollutants.

6.2 Toxicity Testing

Toxicity testing was not useful because the test was too sensitive and no changes (positive or negative) could be observed. The usefulness of toxicity testing to determine trends could be improved if dilution series were incorporated into

Table 6-1: Claytor and Brown (1996) indicator utility and SEIDP criteria used to evaluate each indicator.

Indicator	Utility of Indicator to Assess Stormwater Impacts (as interpreted from Claytor and Brown 1996)	Criteria Used to Evaluate Indicator (SEIDP 1999)
COYOTE CREEK		
Physical and Hydrological Indicators		
Stream Widening and Downcutting	⇒ Can be used to identify stream segments susceptible to channel erosion. ⇒ Can document the rate of change to channel geometry as a function of increased urbanization. ⇒ Useful in estimating the effectiveness of stormwater Best Management Practices and document the locations where additional controls are needed. ⇒ Useful in estimating habitat quality by determining if excessive flow rather than water quality, are limiting factors for aquatic health. ⇒ Can assist municipalities to develop better stormwater management criteria to reduce streambank erosion.	⇒ Can indicator be used to identify changes in channel morphology in Coyote Creek as the watershed became urbanized (early 1980's to present)? ⇒ Is it possible to evaluate whether any influence on channel morphology could be attributed to BMPs implemented in connection with the stormwater Program (initiated in the early 1990s)? ⇒ Determine whether to recommend channel widening and downcutting as an indicator for impacts related to urban run-off and as a measure of stormwater Program effectiveness.
Physical Habitat Monitoring	⇒ Can help isolate and assess whether water quality or habitat is limiting aquatic biological health. ⇒ Can help identify specific causes of degraded habitat, e.g., uncontrolled stormwater runoff. ⇒ Can evaluate restoration potential. ⇒ Can be used to enhance physical structure of a stream system; to increase or maintain habitat.	⇒ Can this indicator be used to determine whether habitat and/or water quality are factors limiting aquatic biodiversity? ⇒ Can this indicator be used to identify creek reaches with restoration potential? ⇒ Is this indicator useful for identifying causes of habitat degradation?
Increased Flood Frequency	⇒ Can be used to assess the frequency, duration, and quantity of flooding with increasing urbanization. ⇒ Can be used to evaluate the effectiveness of structural BMPs in reducing the potential of flooding and streambank erosion. ⇒ Can be used to evaluate flooding potential associated with different land use development patterns. ⇒ Can indirectly predict potential for streambank erosion and habitat degradation.	⇒ Assess the location, frequency, duration, and quantity of flooding associated with increasing urbanization. ⇒ Evaluate flooding potential associated with land use development patterns. ⇒ Identify flood prone areas.
Stream Temperature Monitoring	⇒ Can be used to assess the effects of urbanization on stream temperature base flows and storm flows. ⇒ Can be used to assess the effects of BMPs on stream temperatures and help in promoting practices, which have fewer impacts.	⇒ Do spatio-temporal comparisons among monitoring stations indicate: ⇒ Where land uses have changed since the 1977-80 baseline study? ⇒ Reaches that could benefit from riparian buffer enhancement?

Table 6-1: Claytor and Brown (1996) indicator utility and SEIDP criteria used to evaluate each indicator.

Indicator	Utility of Indicator to Assess Stormwater Impacts (as interpreted from Claytor and Brown 1996)	Criteria Used to Evaluate Indicator (SEIDP 1999)
	⇒ Can help identify stream reach lengths that may benefit from riparian buffer enhancement. ⇒ Can be used as a watershed land use planning tool in protecting cool water stream systems.	⇒ Is this indicator a useful measure of stormwater program effectiveness?
Water Quality Indicators		
Water Quality Pollutant Constituent Monitoring	⇒ Monitoring results from long-term efforts can be used to identify trends in water quality over time. ⇒ Monitoring results may be compared to reference rural or "least impacted" watershed to assess the degree of impairment. ⇒ Trends may result from land-use changes in the watershed or watershed restoration efforts.	⇒ Has water quality changed during the monitoring period? ⇒ How much of the variability is due to hydrologic factors? ⇒ Can the influence of hydrologic factors be accounted for and how much monitoring would be required to determine a given change in water quality with and without accounting for changes in hydrology?
Exceedance Frequencies of Water Quality Standards	⇒ Can characterize water quality impacts due to urban runoff with respect to various storm categories (frequent storms, flood events). ⇒ Can identify long-term and seasonal trends in regional water quality. ⇒ Can document periods of poor water quality (e.g., following large storm events; during low-flow summer months). ⇒ Can be used to evaluate the performance of stormwater BMPs with respect to various storm frequencies.	⇒ Are water quality standards exceeded? ⇒ Are time-trends in the number of exceedances of water quality standards present? ⇒ Is it possible to show further improvements in the number of exceedances of water quality standards?
Sediment Characteristics and Contamination	⇒ Can indicate contamination levels in urban embayments, and by proximity, the probable source of contamination in the drainage area. ⇒ Samples taken within and/or immediately upstream and downstream of stormwater management facilities can be used to evaluate BMP performance. ⇒ Analyzing trends in sediment pollutant levels may indicate long-term changes in pollutant loadings. ⇒ Over a long period of time, analysis of sediment pollutant levels may be used to evaluate stormwater management efforts to control particular pollutant sources.	⇒ Have the concentrations of surficial sediment contaminants increased since the 1978-79 baseline study? ⇒ Do the concentrations of sediment contaminants in the urbanized area differ from those at the reference sites? ⇒ Are the concentrations of sediments a function of increased urbanization? ⇒ Does this indicator provide a useful measure of stormwater program effectiveness? ⇒ Can the protocols be refined to make this indicator more effective?
Biological Indicators		
Fish Assemblages	⇒ Can characterize the existence and severity of aquatic ecosystem degradation and help identify causes and sources of degradation. ⇒ Can be used to evaluate the effectiveness of restoration programs and help prioritize sites for future evaluation.	⇒ Do spatio-temporal comparisons among the station groups indicate where land uses have changed since the 1977-80 study? ⇒ Can the revised Rapid Bioassessment Protocols (Barbour et al. 1997) be applied to the Coyote Creek Watershed? ⇒ Is this indicator a useful measure of stormwater program effectiveness?

Table 6-1: Claytor and Brown (1996) indicator utility and SEIDP criteria used to evaluate each indicator.

Indicator	Utility of Indicator to Assess Stormwater Impacts (as interpreted from Claytor and Brown 1996)	Criteria Used to Evaluate Indicator (SEIDP 1999)
	⇒ Can be used to help evaluate the effectiveness of BMP controls. ⇒ Can be used on both a regional and local level. ⇒ Can help identify barriers to fish migration. ⇒ Can be used to mobilize public support when popular species are impacted.	effectiveness? ⇒ Can the protocols be refined to improve effectiveness; if so, how?
Macroinvertebrate Assemblages	⇒ Can be used to characterize the existence and severity of aquatic ecosystem degradation. ⇒ Can help screen potential sources and causes of such degradation. ⇒ Can help assess the performance of watershed restoration measures (particularly in-stream habitat restoration projects). ⇒ Can help evaluate the performance of stormwater BMPs. ⇒ Can be used to identify short-term impacts (e.g., from new construction) to aquatic ecosystems.	⇒ Do spatio-temporal comparisons among the station groups indicate where land uses have changed since the 1977-80 study? ⇒ Can the revised Rapid Bioassessment Protocols (Barbour et al. 1997) be applied to the Coyote Creek Watershed? ⇒ Is this indicator a useful measure of stormwater program effectiveness? ⇒ Can the protocols be refined to improve effectiveness; if so, how?
Programmatic Indicators		
Number of Illicit Connections Identified/Corrected	⇒ Quantifying the number of illicit connections identified and corrected can characterize pollutants that have a direct and immediate effect on water quality. ⇒ Estimate the frequency and severity of illegal discharges to the storm drainage system ⇒ Can be used as a measure to assess the effectiveness of a municipality's overall stormwater program.	⇒ Do Co-permittee ICID programs identify the type, location, and frequency of pollutants introduced illegally to the stormdrain system? ⇒ Is information reported by ICID inspectors useful for improving efforts to reduce occurrences of ICID incidents? ⇒ Is information reported by ICID inspectors useful for evaluating potential pollutant effects on water quality and on biological communities?
Permitting and Compliance	⇒ Can be used to identify potentially significant contributors of pollutants. ⇒ Can be used to assess the level of industrial support for stormwater management efforts. ⇒ Can be used by NPDES program managers to assess compliance with regulations and designate areas for improvement. ⇒ Allows identification of uncontrolled sources of pollution to stormwater.	⇒ Is information available in existing databases useful to identify potential impacts of pollutants on aquatic communities? ⇒ Is data quality sufficient to support evaluation of stormwater program effectiveness?
Growth and Development	⇒ Can estimate existing and potential cumulative impacts of urbanization on aquatic ecosystem functions. ⇒ Used as a planning tool in making zoning and master planning decisions.	⇒ Can estimates of imperviousness be correlated with indicators for aquatic health? ⇒ Can imperviousness estimates be used to assist planners with future development strategies?

Table 6-1: Claytor and Brown (1996) indicator utility and SEIDP criteria used to evaluate each indicator.

Indicator	Utility of Indicator to Assess Stormwater Impacts (as interpreted from Claytor and Brown 1996)	Criteria Used to Evaluate Indicator (SEIDP 1999)
	⇒ Used to evaluate effectiveness of Best Management Practices (BMPs) in extending development thresholds. ⇒ Cost-effective (compared, for example, to hydrologic modeling). ⇒ An easily quantified indicator of urbanization. ⇒ Well-understood within a variety of professional disciplines.	⇒ Can imperviousness be used to monitor BMP effectiveness?
Social Indicators		
Public Involvement and Monitoring	⇒ Can be used to help modify citizen behaviors related to source controls. ⇒ Can help reduce monitoring expenses and expand a jurisdiction's monitoring database. ⇒ Can help identify pollutant sources through citizen watchdog actions. ⇒ Can educate students about water pollution issues. ⇒ Can generate political support for additional stormwater and watershed funding. ⇒ Can foster acceptance of projects through close relationships with communities.	⇒ Comparison to PIP goals. ⇒ Comparison to previous year's results. ⇒ Feedback from target audience, Co-permittees, educators, co-sponsoring organizations, or other staff involved. ⇒ Estimates of attendance or participation. ⇒ Amount of trash removed, miles of creek cleaned, etc. ⇒ Trends observed in pollution problems. ⇒ Observed changes in behavior.
Public Attitude Surveys	⇒ Can assess the publics perception of existing or proposed water quality problems. ⇒ Can identify the relative value the public places on a particular water quality issue and thus a foundation for political action. ⇒ Solicit public or private funding for a particular water resource issue. ⇒ Used to develop a public education campaign which incorporates results of surveys into future programs. ⇒ Used to develop more effective pollution prevention programs based on reported behaviors and target resources to watershed related activities.	⇒ Do surveys indicate public's attitudes and awareness of urban runoff pollution issues? ⇒ Has the public's awareness or behavior changed as a result of the Program's public education efforts? ⇒ Do surveys provide information to guide the Program in the development of future public education efforts?
User Perception	⇒ Can assess the publics preception of conditions in the watershed. ⇒ Can educate the public about the hidden impact of water quality pollution. ⇒ Used to generate stewardship programs and public support for water restoration efforts. ⇒ Used to develop a public educational program which incorporates the results of surveys into future programs.	⇒ Do surveys indicate public's attitudes and awareness of urban runoff pollution issues? ⇒ Has the public's awareness or behavior changed as a result of the Program's public education efforts? ⇒ Do surveys provide information to guide the Program in the development of future public education efforts?

Table 6-1: Claytor and Brown (1996) indicator utility and SEIDP criteria used to evaluate each indicator.

Indicator	Utility of Indicator to Assess Stormwater Impacts (as interpreted from Claytor and Brown 1996)	Criteria Used to Evaluate Indicator (SEIDP 1999)
WALSH AVENUE CATCHMENT		
Water Quality Indicators		
Toxicity Testing	⇒ Considerable amounts of existing data describe acute and chronic toxicity limits for various species. ⇒ Toxicity testing can be used to evaluate the effectiveness of stormwater BMPs and other stormwater pollution reduction measures. ⇒ Results of toxicity testing can be used by watershed managers to identify areas of high concern and to establish restoration priorities. ⇒ Phase I, II, and III TIE procedures can be used to help identify specific pollutant sources.	⇒ Is toxicity present? ⇒ Are toxicity time trends observed? ⇒ Are toxicity trends correlated to measured water quality?
Non-point Source Loadings	⇒ Trends in NPS pollutant loadings can be compared to land use changes or implementation of BMPs to assess potential increases or reduction in NPS pollution. ⇒ Can be used to help identify major land uses that are significant sources of NPS pollution. ⇒	⇒ Have pollutant loads changed during the monitoring period? ⇒ How much of the variability in pollutant loadings due to hydrologic factors? ⇒ Can the influence of hydrologic factors be accounted for, and how much monitoring would be required to determine a given change in pollutant loads with and without accounting for changes in hydrology?
Programmatic Indicators		
Industrial/Commercial Pollution Prevention	⇒ Can be used to assess industry's perception of effectiveness of stormwater BMPs and methods for improvement. ⇒ Can be used to assemble and compare implementation costs between different industries and geographic locations. ⇒ Can be a component of an industry stormwater educational program which incorporates results into future pollution prevention efforts. ⇒ Can foster partnerships with industry and help managers identify site conditions of which they may be unaware.	⇒ Can it identify effectiveness of stormwater BMPs? ⇒ Can it determine if BMPs are cost effective? ⇒ Can it provide guidance for improvements to future pollution prevention efforts?
BMP's Installed, Inspected and Maintained	⇒ Can expose weakness in BMP design, reveal maintenance needs, and determine needs for enforcement actions. ⇒ Determine if existing BMP's are sufficient in scope and size. ⇒ Propose improvements to the design criteria for future BMPs.	⇒ Does it provide information to refine BMP design and maintenance strategies? ⇒ Are BMPs adequately installed, maintained and in the correct locations?

Table 6-1: Claytor and Brown (1996) indicator utility and SEIDP criteria used to evaluate each indicator.

Indicator	Utility of Indicator to Assess Stormwater Impacts (as interpreted from Claytor and Brown 1996)	Criteria Used to Evaluate Indicator (SEIDP 1999)
	⇒ Provide useful data when conducting stormwater retrofit inventories.	
Industrial Site Compliance Monitoring	⇒ Can help to evaluate the performance of structural and non-structural stormwater BMPs. ⇒ Determine the industry's contribution to overall water quality degradation or improvement. ⇒ Induce public education, support and activism. ⇒ Solicit political pressure and support for planning issues. ⇒ Determine industrial stormwater management needs, water quality trends and target restoration efforts. ⇒ Identify areas where technical support or research are needed to help address problems.	⇒ Can it identify the effectiveness of stormwater BMPs? ⇒ Can it show correlation between industrial pollutants and water quality? ⇒ Can it be used to educate the public and influence political leaders and planning officials? ⇒ Can it identify stormwater management needs, water quality trends and restoration sites?

Table 6-2. Recommended Refinements to Stormwater Environmental Indicators

Indicator	Indicator Refinements
Water Quality Indicators	
Water Quality Pollutant Constituent Monitoring	⇒ Evaluate relationships between hydrology and water quality. ⇒ Monitoring during dry winters or selecting lower flow events may help overcome the influence of constituents in eroded soils. ⇒ It might be more feasible to detect trends in pollutant concentrations in storm drain discharges, rather than creek flows, with potential for continuous monitoring using sondes.
Toxicity Testing	⇒ Evaluate event hydrology to ensure flows are adequately measured. ⇒ Incorporate dilution series into test design, especially for stations where acutely toxic concentrations are expected. ⇒ Consider factors such as duration of exposure and temperature when interpreting results.
Non-point Source Loadings	⇒ Screen event flow for large events or conduct a separate analysis for events of different return frequencies to ensure loads are not unduly biased by trends in flow. Adequate flow monitoring is necessary to ensure accurate measurements throughout the flow range. ⇒ Monitor as many storms as possible within a season to provide a range of flows and quality data. ⇒ Monitor for multiple years to capture the effects of year to year changes in hydrology.
Exceedance Frequencies of Water Quality Standards	⇒ The indicator could be successfully applied only in cases where many exceedances have occurred for several parameters. ⇒ Tracking the number of exceedances of total metals WQOs (as opposed to WQCs) showed more promise as an indicator of water quality. ⇒ Estimate background concentrations either through a paired watershed design or evaluation of upstream or rural areas. ⇒ Perform power analysis to determine adequate sampling frequency for trend detection. ⇒ Note: stormwater sampling periods (typically 24 hours) don't necessarily coincide with the water-quality criteria that apply to exceedances (e.g., 1-hour acute toxicity or 4-day chronic toxicity criteria).
Sediment Characteristics and Contamination	⇒ As with Indicator #1, trends may be more apparent when this indicator is applied to sediments in storm drains rather than in creeks. ⇒ *Improvements to sampling protocol* ⇒ Addition of iron, aluminum, lithium and other tracer metals to the analytical set in order to enable analysis of enrichment of contaminants relative to background conditions and assist in source identification. ⇒ Sieve sediments through a 200 micron sieve prior to analysis. ⇒ Establish background concentrations of the target analytes (including major elements to be used for normalization) in the primary soil classifications contained in the watershed using consistent methodology. ⇒ Consider use of sediment traps to augment grab samples. ⇒ Extend sampling program into tributaries and stormwater conveyances. ⇒ Schedule sampling during the storm season at intervals based upon seasonal rainfall accumulation.
Physical and Hydrological Indicators	
Stream Widening and Downcutting	⇒ For monitoring impacts related to impervious surfaces, this indicator is best used in small watersheds that lack major dams, have few or no channel modifications, and minimal alterations to the stream channel from mines and quarries. ⇒ Regardless of the context in which they are applied, stream geometry measurements are useful only when they are appropriately monumented and repeated. ⇒ The use of cross-section geometry measurements is preferable to interpretation of aerial photos. ⇒ To assess stream quality, it is important to characterize streams based on their structure and function.

Table 6-2. Recommended Refinements to Stormwater Environmental Indicators

Indicator	Indicator Refinements
Physical Habitat Monitoring	⇒ Use of habitat assessment approach that is adapted to regional stream conditions and data collection standards is recommended. ⇒ In a smaller, less complex watershed, changes in study design to compare habitat condition above and below outfalls, or catchments with and without BMP controls, may improve evaluations of urban runoff effects and effectiveness of a stormwater program. ⇒ Indicator may best be used prospectively, in conjunction with a suite of indicators, in watersheds that are beginning to urbanize, in order to develop temporal baseline data often lacking in highly urbanized regions.
Increased Flood Frequency	⇒ Measure changes in streamflows rather than location, frequency, and magnitude of flood events. This is particularly relevant for watersheds in which existing dams regulate the natural hydrography. ⇒ Identify and estimate the impacts of instream infrastructure and channel modifications on creek hydrographs.
Stream Temperature Monitoring	⇒ Consider including other water quality parameters, particularly DO, which are useful for interpreting the relative influences of water quality and habitat on biological indicators. ⇒ Consider using aerial photo interpretation rather than temperature monitoring where the primary objective is to identify stream reaches needing riparian restoration. ⇒ Consider using temperature probes in stormdrain inlets, which would indicate whether stormwater temperature is significantly different than receiving water.
Biological Indicators	
Fish Assemblages	⇒ Correlate assemblage shifts observed from historical data with major changes in human activities as evident from landscape changes (e.g., dam construction, channel modification, etc.). ⇒ Correlate assemblage shifts observed from historical data with changes in stream hydrology - both caused by precipitation variation, and flow regulation. ⇒ protocols used for application of this indicator should be selected based on methods developed and recommended for the particular region where it is to be implemented *Improvements to California Rapid Bioassessment sampling protocol* ⇒ Single sampling event may be sufficient and time of sample may be determined by natural history of fish species (e.g. Spring season for rainbow trout) ⇒ Consider using single pass electrofishing method rather than three pass to increase efficiency; method employed may be dependent on type of habitat sampled. ⇒ Data on length of individual fish was not used. Eliminating length or recording class size would reduce field time. ⇒ Field duplicates are highly variable and are not cost effective. ⇒ Monitoring of dissolved oxygen concentration was useful for interpretation of fish sampling results.
Macroinvertebrate Assemblages	⇒ Consider using sampling protocol that is adapted to regional stream conditions and data collection standards. ⇒ To conduct temporal comparisons, it is critical that taxonomy be identified to a similar level in previous studies. In addition, it is important to maintain regional consistency in sampling protocol to enhance data comparisons ⇒ Monitoring needs to be appropriately designed with respect to location and timing of factors contributing to degradation. This might require that the monitoring program be prospective (i.e. put in place prior to a significant change such as a stream restoration effort or development of a tributary area) rather than retrospective. *Improvements to sampling protocol* ⇒ Sample effectiveness is limited in stream reaches that have low velocity and are predominately silt and clay; sampling these habitat types may not be efficent. ⇒ The number of organisms counted and identified from a composite sample, and the number of subsamples varies among researchers. The California Department of Fish and Game is establishing standardized protocols.

Table 6-2. Recommended Refinements to Stormwater Environmental Indicators

Indicator	Indicator Refinements
Social Indicators	
Public Attitude Surveys	⇒ Retitle indicator to "Public Attitude and Behavior". ⇒ Focus on the behavioral changes in the public to evaluate Program effectiveness. ⇒ Use a combination of broad and specific level surveys to obtain information to evaluate stormwater Program effectiveness.
Industrial/Commercial Pollution Prevention	⇒ Clearly inform businesses of the intent and focus of stormwater pollution prevention inspections and conducting follow-up re-inspections on a timely basis. ⇒ Site visits were found to be very effective for information exchange. The written surveys alone would not have been as effective in determining the Program's impact and the industries' understanding of the Program.
Public Involvement and Monitoring	⇒ Conclusions regarding program effectiveness need to be based on pre-defined, measurable program goals, and must be specified prior to evaluation. ⇒ Pre-establish standard formats and requirements for follow-up evaluations of outreach programs, so that results are well documented.
User Perception	⇒ Stormwater programs may most successfully apply user perception to justify resources and focus pollution prevention efforts. ⇒ There are many external variables that influence user perception and thus limit the usefulness of this indicator.
Programmatic Indicators	
Number of Illicit Connections Identified/Corrected	⇒ Consider the following when applying the indicator:: trends in population, transportation, and development growth; tormwater program self-evaluations; changes in stormwater programs, including targeted sectors, changes in staff and training, increased enforcement, and the use of new technology; increased outreach efforts; length of time program has existed. ⇒ Revising categories used for ICID incident reporting so that associated pollutants reflect the category title. ⇒ Storing ICID incident data in a relational database that includes the street address and the pollutants likely associated with the incidents. ⇒ Georeferencing ICID data to identify spatio-temporal patterns of incidents, guide future targeted pollution prevention efforts, and facilitate efforts to analyze impacts of pollutants on aquatic communities.
BMP's Installed, Inspected and Maintained	⇒ Consistent documenting inspections in an efficient record-keeping system. A relational database is suggested to systematically organize documentation by site visit, potential pollutants, and best management practices. ⇒ The indicator's usefulness might be limited to businesses that are required to install specific devices to prevent stormwater pollution rather than operational BMPs (e.g., housekeeping, materials storage, and waste disposal).
Permitting and Compliance	⇒ Include in the indicator whether, and how, programs prioritize their inspections. (Evaluating programs based only on the number of inspections does not indicate whether industries with the greatest potential to discharge the most toxic pollutants are prioritized for inspections, nor the frequency of inspections.) ⇒ Encourage state regulatory agencies to integrate and coordinate implementation of their statewide general permits for specific activities with implementation of municipal stormwater NPDES permits. ⇒ Encourage state regulatory agencies to implement systematic review and documentation of SWPPPs, annual reports and updates to SWPPPs, and monitoring reports. ⇒ Encourage state regulatory agencies to provide businesses covered under general permits with guidance for sampling and analyzing runoff. In addition, regulatory agencies should enter submitted water quality data into an accessible database that can be linked to georeferenced facility locations.

Table 6-2. Recommended Refinements to Stormwater Environmental Indicators

Indicator	Indicator Refinements
Growth and Development	*Techniques for Estimating Imperviousness* ⇒ Consider alternative methods to estimate existing and future percent imperviousness. Criteria for method selection should include the accuracy and availability of data sources as well as watershed size. ⇒ Document data sources and methods so that valid comparisons can be made to other studies. ⇒ Consider how estimates of imperviousness can be used to estimate runoff coefficients and pollutant loads ⇒ Distinguish among components of imperviousness attributable to major land uses. Consider how this information might be used in a strategy to reduce the effects of imperviousness. *Application of Indicator* ⇒ To more closely associate impacts associated with imperviousness with aquatic ecosystem functions, consider selecting a subwatershed or catchment scale for analysis. ⇒ Compare changes in percent imperviousness with implementation of structural BMPs. ⇒ Track whether results from imperviousness analyses are influencing land-use planning. ⇒ Consider how increased imperviousness is accommodated by drainage system improvements. ⇒ Compare existing imperviousness to projected imperviousness to estimate the potential urban impacts to streams, and to guide development and implementation of watershed management strategies. Re-evaluate watersheds on a 5-year cycle, and reexamine watershed management strategies. ⇒ After estimating the rate and pattern of how imperviousness is changing, consider using the indicator to select monitoring locations for hydrological, physical, and biological indicators.
Industrial Site Compliance Monitoring	⇒ Providing inspectors with routine refresher training. Inspectors should receive updates on Program activities and on new or revised BMPs. The inspectors should also be trained to effectively communicate this information to site managers during inspections. ⇒ Better documentation of inspections would make it possible for stormwater programs to use the indicator to target outreach and document progress.

the test design, especially for stations where acutely toxic concentrations are expected. Other factors such as duration of exposure and temperature need to be considered when interpreting results.

Most importantly, samples from storm drains may not accurately represent in-stream conditions, and so cannot be directly related to potential ecological effects. Substances that contribute to toxicity may be diluted to non-toxic levels or may complex with sediment and organic materials in-stream, greatly reducing their bioavailability.

6.3 Nonpoint Source Loadings

We were able to identify a trend toward reduction in concentration of some pollutants, and to a lesser extent event loads, in the Walsh Avenue Catchment. These may be attributable to improved housekeeping and use of BMPs.

For all parameters with significant trends (solids, lead, and nickel), decreases in concentration were easier to detect and more statistically significant than decreases in event loads. This is due to the increased variability in event loads because of the changing event flows. Use of loads for the assessment required a detailed examination of both the concentration database and the hydrology database.

Compared with Water Quality Pollutant Constituent Monitoring (Indicator #1) this indicator adds another layer of complexity and variability while providing little additional relevance to protection of beneficial uses. This is particularly true in semi-arid climates, where year-to-year differences in rainfall will strongly affect the quantity of any runoff constituent (regardless of natural or anthropogenic source) that reaches receiving waters. One might ask the relevance of achieving, say, a 20% reduction in average annual runoff pollutant loading, when the year-to-year variation in loading (due to differences in rainfall) could be ten times that amount.

Much of the dataset used for this project was compromised due to incomplete hydrology data and problems with pipe surcharging (backing up) during high flows. (When flow is backed up, samples are no longer accurately flow-weighted, and an event mean concentration cannot be calculated). Installation of a weir (to allow calculation of flow) in the sampling manhole probably contributed to surcharging. An alternative might be to use velocity sensors to record flow.

The following information should be considered when applying Indicators #1 (Water Quality Monitoring) and #3 (Nonpoint Source Loading) to small catchments :

⇒ Changes in businesses and business types.

⇒ Annual and seasonal trends in event flows.

⇒ Adequate flow monitoring to ensure accurate measurements throughout the flow range.

⇒ Concentrations of pollutants relative to urban background.

⇒ Length of time program has existed.

To enhance the utility of Indicator #3 we recommend:

⇒ Evaluating event hydrology to ensure flows are adequately measured.

⇒ Screening event flow for large events or conducting a separate analysis for events of different return frequencies to ensure loads are not unduly biased by trends in flow.

⇒ Monitoring as many storms as possible within a season to provide a range of flows and quality data.

⇒ Monitoring for multiple years to capture the effects of year-to-year changes in hydrology.

In industrial areas, sampling of storm drain sediments may be a useful substitute or adjunct to water-quality sampling. See Section 6.5.

6.4 Exceedance Frequencies of Water Quality Standards

This indicator measures the frequency with which water quality standards have been exceeded; however, to understand potential effects on beneficial uses, it is also necessary to review each specific standard and the degree to which it has been exceeded. For example: Is a large exceedance by a single parameter worse than smaller exceedances by many parameters?

In addition, it may be impossible to accurately apply this indicator to stormwater sampling data, because stormwater sampling periods (typically 24 hours) don't necessarily coincide with the water-quality criteria that apply to exceedances (e.g., 1-hour acute toxicity or 4-day chronic toxicity criteria).

The indicator could be successfully applied only in cases where many exceedances have occurred for several parameters. Improvement in the environmental health of the water body would then be indicated by a decrease in the number of exceedances and possibly in the number of parameters that exceed. In Coyote Creek, despite the variability in the data, tracking the number of exceedances of total metals WQOs (as opposed to WQCs) showed more promise as an indicator of water quality. A high percentage of copper and lead samples still exceed the criteria, which provides an opportunity for changes to be observed.

Background levels of some constituents may exceed the water-quality objective for chronic effects. The objectives are based on the water hardness. Objectives are lower in softer water. Stormwater runoff tends to be softer than base flow (which is primarily groundwater), and therefore, lower standards apply during storm events then apply before and after. However, erosion and sediment transport during storm events raise the concentrations of metals naturally found in sediments above dry weather levels. Since the standard is lower and the background concentrations are higher the chance of background concentrations exceeding the objectives is increased during the storm events.

In the case of Coyote Creek, since there are so few parameters that exceed the criteria for dissolved metals and the few that do only exceed chronic criteria (which is usually an overly conservative criteria for most storm events) tracking the number of exceedances of dissolved criteria did not provide a mechanism to show additional improvements in stream water quality.

6.5 Sediment Characteristics and Contamination

In Coyote Creek, lead and cadmium, and to a less extent mercury, demonstrated spatial differences that corresponded to urbanization. Mercury concentrations in Coyote Creek sediments appear to have decreased significantly over 20 years. Other metals (copper, chromium, arsenic) showed neither spatial nor temporal trends.

Lead and cadmium concentrations in stream sediments appears to have a distinct relationship to the influence of urban drainage, and may be useful to correlate the general influence of that drainage on creeks over time. The measurement of lead concentrations over time could have the additional benefit of characterizing the expected pattern of slowly decreasing concentration in stream sediments, a delayed result of reductions in the use of tetraethyl lead as a gasoline additive. This may provide perspective on the behavior of other "legacy" pollutants, such as PCBs or chlorinated pesticides.

Monitoring pollutants in sediment influenced by urban runoff appears to be a more robust indicator compared to the characterizing pollutant concentrations in runoff (Indicator #1, Water Quality Pollutant Monitoring). It is also more cost effective because sediments are easier to sample (i.e. "catching" storm events is not required) and because fewer samples are required to characterize them (because there is less variation sample-to-sample).

As with Indicator #1, the relationship of the indicator to beneficial uses will be somewhat indirect in cases where (as in Coyote Creek) the concentrations measured are not associated with impacts to biota.

As with Indicator #1, trends may be more apparent when this is applied to sediments in storm drains rather than in creeks. Measurement of pollutant concentrations in storm drain sediments might be useful in connection with targeted pollution prevention measures (e.g. BMPs), at specific industrial sites or in industrial areas, and may be an improvement over mandated requirements to sample runoff from these sites. It would be difficult to make these connections using in-stream data.

The usefulness of this indicator could be improved by a number of modifications to the protocol and study design. The current study could have been improved by including more downstream sites to fully cover the urban portion of the Creek. This study also demonstrated the importance of consistent methodology in order to allow better spatial and temporal comparisons. Sampling and analytical protocols were not well documented in the historical data set and particle size information associated with the older data set were incomplete. These factors limited the ability to compare the two data sets.

One disadvantage of using this indicator is the lack of accepted sediment quality criteria. However, if sampling and analytical protocols are adequately documented, temporal comparisons can be made, as can comparisons with other local sites with similar land use and geology.

Several changes in the sampling protocol could enhance the utility of this indicator:

⇒ Add iron, aluminum, lithium and other tracer metals to the analytical set to enable analysis of enrichment of contaminants relative to background conditions and assist in source identification.

⇒ Sieve sediments through a 200 micron sieve prior to analysis.

⇒ Establish background concentrations of the target analytes (including major elements to be used for normalization) in the primary soil classifications contained in the watershed using consistent methodology.

⇒ Consider use of sediment traps to augment grab samples.

6.6 [Indicator not Tested]

6.7 Stream Widening and Downcutting

Application of the indicator in Coyote Creek yielded inconclusive results because suitable baseline (pre-development) data were unavailable. Even if such data were available, we consider it unlikely that widening and downcutting measurements could be used to demonstrate impacts of urbanization in this watershed. Dams, water diversions, channel modifications, historical instream mining, as well as infrequent catastrophic flow and sediment events, are all confounding factors affecting stream morphology in Coyote Creek.

In highly variable and complex watersheds, the channel widening and downcutting indicator may be useful for detecting the susceptibility of reaches to bank erosion as a result of changing flow regime over time. In such conditions, however, this indicator does not appear to be useful in identifying changing land use as the primary cause for these changes.

For monitoring impacts related to impervious surfaces, this indicator is best used in small watersheds that lack major dams, have few or no channel modifications, and minimal alterations to stream channel from mines and quarries. Stream segments above dams or headwater areas that are being developed may provide the appropriate conditions.

As described in Section 4.1.1, we found it more useful, when working at a watershed scale, to develop a geomorphic stream classification based on natural (geology, lithology, elevation, hydrology, and creek planform), and anthropogenic (land use and modified channel characteristics) factors.

To assess stream quality, it is important to characterize streams based on their structure and function. This facilitates an understanding of the variables affecting a target assessment group, and leads to a more meaningful evaluation of the factors affecting beneficial uses. Classifying stream reaches also provides a mechanism for extrapolating site-specific data to other stream reaches that have similar characteristics. Classification serves as a tool for predicting future stream responses to perturbations and as a basis for selecting future sampling sites and methodologies for field monitoring.

Basic stream processes have been characterized as part of a continuum (Vannote et al. 1980), in which headwater reaches typically deliver sediment to a stream, lower-elevation, lower-gradient reaches typically transport sediment, and reaches traversing relatively flat valley floors typically receive sediment. Both natural and human factors influence how streams "work" to move water and sediment. Natural factors such as topography, elevation, gradient, geology, lithology, soils, vegetation, and drainage density influence stream hydrologic processes, channel dynamics, and ultimately habitat quality for aquatic organisms. Human factors such as dams/reservoirs, diversions and discharges, percolation facilities, modified channels, mining activities, and development, also modify biogeochemical processes and alter stream structure and function. Because both natural and human factors fundamentally influence stream structure and function, they can be used to classify streams into reaches or segments based on structure and function.

The number of classes chosen to characterize stream structure and function should represent the range of relevant variation in a region and the level appropriate for detecting effects of human activity on stream function and biological condition; however, it is critical to neither over- nor under-represent the number of classes. We classified eight reaches that characterize different functions in Coyote Creek. (Table 1, Figure 1).

For initial assessments we recommend evaluating the following three stream functions. This approach has been used successfully on Coyote Creek as part of a separate project (Buchan et al., 1999) and is consistent with national guidelines developed for evaluating functions of riverine wetlands[8] (Brinson et al., 1995).

⇒ *Maintenance of Characteristic Hydrologic Processes and Channel Dynamics:* This function refers to the extent to which a stream reach exhibits physical processes and structural attributes within the natural range of variability of the hydrologic and hydraulic regimes. Physical processes, structural attributes, and ecological conditions include the amount, timing and duration of discharges, watershed condition (e.g., percent of urbanized/impervious surface), sediment dynamics, and condition and behavior of the channel and adjacent riparian vegetation. Variables used to assess this function may include alteration to the hydrologic regime, sediment delivery to the channel, and conditions of the watershed, flood-prone area, riparian habitat and channel.

⇒ *Maintenance of Aquatic Habitat Variation and Richness:* This function refers to the capacity of a stream reach to support assemblages of native aquatic organisms through the maintenance of heterogeneous habitats. Variables used to assess this function may include alteration to the hydrologic regime, sediment delivery to the channel, riparian habitat condition, surface water persistence, surface hydraulic connections, instream channel cover, instream and macro-/micro-topographic complexity.

⇒ *Maintenance of Landscape-Level Aquatic Habitat Connectivity:* This function refers to the capacity of a stream to allow for the upstream, downstream, and/or lateral dispersal and/or migration of native aquatic organisms within a watershed via permanent or intermittent channels or floodplain areas. This function encompasses opportunities for aquatic organisms to utilize and move between existing stream environments, colonize new habitats, or recolonize aquatic habitats following local extinctions. Variables used to assess this function may include alteration to the hydrologic regime, sediment delivery to the channel, channel condition, surface hydraulic connections, longitudinal connections to up- and down-gradient aquatic habitats, and condition of flood-prone area.

Initial pilot assessments based on these functions should provide a programmatic basis for prioritizing additional monitoring and assessment throughout the watershed. By identifying specific reaches and locations where resources are exceptional (or may be threatened), and by documenting preservation and enhancement projects currently underway, the pilot watershed assessment should help watershed stakeholders (including stormwater programs) to target future analyses and collection of field data.

For example, if the initial assessment suggests that a surplus or paucity of sediment is affecting an otherwise high-quality reach, the next step may be an analysis of upland hillslope processes and development of a sediment budget. Likewise, if modifications to the hydrologic regime appear to impair biological beneficial uses, subsequent steps may be to begin a dialogue with

[8] Riverine wetlands are broadly defined to include the stream channel and adjacent riparian areas.

agencies and entities that influence water supply to identify opportunities for restoring base flows. As another example, uncertainty about suitable water quality or temperature might lead to monitoring of macroinvertebrate populations in a specific reach and an in-depth analysis of changes in the distribution of riparian canopy over time.

6.8 Physical Habitat Monitoring

As implemented, this indicator was useful for characterizing restoration potential and causes of habitat degradation and in some cases indicated whether habitat and/or water quality were factors limiting aquatic biodiversity. Measurements of riparian canopy cover and streambank vegetation indicated that most of the creek was well-vegetated. Exceptions included one of the rural stations (R-3) that had been previously mined and was virtually denuded. Disturbance at this site was also evident from measurements of substrate which indicated unusually high percentages of cobbles and gravels. Together, such measurements clearly supported the cause of habitat alteration, and indicated potential for restoring the habitat composition typical for reaches in this part of the creek. However, the decision to implement such restoration would depend on the management objectives. For example, because this station supported extremely high abundances of prickly sculpins and no rainbow trout, it would meet an objective of managing for native warmwater but not coldwater fishes.

As another example, high flow volume below Anderson Dam correlated with evidence of scoured substrate, indicating habitat degradation at the R-5 station. Data collected for the temperature indicator, however, indicated that managed flows released from the Dam maintained cool water and enhanced habitat for cold water fisheries, yet no rainbow trout were found at this site. Thus, the combination of these data indicated how urban factors influence habitat and biological assemblages and identified the potential for restoring coldwater fisheries habitat within the context of managed hydrology.

In a smaller, less complex watershed, where stormwater (as opposed to hardscaping, dams/diversions, etc) is more clearly the main human influence to a stream, changes in study design to compare habitat condition above and below outfalls, or catchments with and without BMP controls, might be one method to improve the indicators usefulness for evaluating impacts (both positive and negative) associated with increased urban runoff and effectiveness of a stormwater program. However, the indicator may best be used prospectively, in conjunction with a suite of indicators, in watersheds that are beginning to urbanize, in order to develop temporal baseline data that is often lacking in highly urbanized regions.

6.9 [Indicator Not Tested]

6.10 Increased Flood Frequency

We found this a difficult indicator to implement in the Coyote Creek watershed largely due to the highly modified nature of the creek's hydrology, the watershed's size, and the paucity of accurate historical flood data. Construction of levees and Anderson Dam increased channel capacity, reduced flows to the urbanized from the nonurbanized portion of Coyote Creek, and decreased the incidence of flooding that had otherwise previously occurred. This confounded our ability to relate changes in land use and imperviousness to flood incidence.

The effects of urbanization on floods of different return periods have been summarized by Hollis (1975) (Figure 8):

1. floods with a return period for 1 year or more are not appreciably affected by a 5% paving of their catchment area;
2. small floods may be increased by a factor of 10 or more depending upon the degree of urbanization;
3. floods with a return period of 100 years may be doubled in size depending upon the degree of urbanization of a catchment if that urbanization results in at least 30% paving of the catchment;
4. the effect of urbanization declines in relative terms as flood recurrence intervals increase.

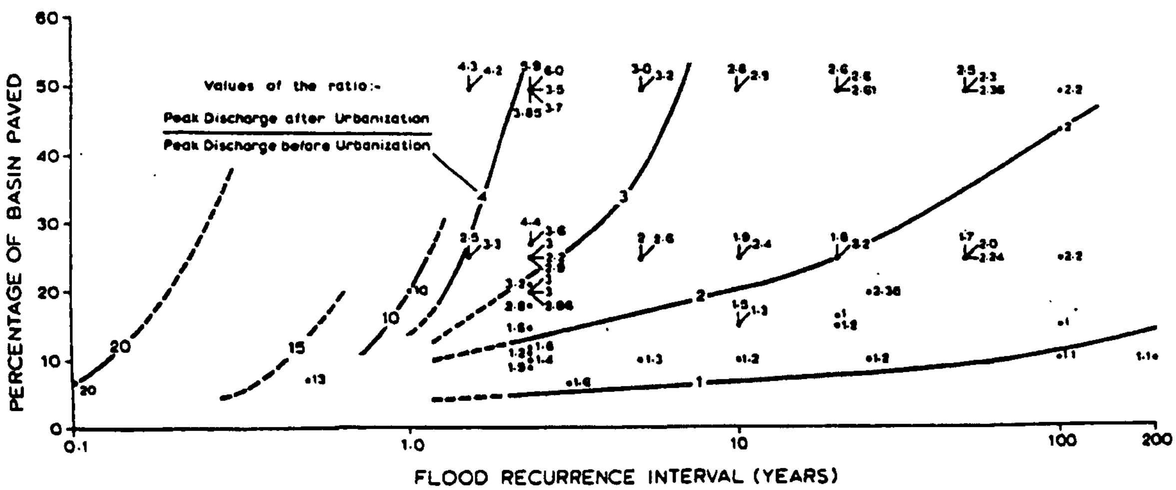


Figure 6-1: Effect of Urbanization on Flood Peaks

Figure 6-1 illustrates that impacts of urbanization on flooding are primarily caused by small floods. For small events in undeveloped watersheds, a relatively large percentage of the rainfall infiltrates into the soil and does not generate runoff. This explains the small runoff coefficients usually assigned to undeveloped land uses. Rainfall on paved land uses produce large amounts of runoff , thus large runoff coefficients are usually assigned to impervious surfaces and highly developed land uses. Large flood events generally occur when soils are highly saturated and have correspondingly low infiltration rates. Therefore, even undeveloped areas have large runoff coefficients when large flood events, such as a 100-year flood, occur. Under these circumstances, the runoff coefficient only increases by a small amount for paved areas.

About 15 - 22% of the watershed below Anderson Reservoir is impervious. Under this condition, the 100 year flood would be increased by about 10%, the 10-year by about 50% and the 5-year by about 100%. Based on the analysis presented by Hollis, it is difficult to determine the impacts of urbanization in the Coyote Creek watershed on these large events since so few of them have occurred since urbanization, and because the expected increase in flow rate is small.

We had limited data with which to assess impacts of urbanization on local flooding, but found some support for this in a subwatershed (Penitencia) of the Coyote Creek watershed. Here increased urbanization correlated with peak flows and increased urbanization. Therefore, we concluded that while this indicator is more useful for identifying relationships between urbanization and small rather than large flood recurrence intervals, it would be an even more useful indicator if it was designed to track not only flooding incidents, but also to measure changes in stream flow and identify instream infrastructure that influences stream hydrology.

6.11 Stream Temperature Monitoring

Application of this indicator is dependent upon regional climatic conditions. This indicator, as implemented, may have more applicability in climates where summer rainfall contributes to high flows, because impervious surfaces effectively heat runoff, contributing to increased stream temperatures, and this indicator may be used to assess this impact. In semi-arid climates, however, this effect is not present since the majority of the rainfall occurs during cool, winter months (November – March). In such climates urban runoff may contribute significantly to stream flows during summer months when stream flows are low (e.g., it can provide the majority of stream flows). Thus, this indicator may be used to identify where temperature changes along creeks.

The ability to link temperature effects to a stormwater program, however, depends upon the monitoring design and a watershed's complexity.

In streams such as Coyote Creek, dams, diversions, gravel pits, and distribution of riparian canopy influence stream temperature, in addition to urban runoff. Detecting the relative influence of each of these factors requires an intensive long-term monitoring effort, which may be impractical for stormwater programs. We placed five probes along Coyote Creek. While that was not a sufficient number to distinguish among all factors influencing stream temperature, it provided useful information for interpreting some of the data we collected for the biological indicators, and distinguishing between water quality and habitat influences on biological assemblages (as discussed above).

An alternative to instream monitoring is to place temperature probes within stormdrains. This would indicate whether stormwater temperature is significantly different than receiving water. To be useful, this would require comparison with a historic record (or reasonable estimate) of in-stream temperature prior to development. As with Toxicity Testing (Indicator #2), this approach assumes a verifiable nexus between storm drain discharges and potential in-stream effects. Stormwater may be found to have significantly different temperature differences than what would be expected in receiving water, however, determining the magnitude of any negative effects on in-stream conditions, especially in a complex watershed like Coyote, would still require an intensive monitoring effort to clarify.

To a limited extent, our temperature data could be used, as suggested by Claytor and Brown, to indicate reaches that could benefit from riparian restoration and/or riparian buffer enhancement. However, analysis of aerial photos, where available, may also accomplish this objective and require many fewer resources. Particularly in headwater streams where development has not, or is just beginning to occur, and few if any other non-natural factors are influencing a stream, monitoring stream temperature may, as suggested by Claytor and Brown, be an effective means of protecting cool water streams by demonstrating warming effects caused by development. In streams where development is beginning, temperature probes may be placed above and below developed areas. In pristine areas, data may be collected and compared to other data collected in streams with different levels of development.

6.12 Fish Assemblage

We found several types of comparisons of current and historical fisheries data very useful for characterizing the overall condition of the Coyote Creek watershed. Statistical comparisons of fisheries metrics between station groupings and to percent subwatershed imperviousness indicated that the extension of urbanization upstream did correlate with observed shifts in fisheries assemblages. However, its utility for evaluating stormwater program effectiveness was limited, because distinguishing the relative contribution made by stormwater to changes in fisheries assemblages is difficult in a complex watershed such as Coyote, where a multitude of factors related to urbanization are at work.

Comparisons to historical fisheries and hydrology data helped identify the relative influence of natural and anthropogenic factors on hydrologic fluctuations that influence fisheries assemblages. Understanding observed changes in the distribution and composition of fish assemblages requires identifying the relative contributions of natural and human factors. Fish habitat changes in response to hydrologic fluctuations, which as already discussed, can be considerable in western streams, caused by natural and urban factors – those both related to stormwater programs (e.g., imperviousness), and those beyond a program's purview (e.g., instream infrastructure related to water supply and flood control, mining activities). Biotic interactions, particularly those caused by nonnative introductions also greatly influence fish assemblages.

One method to understand the relative importance of human impacts is to correlate observed assemblage shifts with major changes in human activities as evident from landscape changes (e.g., dam construction, channel modification, etc.). Adopting this approach provides an understanding of the trajectory of change that fish assemblages have experienced. It may facilitate understanding how change was occurring in the absence of a stormwater program, and what, if any change may be attributed to the establishment of a program. This approach also provides a method of estimating reference conditions in regions where they have not yet been established (Buchan and Leidy in preparation).

It is important to emphasize that protocols used for application of this indicator should be selected based on methods developed and recommended for the particular region where it is to be implemented. In addition, use of methods similar to those used in historical studies will result in more accurate temporal comparisons. Use of Rapid Bioassessment Protocols in California might be refined based on our results as follows:

⇒ Seasonal variations were not statistically significant for any of the metrics. A single sampling event per year could suffice and based on the 3 events in 1999 (May, June & September) May is the best month for capturing rainbow trout.

⇒ A test could be done comparing 1 pass and 3 pass electrofishing, but limited evidence suggests that 1 pass may be sufficient and cost effective.

⇒ Data on length of individual fish was not used. Eliminating length or recording class size would reduce field time.

⇒ DNA analysis on rainbow trout fin tissues could determine what percent of the trout are wild.

⇒ Station selection is critical: water depth, velocity, turbidity, and conductivity all can limit electrofishing efficiency.

⇒ Field duplicates are not cost effective. Data analysis showed significant differences in the field duplicates, indicating high spatial variability. The RBP methodology requires field duplicate to be immediately upstream of a station. This does not take into account potential habitat similarities or differences comparing the upstream and downstream reaches.

⇒ Metrics analyzing number of native species, number of native individuals and biomass of native fish were found to be the most useful. Other metrics need to be fine-tuned for Coyote Creek (and the Bay Area).

⇒ Continued coordination with the California Department of Fish and Game should be encouraged in order to address the regional need for unimpacted reference sites comparable to the Bay Plain portions of San Francisco Bay area creeks.

⇒ Monitoring of dissolved oxygen concentration was useful for interpretation of fish sampling results.

6.13 Macro-Invertebrate Assemblages

Similar to the Fish Assemblage Indicator, we found the indicator useful for characterizing aquatic ecosystem health, and for predicting the existence and severity of aquatic degradation in creek reaches. The tolerance/intolerance metric was particularly useful in this regard. This indicator has potential to measure responses to short term impacts; however, during our sampling period we did not detect any community shifts or changes in water quality parameters that would indicate short-term impacts. Annual comparison of metrics could indicate impacts to the macroinvertebrate community. However, understanding the cause(s) of such shifts requires monitoring and analyzing simultaneous changes in the same factors mentioned above.

The metrics showed that the total number of taxa and the total number of EPT taxa are greater at the reference stations than at the rural and urban stations. However, it should be noted that there were some dissimilarities in gradient, substrate, and stream flow at the reference stations compared to those stations below the reservoirs, thus confounding interpretation of the results.

The percent of individual EPT insects is similar at the reference and rural stations, but higher than at the urban stations. In other words, the total number of taxa relates information about diversity, but not population composition. The reference stations have the greatest number and percent of low tolerance taxa, as well as percent of low tolerance individuals. The rural stations have more low tolerance taxa and individuals than the urban stations. Evaluating low tolerance taxa appears to be a more discriminating measure than high tolerance taxa. The high-tolerance taxa appear everywhere (albeit in varying numbers) but low-tolerance taxa only exist where the water quality is suitable. Since the tolerance metric is directly related to water quality it should be included in any future macroinvertebrate assemblage analysis.

The potential for this indicator to screen possible sources and causes of degradation, evaluate performance of watershed restoration measures and performance of stormwater BMPs, while not demonstrated in this study, may be feasible if monitoring is appropriately designed with respect to location and timing of influence of contributing factors. This might require that the monitoring program be prospective (i.e. put in place prior to a significant change such as a stream restoration effort or development of a tributary area) rather than retrospective. The three primary variables in the Coyote watershed, for example, are the regulation of stream flow, habitat limitations, and water quality. There are no discharges of treated sanitary effluent into Coyote Creek, thus the causes of degradation of water quality are attributable to urbanization in the broadest sense, including impacts to habitat, and its concomitant non-point source flows. These factors would need to be accounted for in a sampling design to distinguish effects due to stormwater and program effectiveness.

The indicator will be most useful for measuring stormwater program effectiveness when evaluated in combination with other indicators and as a consistently generated, long-term data set is developed for Coyote Creek. Also as the California Department of Fish and Game refines their Index of Biological Integrity (IBI) for first-to-third-order tributaries to the Russian River (Harrington et. al. 1999) the data from Coyote Creek may be able to be evaluated using this IBI.

All of the following refinements relate to sampling protocols:

⇒ Water depths and unconsolidated substrates limit sampling effectiveness. The general direction of macroinvertebrate sampling in California is to sample only riffle habitats. The only inherent problem with this strategy is that if there are no riffle habitats in a particular reach of a creek, then the opportunity to use macroinvertebrates as an indicator is lost. Perhaps in these cases, i.e. locations where the water velocity is low and the substrate is predominantly silt and clay, the composition of the macroinvertebrate community is obviously limited and sampling is not required to confirm the obvious.

⇒ The number of organisms counted and identified from a composite sample varies among researchers. The SEIDP 1999 study identified 400 (± 20%) organisms from each sample. Harrington et.al. (1999) used 300 organism samples and Carter and Fend (2000) used 500 organisms. The California Department of Fish and Game is establishing protocols, if 300 organisms is the sample size selected for analysis, it will decrease sorting time and thus costs.

⇒ The number of kicks/jabs/rubs also varies among studies. The SEIDP 1999 study followed the RBP protocols and collected 20 subsamples to create the composite. Carter and Fend collected five subsamples and Harrington et. al. collected three subsamples. Jerry Terhune (personal communication) collects ten subsamples. Clearly the number of subsamples collected to represent a monitoring station can be reduced from 20. Local protocols, such as the California Department of Fish and Game's three subsamples, can be used to guide the number of subsamples.

⇒ Two sampling protocol items that should be clarified are: how deep to sample in gravels and how long to rub rocks.

⇒ In order to have comparable data sets it is critical that the taxonomy be carried to a similar level in subsequent studies. Also, regional consistency in sampling protocols will improve the ability to compare data sets.

6.14 [Indicator Not Tested]

6.15 [Indicator Not Tested]

6.16 [Indicator Not Tested]

6.17 Public Attitude Surveys

Public attitude surveys are tools to gather data which may assist Programs to evaluate their effectiveness. Measuring awareness and behavior can be useful when the results are used to focus future pollution prevention programs in problematic areas and evaluate the effectiveness of specific outreach efforts. For example, the Program's survey results indicated that gardening and yard care continue to be the most common do-it-yourself activities in Santa Clara County, yet many are not aware of the harm that can be caused by leaves, grass clippings, or water used to irrigate lawns.

Broad telephone surveys, the method employed to evaluate this indicator, are helpful in that they provide a statistically significant overview of the attitudes and behaviors of all area residents in a program's jurisdiction. In addition, these surveys allow for meaningful comparisons between a wide variety of demographic, geographic, and attitudinal subgroups. The fact that these surveys are conducted periodically every few years also makes it possible to measure modest changes in attitudes and behaviors over time.

However, the Program's survey findings suggested the following limitations in measuring awareness alone to gauge program effectiveness (Fairbanks et al. 1999):

⇒ increased awareness is not enough to motivate a behavior change

⇒ the results can not be directly correlated to improvements in water quality;

⇒ population subgroups, often the focus of specific outreach efforts, may not be represented in sufficient numbers in an area-wide survey to detect subtle changes in their opinions or behaviors;

⇒ area-wide surveys conducted once every few years may not capture the results of education efforts that have a limited duration and conclude prior to the time in which the survey is conducted;

⇒ area-wide telephone surveys gather primarily self-reported data; respondents may indicate that their awareness, perceptions or behavior have changed in certain ways, but there is no way that those claims can be independently verified;

⇒ broad scale surveys are expensive and difficult to design.

Broad evaluations may best be used to track the trend of performance over time and to formulate programs and work plans. Specific evaluations on individual components of stormwater programs should also be used whenever possible[9]. Ideally, program managers should embed specific evaluation tools within programs to obtain continual feedback on a program's effectiveness.

6.18 Industrial/Commercial Pollution Prevention

The Program was able to use this indicator to determine the information and outreach gaps between the Program and the industry.

We attributed our success in applying this indicator to our site visits. The written surveys alone would not have been as effective in determining the Program's impact and the industries' understanding of the Program. However, the surveys followed by the site visits provided a general assessment of the attitudes and level of understanding of the individual site managers with respect to the storm water program. Site managers seemed to be more comfortable with verbal communication rather than written, and more willing to ask questions and provide answers in detail. Technical information, e.g. regarding potential pollutants or BMPs, was better received and comprehended by site managers when it was presented in this casual and direct manner.

In addition, visits to the site to discuss the survey were essential for visual and intuitive

[9] Personal communication, Rufus Browning, Public Research Institute, January, 2000.

feedback to Program and City staff. Through the site visits, Program and City staff gained familiarity with the facility operation and staff, and of the conditions under which potential pollutants may occur. With a more relevant context and perspective in mind, City and Program staff were better able to interpret the survey responses and their validity, evaluating the Program's deficiencies and strengths from the point of view of the industry.

6.19 Public Involvement and Monitoring

Public involvement has the potential to modify polluting behaviors and enhance pollution prevention by increasing residents' appreciation of local watersheds and promote understanding and support for local stormwater programs. Application of this indicator can help Programs identify which types of activities would be the most successful in a given community and can help in planning outreach strategies in the future. However, conclusions regarding program effectiveness need to be based on pre-defined, measurable program goals, and must be specified prior to evaluation. For example, increased participation in annual events, as was documented for many SCVURPPP activities, is a good indication that community involvement has increased awareness and concern over urban runoff pollution.

We found that the utility of the indicator was limited due to insufficiency of documented results from public involvement and monitoring activities. This limitation can be avoided if standard formats and requirements for follow-up evaluations of outreach programs are pre-established. For example, the Program could require that annual reports include specific information on numbers of participants or results of evaluation surveys.

However, the arbitrary use of quantitative measures (e.g. number of participants) does not necessarily improve the indicator's usefulness. Information on event organization and accomplishments, percent of community participation, or follow-up evaluations of public attitudes and perceptions would be a more useful measure of effectiveness. Additionally, as with the Public Attitude Surveys indicator, it is difficult to correlate public involvement and monitoring activities with actual changes in polluting behaviors, especially since it may take several years for behavioral changes to occur.

6.20 User Perception

This indicator was somewhat useful in gauging the value that the general public or a targeted group places on a water body or other urban runoff pollution issue. Stormwater programs may most successfully apply user perception to justify resources and focus pollution prevention efforts.

However, a principal disadvantage of this indicator is that user perception can be heavily influenced by external socio-economic variables such as education level of the populace, crime rate, economy, cost of living, unemployment rate, and transportation issues, all of which can heavily influence the perception and importance of water pollution issues. The results of the Program's surveys reinforce this argument (see Appendix XX – indicator tech memo – for Program specific information).

The awareness, perceptions and ultimate value that a community places on urban runoff pollution prevention are also dependent on the urban environment (e.g., in a suburban area planned around open space, residents may place a higher emphasis on creeks, rivers, and other water bodies than in a highly urbanized area), as well as the extent to which waterways are actually polluted. The perception of water pollution may be higher in areas where water pollution is extremely acute and visible in contrast to low-level chronic pollution problems.

However, perhaps the most important limitation of this indicator is that perceptions may not be consistent with reality. User perception should be applied to gauging the effectiveness of storm water programs cautiously. A populace may perceive a water body to be polluted when it is actually in good health. Clearly, user perception should not be used to measure the success of water quality efforts unaccompanied by other indicators.

6.21 Number of Illicit Connections Identified/Corrected

The 70-fold decrease in reported illicit connections reported 1993-1998 suggests the cities' surveys and monitoring of storm drains (particularly a 1993-1994 initial effort) effectively eliminated illicit connections to storm drains. The 1993-1998 trend toward fewer illegal dumping incidents (as reported for most categories) suggested that the Co-permittees' efforts were effective. These efforts included outreach (advertising, workshops, events, industrial/ commercial inspections), inspections of industrial and commercial facilities, response to dumping incidents, and enforcement.

Most illegal dumping incidents are identified by inspectors responding to public reports, city department referral, or through routine inspections of industrial/commercial or construction sites included on the State's NPDES permit. Therefore, it is difficult to evaluate what percentage of these incidents that actually occur are subsequently discovered, reported, and documented.

Using available data generated from Co-permittee ICID programs enabled us to identify the majority of pollutants associated with illegal dumping incidents and the minority of pollutants associated with illicit connections. However, we were unable to determine the accuracy of ICID reports (e.g. correct categorization of incident, description of pollutant). Some illegal dumping reports noted the color of the liquid dumped, but there was no additional information available to determine pollutant type. Few ICID discharges are tested in analytical laboratories to determine constituent types or concentrations.

Despite difficulties in implementation, this indicator was found to be good indicator of Program effectiveness, tying into both the Clean Water Act and one of the major foci of stormwater programs. However, program efforts need to be taken into account, because increased outreach and awareness may actually increase *reporting* of illicit discharges/connections, thus confounding the results.

The following information should be considered when applying the indicator:

- ⇒ Trends in population, transportation, and development growth.
- ⇒ Stormwater program self-evaluations.
- ⇒ Changes in stormwater programs, including targeted sectors, changes in staff and training, increased enforcement (e.g., approval to apply and/or increase citations and civil penalties to violators), and the use of new technology such as cellular phones to improve communication and response time to incidents.
- ⇒ Increased outreach efforts.
- ⇒ Length of time program has existed.

6.22 Number of BMPs installed, inspected, and maintained

The utility of this indicator was found to be limited as applied in the Walsh Avenue catchment due to lack of sufficient documentation. The City's NPS inspectors do not routinely document BMPs being implemented at the site. Without this documentation, (and without much documentation of previous industrial inspections), it was not possible to determine the number of BMPs installed, inspected and maintained.

For many facilities in the Walsh Avenue catchment, the appropriate BMPs are operational BMPs (e.g., housekeeping, materials storage, and waste disposal), and require no specific capital equipment that would need to be installed or maintained. Further, many of these operational BMPs are implicitly required by other environmental and health and safety regulatory requirements. The indicator's usefulness might be limited to businesses that are required to install specific devices to prevent stormwater pollution.

6.23 Permitting and Compliance

As described in Claytor and Brown (1996), this indicator is specific to industrial and construction sites covered under NPDES requirements. The usefulness of the indicator is limited by the quality and availability of compliance data.

Industrial facility non-filing is known to be prevalent and difficult to quantify (Duke and

Bauersachs 1998). For example, Duke (1999) found that about 50% of heavy industries that should be filing under the Permit were not. Primary compliance is low because, in part, filing is voluntary and requires that facility operators interpret whether their on-site industrial activities are "typical of" any of a list of SIC codes.

As Duke (1999) noted "No U.S. agency assigns businesses or facilities an SIC intended to describe its activities, and in fact facilities may report under different SIC codes for different purposes such as corporate revenue statistics, facility employment data, and wastewater discharge characteristics." Thus, different databases are likely to associate different SIC codes with the same business, preventing the use of a single database to identify the population of facilities that should be filing under the Permit. Duke (1999) also concluded that facility operators have a disincentive to file under the Permit because of the cost of filing and because, under current circumstances, they are unlikely to be discovered by regulatory agencies. The RWQCB is drafting a notice of violation to send to known non-filers informing them of their regulatory obligation and the civil penalties that can be enforced if they do not come into compliance (Barsamian 1999). The effectiveness of this effort to increase compliance will partly depend on how complete their list of non-filers is.

City of San Jose staff reported several obstacles to enforcing compliance. Many SIC codes recorded in San Jose's business license database did not correspond to those included in the SWRCB NOI database. In addition, many records contained only general SIC codes, which did not reflect activities that can contribute runoff pollutants. City staff addressed this problem by looking up the SIC code most accurately associated with the "primary activity" listed for each business. City staff also reported that some information in the NOI database (including addresses and operating status of some facilities) was not current. This impeded their ability to efficiently schedule and conduct site inspections.

City of San Jose staff reported that storing inspection data in a relational database (beginning in FY 95-96) improved their ability to summarize and review inspection results and to prioritize future inspections. However, the State did not provide updated lists of the NOI filers in their jurisdictions (City of San Jose 1995, 1996, 1997, 1998). This problem was recently remedied. In early 1999, the SWRCB began posting monthly updates to the NOI database on their website. However, the State has yet to create a mechanism for Co-permittees to report non-filers or to track state actions to bring non-filers into compliance.

Within the Walsh Avenue Catchment, reporting compliance was poor, particularly for monitoring reporting. The RWQCB is developing a database to track submittal of annual reports and monitoring reports submitted by NOI filers. The SWRCB has not announced any plans to include NOI filer report contents in a database. Therefore, it is difficult currently to access monitoring data (except for the paper copies of reports stored at RWQCB offices). If a database tracking report submittal were operational, it would be possible to calculate the percentage of required reports that are submitted by NOI filers for any study area, and compare such performance regionally.

Both report submittal and monitoring data would be required to evaluate accurately (e.g., to improve upon our estimate of potential pollutants and polluters based on SIC codes) two of the potential benefits that the Center for Watershed Protection listed for this indicator:

⇒ Identify potentially significant contributors of pollutants.

⇒ Identify types of untreated pollutants entering surface waters via stormdrain system.

One of the two active industrial NOI sites within the Walsh Avenue Catchment had a SWPPP on-site, but it had not been updated since 1996. The SWRCB has no program to insure that industrial SWPPPs are updated annually, nor to insure that SWPPPs are implemented in compliance with the statewide permit. In accordance with SCVURPPP's Model Performance Standard for Industrial/Commercial Discharge Control, inspectors ask, during site inspections, to see a copy of the facilities' NOI and SWPPP. However, Co-permittee inspectors do not, as a rule, review the SWPPPs to insure they are current or complete.

In general, industries covered under the statewide Permit did not document the number and type of BMPs implemented in conjunction with the Permit.

As we found in assessing the Number of BMPs Installed, Inspected and Maintained (Indicator #22), non-structural BMPs such as housekeeping, preventative maintenance, spill response, and material handling and storage are not typically documented by site operators, nor easy to quantify. Thus, assessing the "tracking BMPs" component of this indicator was difficult due to both the nature of non-structural BMPs and the paucity of their documentation in inspection reports. Structural BMPs such as overhead coverage, retention ponds, control devices that re-route runoff, secondary catchment structures, and treatments (inlet controls, infiltration devices, detention ponds, vegetated swales, etc.) are easier to identify and track, and inspection reports may better document these types of BMPs.

We identified some pollutants that may be discharged by industrial NOI facilities in the Coyote Creek watershed by listing pollutants typically associated with the primary SIC codes and linking this information to the group of facilities identified from the SWRCB NOI database. With the exception of sediment, pollutants discharged by construction sites are harder to characterize, being dependent on past and present use of toxic materials on the development sites. By georeferencing both the NOI facilities and the stormdrain outfalls, we were subsequently able to identify which stream reaches within the Coyote Creek watershed could be affected by site discharges. Because we could not access monitoring report data for all sites in the watershed, we did not identify which NOI facilities might have the most significant impact on pollutant loads.

Even if the monitoring data had been accessible, the lack of quality assurance and quality control (QA/QC) for the data would have presented additional obstacles. SWRCB regulations require that NOI facilities monitor twice annually, but the SWRCB does not provide guidance to insure that samples are representative of pollutant loads nor that sampling and analyses are subject to QA/QC.

Georeferencing locations of permitted sites made it possible to link potential runoff pollutants with specific stream outfalls. However, inconsistent use of Standard Industrial Classification (SIC) codes made it impossible to use other databases (e.g. business licenses) to estimate the number of businesses that operated without required stormwater NPDES permits. The SWRCB does not track whether permitted sites file required annual reports or semiannual monitoring data, and does not keep information that is submitted in an accessible format. Examination of two permitted sites at the catchment scale showed relatively poor compliance with SWRCB monitoring and reporting requirements.

Tracking administrative compliance with industrial and construction stormwater NPDES permit requirements could be a useful programmatic indicator if the data were better organized, more complete and more readily available, and if better estimates were available of the number and type of industrial businesses that have failed to file (and are therefore not in the compliance database). The other suggested uses of the Permitting and Compliance indicator are more elusive, not only because of poor reporting and data compilation, but because of the inherent problems in quantifying implementation of operational BMPs (Indicator #22) and characterizing the quantity, fate, and potential effects of runoff pollutants (Indicators #1, #3).

6.24 Growth and Development

Implementing the indicator as recommended by Claytor and Brown (1996), we were able to estimate imperviousness at different spatial scales and associate these estimates with selected aquatic metrics. Such comparisons indicate cumulative influences of urbanization, but could not be used to directly evaluate stormwater program effectiveness. We also demonstrated a methodology for estimating future imperviousness for the purpose of guiding selection of monitoring sites and BMP implementation.

In addition, we demonstrated a methodology for examining the relative contribution to overall watershed imperviousness contributed by different land uses. This methodology may be useful in identifying aspects of urbanization that may be causing the greatest harm to aquatic ecosystem functions, and could also inform decisions in planning, zoning, site design, and BMP selection. The following section explores how the indicator might be implemented differently to evaluate stormwater program effectiveness.

Imperviousness is a general indicator of urbanization. Urbanization — itself a complex phenomenon — is associated with a number of complex, detrimental effects on aquatic ecosystems. Because urbanization is associated with many confounding effects that influence watershed hydrology and aquatic ecosystem functions, the effectiveness of stormwater programs may be most discernible when the indicator is applied to small watersheds or catchments. In larger, more complex watersheds, the imperviousness can be used as a general indicator of watershed health.

Stormwater programs can work with land-use planners and developers to:

⇒ Reduce imperviousness.

⇒ Implement structural BMPs (e.g. detention basins) to maintain the hydrological characteristics and quality of runoff.

The creation of newly impervious area in new developments can be minimized through an integrated strategy of minimizing paved area, directing runoff to landscaped, pervious areas, using permeable pavements, and incorporating concave vegetated surfaces into landscape design (BASMAA 1997).

As Schueler (1994) has pointed out, the transportation component of imperviousness often exceeds the rooftop component, but zoning regulations more often regulate housing density than road density. Further, streets and highways are typically directly connected to drainage systems. Narrower roadway widths, pervious pavements, and less directly connected street drainage must be incorporated into such a strategy.

Structural BMPs may be implemented so that increased development does not concurrently increase urban runoff impacts to streams. For example, detention swales and ponds can prevent or decrease the rate at which increased runoff reaches storm drains and streams (Roberts 1999).

To fully demonstrate the effects of these actions, it would be necessary to show:

⇒ That specific program actions have led to reductions in imperviousness or to an increase in the number of BMPs implemented.

⇒ That these measures are protecting and enhancing watershed hydrology and aquatic ecosystem function.

BMPs and Reductions in Imperviousness

To demonstrate the first point above, it may be useful to implement the imperviousness indicator in conjunction with programmatic indicators.

Tracking Structural BMPs Implemented.

Booth and Jackson (1997) concluded that structural BMPs, such as storm detention ponds, frequently fail to achieve standards for duration of detention and accommodation of peak flows. Moreover, in many communities, municipal plan review staff report difficulty in getting infiltration and detention features incorporated into the drainage design for newly developed sites. Typically cited concerns include geotechnical stability, maintenance costs, and allocation of space on the site. Some municipal staff report that, given a choice, developers will choose prefabricated BMPs (e.g., screening filters that fit into storm drain inlets, precast buried baffled detention tanks) instead of implementing an integrated strategy of imperviousness reduction combined with swales and detention ponds (Eric Anderson, City of Mountain View, personal communication, 2000). Implementation of an appropriate integrated strategy can be hindered by competing priorities and lack of communication among the municipal staff responsible for public works, planning, environmental, and economic development.

Consideration of Imperviousness in Project Approvals.

In addition to tracking whether BMPs are being implemented in newly developed areas, stormwater programs might also track the extent to which development project environmental reviews have considered specific potential impacts of imperviousness on the functions of local aquatic ecosystems. A review of local land use policies within the flood plain and riparian corridor may also reveal whether potential impacts of imperviousness are being addressed by local decision-makers.

Imperviousness of Individual Subdivisions.

Another approach to implementing this indicator might be to track the imperviousness of new subdivisions designed and built before and after program implementation. The data might be normalized by comparing total impervious area versus total housing units created. Transportation right-of-ways should be included in this analysis, since they typically comprise a large percentage of watershed imperviousness.

Effects on Hydrology and Ecosystems

The imperviousness indicator will be most useful in showing that Programs are successfully protecting and enhancing watershed hydrology and ecosystem function, when the imperviousness indicator is implemented in combination with other indicators to illustrate the links between land development, drainage, and ecological impact.

Estimating Hydrologic Impact of Imperviousness.

To measure the effects of BMPs and other measures to reduce the effects of imperviousness, it may be useful to apply this indicator in conjunction with measures of changes in flow frequency (taking into account related urban factors such as dams, diversions, and channel modifications). Horner et al. (1996) found that increased hydrologic fluctuations were an early indicator of impacts associated with even low levels of imperviousness by comparing percent watershed imperviousness to the ratio of the 2-yr peak flow to winter base flow. In the semi-arid west, this method would need to account for extreme inter-annual variation.

Linking Imperviousness to Pollutant Loading.

Many researchers have estimated pollutant loads by using estimates of imperviousness for different land uses in conjunction with models predicting urban runoff (Woodward Clyde Consultants 1991, Horner et al. 1996, Shamsi and Fletcher 1996). However, as discussed previously, variation in rainfall is such a strong determinant of pollutant loadings that any change to loading due to changes to imperviousness is likely to be undetectable.

Tracking Drainage System "Improvements".

It may be useful to examine, quantify, and track the expansion of urban drainage facilities (e.g. number of stormdrain outfalls and proportion of "improved" stream channel) in conjunction with changes in impervious area. In developing urban areas — particularly in the erodable landscapes of the West — increased runoff is generally accommodated by new pipes, culverts, and "improved" stream channels. These new facilities may be constructed prior to or concurrent with development, or may be built post-development, often in response to increased flooding frequency or stream widening and downcutting. (One of the benefits of reduced imperviousness is to reduce the need for these facilities, avoiding both their costs and environmental impacts.)

Target Monitoring of Stream Characteristics

The geographic distribution of imperviousness, and projections of increased imperviousness associated with land development, can be used to select locations for monitoring of physical and biological characteristics of streams before and after development.

Summary of Suggested Refinements

Selecting a technique to estimate percent imperviousness depends on the precision required of the estimate, the available budget and data sources, and the watershed size. For the purpose of estimating impacts of imperviousness on aquatic health, we chose to augment a current (April, 1999) land use base map of fine spatial resolution with multiple data sources. Comparison of subwatershed impervious estimates derived from the compiled, current land use data set to those derived using an older (1995), coarser-resolution (1-hectare) land use data set demonstrated that estimates using these less-accurate data were 5- 39% higher in urban subwatersheds.

This difference demonstrates the need to consider the accuracy of the estimate required to achieve study objectives, and also shows the value of using alternative techniques to generate estimates. It also highlights the need to investigate methods used before making any comparisons to estimates of imperviousness cited for other studies or regions. Booth and Jackson (1997) concluded similarly.

Researchers frequently report threshold values for percent imperviousness at which shifts in biological communities and/or habitats are observed; yet the data and methods used to derive these estimates of imperviousness are not well documented. If estimates of imperviousness are derived from data of different resolution and accuracy, then comparisons across studies will be invalid, and erroneous conclusions may be drawn about the level of imperviousness that appears to impact stream conditions. The same will hold true if imperviousness is calculated differently, for example, as cumulative percent subwatershed imperviousness in one study but not in another. For this reason, we have not attempted to compare numeric values derived from our associations between imperviousness and fisheries metrics with those from other studies.

Using parcel-based land use data to estimate percent imperviousness was advantageous both due to its high spatial accuracy relative to other available sources, and because its spatial resolution (ownership parcel) provided a mechanism for linking results to zoning and master planning. Augmenting this basemap using additional data sources was valuable for improving its accuracy. Using data that provided a precise estimate of the transportation right-of-way (including roads and sidewalks) was especially useful since transportation is the primary land use that is entirely and directly connected to the stormdrain system, (typically comprising greater than 60% of watershed imperviousness in suburban areas (City of Olympia 1995)), and it directly corresponds to mitigating design features such as narrower roads.

We were unable to estimate the percent effective impervious area (%EIA) because we lacked the necessary data on parking, driveway, and rooftop area. It is possible to estimate the expected contribution of these surfaces by randomly sampling within different land uses (City of Olympia 1995). The size of the Coyote Creek watershed, however, precluded such effort in this study. In smaller watersheds, it is more feasible to directly measure driveway, parking, and rooftop contributions in similarly developed neighborhoods and thereby derive estimates of %EIA that are specific to development patterns. In some cases, municipal public works or planning departments may be able to provide information about patterns of rooftop drainage and driveways. Thus, the feasibility of this approach depends largely on watershed size, complexity, and data availability and format (e.g., hardcopy, or stored electronically in a relational database).

We recommend consideration of the following refinements to the Claytor and Brown (1996) methodology for applying this indicator:

Techniques for Estimating Imperviousness

⇒ Consider alternative methods to estimate existing and future percent imperviousness, including accuracy and availability of data sources and select methods appropriate to the watershed size.

⇒ Include documentation of data sources and methods used so that valid comparisons can be made to other studies.

⇒ Consider how estimates of imperviousness can be used to estimate runoff coefficients and pollutant loads.

⇒ Distinguish among components of imperviousness attributable to major land uses. Consider how this information might be used in a strategy to reduce the effects of imperviousness.

Applications of Indicator

⇒ To more closely associate impacts associated with imperviousness with aquatic ecosystem functions, consider selecting a subwatershed or catchment scale for analysis.

⇒ Compare changes in percent imperviousness with implementation of structural BMPs.

⇒ Track whether results from imperviousness analyses are influencing land-use planning.

⇒ Consider how increased imperviousness is accommodated by drainage system improvements.

⇒ After estimating the rate and pattern of how imperviousness is changing, consider using the indicator to select monitoring locations for hydrological, physical, and biological indicators and to guide development and implementation of watershed management strategies.

6.25 [Indicator Not Tested]

6.26 Industrial Site Compliance Monitoring

This indicator was useful in gauging the effectiveness of the City's industrial stormwater inspection efforts. Compliance monitoring identified potential sources of stormwater pollutants and ways to prevent those pollutants from reaching storm drains. It was also an effective way to begin outreach to site managers.

The results of this indicator reinforced our conclusions from applying the Industrial/Commercial Pollution Prevention indicator: businesses are implementing BMPs for reason of general hygiene and efficient organization, and to comply with safety regulations and other non-stormwater environmental regulations. The compliance monitoring conducted by Santa Clara in connection with this study revealed the need for additional outreach, in connection with site inspections, to insure that site managers implement and maintain stormwater BMPs.

Application of the indicator also revealed the need for follow-up inspections. Successive inspections showed that several of the businesses remained in non-compliance while others were inconsistently in compliance. Most violations were in repeated problem areas. Better documentation of inspections would make it possible for stormwater programs to use the indicator to target outreach and document progress.

7. Usefulness Of The Stormwater Indicator Methodology

Claytor and Brown (1996) propose a 2-phase methodology (Figure 7-1) for using environmental indicators to assess stormwater pollution prevention programs. The Level I phase calls for a review of management responsibilities, historical data, potential receiving water impacts, and available resources before selecting a group of indicators to assess baseline conditions. The Level II phase calls for a statement of program goals, review of ongoing efforts, and implementation of a management program before applying the indicators to assess the results of program implementation.

The results from any measurement, whether narrowly programmatic or broadly environmental, are useful to the extent that they can be placed in context and used as a guide to action. Stormwater environmental indicators will be useful only to the extent that stormwater programs, regulatory agencies, and the public have a consensus view of the program's role, responsibilities, and ability to achieve specific aims.

Analysis of the results of applying the indicators revealed the advantages of beginning an indicator-based monitoring project with:

⇒ A consensus understanding of the general relationships between urbanization, functioning of stream ecosystems, and beneficial uses.

⇒ A consensus understanding of Program goals, objectives, practices, and procedures.

⇒ A consensus definition of Program "effectiveness."

We found that our ability to use indicator results as a guide to future action depended, in large part, on these conditions. At the same time, some of the indicators proved useful in achieving these conditions — i.e., in providing input to the process of building a consensus understanding of the watershed and the Program's role in protecting and enhancing the watershed.

In other words, some indicators were most useful in assessing general conditions and identifying problems in the urban watershed (corresponding to Level I of Claytor and Brown's methodology) and other indicators were useful in assessing and continuously improving the management program (corresponding to Level II).

With this in mind, for the purposes of evaluating the stormwater indicator methodology, we found the indicators grouped into two categories:

⇒ Watershed-related indicators.

⇒ Program-related indicators.

This categorization relates to Claytor and Brown's categorization as follows:

Watershed-related indicators include Claytor and Brown's water quality indicators, physical and hydrological indicators, and biological indicators (Indicators 1 – 16).

As discussed in Chapter 6, we found Growth and Development (Imperviousness, Indicator #24) to be useful in characterizing watershed conditions, rather than in evaluating program activities.

Program-related indicators include three of Claytor and Brown's programmatic indicators (# 21, Number of Illicit Connections Identified/Corrected; #22, Number of BMPs Installed, Inspected and Maintained, and #23, Permitting and Compliance) and the one site indicator we tested (#26, Industrial Site Compliance Monitoring). Two of Claytor and Brown's social indicators, (#18, Industrial/Commercial Pollution Prevention, and #19, Public Involvement and Monitoring) were also useful for directly evaluating the pollution-prevention activities.

The other two social indicators (#17, Public Attitude Surveys and #20, User Perception) were not very useful as measures of program effectiveness, but did provide information that can be used to target future outreach efforts.

7.1 Watershed-related indicators

The watershed-related indicators included physical, water-quality, and biological indicators that are usually applied at a watershed scale to assess the health and level of function of aquatic ecosystems, to understand the natural and anthropogenic factors influencing those functions, and to identify potential problems and problem areas. For this study, these indicators were useful when applied to the Level I phase of the Claytor and Brown methodology. However, they are of limited use in the Level II phase.

7.1.1 Application to Level I.

The results of these indicators, by themselves, are not sufficient to help stakeholders achieve a consensus understanding of the relationships between urbanization, functioning of stream ecosystems, and beneficial uses. These indicators require a framework for understanding the relationships among and between natural factors (e.g., flow regime, hydrogeomorphology, habitat, temperature, water quality, sediment supply) and urbanization (e.g., site design, street design, imperviousness, alterations to drainage density and stream channels, flooding, runoff pollutants). In the absence of such a framework, stormwater programs and watershed stakeholders will find it difficult to select indicators or to evaluate the results of applying them.

A regulatory-based framework such as those typically adopted by water-quality programs might expand consideration of pollutant effects to examine other "stressors" such as changes to flow regime and habitat change. Within such a framework, biological indicators are regarded as integrative of the cumulative effects of human influence. Comparison to relatively unimpacted reference sites, or a reference condition, is used to measure the degree of cumulative impact. Follow-up study may be required to allocate the degree of impairment among various stressors.

The limitations of this approach stem from reductionism; i.e., the approach is focused on measuring overall health or impairment rather than on gaining a general understanding of the interrelationships among human activities and stream characteristics. The attempt to develop a single group of indices that can be applied within or across watersheds — i.e. that can sum up the entire natural and human history of a watershed, or even compare one watershed against another — may lead to use of abstract measurements that reflect very generalized differences between "uninfluenced" and "influenced" biotic communities. Some methodologies suggest that the index itself should be refined and calibrated by selecting metrics that best correlate with obvious evidence of "human influence" within a watershed. This might ultimately result in an index that correlates well to perceived "human influence" but is of little practical value in watershed planning and urban design.

A framework focused on management of resources — i.e. on opportunities to change stream conditions so as to maximize their function as habitat, or to avoid potential threats to stream functions — provides better opportunities to use physical and biological indicators. Such an approach typically begins with investigation and analysis of changes to the way that streams transport water and sediment and change their shape in response to flood flows. These hydrogeomorphic functions are then related to habitat functions, which, in turn, provide context for the examination of the abundance and distribution of fish and other aquatic life. (See Section 6.7.)

To be useful in assessing the attainment of aquatic life beneficial uses, biological, water-quality, and other watershed indicators should be applied and interpreted in the context of the hydrogeomorphic and habitat functions of specific watersheds.

Ultimately, the purpose of such an assessment is not to measure differences between watersheds or stream reaches that are "influenced" or "less-influenced" by human activity. Rather, the purpose of investigating and measuring the physical, chemical, biological and ecological characteristics of streams should be integrally tied to the complex and collective work of preserving and enhancing beneficial uses.

To facilitate that collective work, the indicators must be applied within a resource-management framework and must also convey a message or story that impels stakeholders to action.

Kimberly Walesh of Collaborative Economics has illustrated the role of indicators as shown in Figure 7-1 (Walesh 2000).

Each of these elements is necessary, because:

⇒ Without a compelling, well-communicated story, it is difficult to catalyze action.

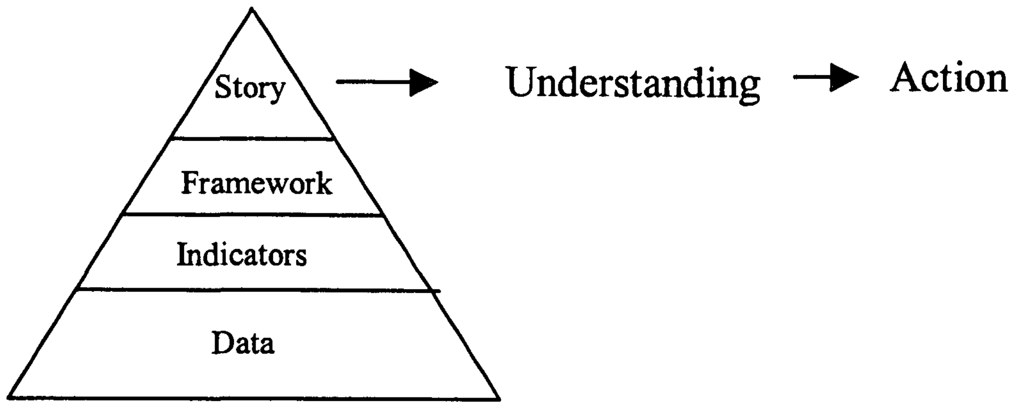


Figure 7-1. Relationship of Indicators to Actions

⇒ Without an organizing framework to provide a unifying theme, it is difficult to choose a consistent set of indicators.

⇒ Without indicators that organize the data, the data are impenetrable.

⇒ Without timely, relevant data, a story's significance is dramatically reduced.

To inform and motivate watershed stakeholders, physical, hydrological, chemical and biological indicators are best used to "tell the story" of how a watershed has changed, and is changing, in response to human influences. A compelling, well-communicated story can stimulate actions to improve the watershed.

We developed useful techniques and information for understanding the relationships between urbanization and stream function through implementation of the Growth and Development Indicator (#24), the Stream Widening and Downcutting Indicator (#7), and to a lesser extent, the Increased Flooding Frequency Indicator (#10). Additional valuable information came from the survey of stream conditions in connection with the Physical Habitat Indicator (#8) and the Sediment Characteristics and Contamination Indicator (#15). However, these useful results were achieved largely by reinterpreting the Claytor and Brown indicator profiles in the context of a general assessment of the relationship between hydrogeomorphic functions (i.e. the transport of water and sediment, and the flood-induced construction and reconstruction of physical habitat within the creek) and biological functions (as represented by presence/absence and relative abundance of fish and macroinvertebrates).

The usefulness of the watershed-related indicators was facilitated by their application in the context of the Program's ongoing participation in the SCBWMI. This participation established the expectation that assessment of watershed conditions would lead to recommendations of specific actions, within the Co-permittees' authority and capabilities, to preserve and enhance beneficial uses. Perhaps most significantly, the SCBWMI established the mechanism for the SCVURPPP and Co-permittees to share the responsibility for the watershed among many stakeholders and to sort out what specific actions it was most appropriate for each stakeholder to implement. Outside this context, the Co-permittees may have been less likely to acknowledge and accept the connection between the results of the physical and biological indicators and the goals of the urban runoff pollution prevention program.

The benefits of the indicator project suggest the potential for refining and perhaps streamlining some of the indicators and incorporating them into an general methodology that uses stream hydrogeomorphology, together with the most relevant and easily characterized measures of urbanization (e.g. extent of outfalls and altered stream channel, extent of riparian area, concentration of pollutants in stream sediments) to illustrate key watershed relationships.

If the indicator methodology were simplified and streamlined, it would be easier and faster to use indicators to motivate watershed stakeholders to preserve and enhance riparian corridors, improve value and connectivity of habitat, manage streamflow, avoid further disturbance within the stream channel, avoid construction of additional engineered drainage, and (most relevant to the SCVURPPP) avoid summer discharge of oxygen-demanding substances to urban reaches.

7.1.2 Application to Level II.

Application of watershed-related indicators to evaluating the effectiveness of stormwater programs requires a detailed consensus understanding of stormwater program activities and the expected effects these may have on watershed characteristics. This consensus understanding is best developed in the context of a stakeholder-based watershed management effort.

Stormwater program participation in watershed management can be measured programmatically, e.g., by funds and staff effort contributed and by review of the specific planning products produced. As a specific example, SCVURPPP and its Co-permittees contributed nearly all the administrative and technical support that the SCBWMI has required in its watershed planning efforts so far, and the results are document the first of three planned volumes of the Santa Clara Basin Watershed Management Plan.

Watershed-related indicators are best used to measure the effects of comprehensive efforts to restore stream functions, or to monitor expected changes due to urbanization. Attempts to correlate changes in watershed-related indicators with the implementation of BMPs and control measures have nearly always yielded inconclusive results. Stormwater programs should consider carefully the selection of indicators and design of studies to examine these relationships.

Correlations can sometimes be shown where pollutant sources are unusually rich and effects are measured immediately downstream.

7.2 Program-related Indicators

Program-related indicators, targeted at measuring specific program activities, were useful for documenting and understanding pollution-prevention efforts and yielded insight into ways to improve both the pollution-prevention measures and the means of documenting them. For this study, these indicators somewhat useful for documenting existing conditions (Level I of the methodology) and were more useful for evaluating the effectiveness of the Program (Level II).

7.2.1 Application to Level I

Consideration of the basic stormwater pollution-prevention mandates — to eliminate non-stormwater discharges and to require implementation of BMPs — points to the need to characterize and quantify the relevant existing conditions: How common are illicit connections and illegal dumping incidents? What BMPs are businesses and homeowners already implementing?

We applied these questions to data collected at the inception of the Program, including illicit discharge data from the Coyote Creek watershed dating back to 1992, and data collected as part of the pilot industrial inspection program in the Walsh Avenue catchment around the same time.

This data provided a needed baseline from which to gauge the success of Program efforts, and also provided some indication of the extent and potential impact of non-stormwater discharges.

7.2.2 Application to Level II

We found that the programmatic indicators, as with the watershed indicators, were most effective when there was a consensus among stormwater programs, regulatory agencies, and the public regarding the program's role, responsibilities, and ability to achieve specific aims.

In the case of the programmatic indicators, this meant a consensus understanding of Program goals, objectives, practices, and procedures. This consensus is codified in Performance Standards that apply to each Program element. The

Performance Standards have been drafted by the Program and Co-permittees, in cooperation with regulatory agency staff and interested parties, and approved as an integral part of the Program's NPDES permit.

Program elements are continuously improved through the Program's process of annual review (Figure 1-).

The Program's Performance Standards and continuous improvement process facilitated the effectiveness of the indicators because:

⇒ Under the Performance Standards, the Co-permittees maintained systems to collect and report data (e.g. illicit discharge incidents, industrial inspections) that were used to evaluate the indicator.

⇒ This data made it possible to review spatial and temporal trends in the parameters measured.

⇒ Trends in the data revealed opportunities to better target municipal staff efforts and improve efficiency. We found this to be the primary benefit from applying the indicators.

⇒ The continuous improvement process provided a ready mechanism to implement our findings from implementing the programmatic indicators. These mechanisms included budgets required to investigate feasibility, plan and design improvements, and a process to involve the municipal staff (e.g. industrial inspectors and street maintenance supervisors) responsible for implementing the Performance Standards.

In describing the implementation and benefits of the Number of Illicit Connections Identified/Corrected Indicator (#21) and the Number of BMPs Installed, Inspected, and Maintained Indicator (#22) Claytor and Brown's (1996) indicator profile sheets conjoin the benefits of objectively reviewing incident and inspection records with the benefits of the inspections themselves. For example, the description of Indicator #21 begins: "This indicator involves the identification and correction of illegal and/or improper waste discharges into storm drainage systems…"

At first look, the practice of implementing of an activity, while simultaneously applying an indicator meant to measure the results of that activity, could confound any objective assessment of program effectiveness. However, our experience suggests the benefits of integrating implementation and assessment far outweigh potential drawbacks. Involving line staff in measuring the results of their own work — particularly when it is known that the results will be reviewed and reported by management and by regulatory staff — tends to lead line staff to place greater value on the completeness and accuracy of records. Further, it generates enthusiasm and interest in the task at hand.

The value of involving line staff in the assessment process was also apparent in our implementation of the Industrial/Commercial Pollution Prevention Indicator (#18) and the Public Involvement and Monitoring Indicator (#19). In this case of these two indicators, the process of one-on-one and small-group outreach and education is linked with gaining feedback on the results of that outreach and education.

Implementation of these indicators highlighted the potential benefits of improving data-gathering and record-keeping associated with industrial inspections, cleanup of illegal dumping incidents, and outreach to facility managers and the public. Some of the program-related indicators confirmed anecdotal evidence, already being discussed by the Co-permittees, of the need for improvements in the way pollution-prevention measures were being implemented and documented. Some of these needed improvements had already been established as "continuous improvement items" and projects had already begun to be scoped for the following budget year. Outside the context of an established commitment to continuous improvement, the Co-permittees would have been less likely to commit to specific actions in response to the indicator results.

These planned improvements in record-keeping should help the Co-permittees demonstrate that they are implementing these Program elements to the "maximum extent practicable" and facilitate continuous improvements to their methods. The data may also be useful in measuring and improving productivity of the municipal line departments.

The usefulness of this portion of the methodology — i.e. the application of program-related indicators to assess and re-evaluate management programs — depends on:

⇒ Integration of data-gathering and reporting requirements into Program Performance Standards.

⇒ Involvement of municipal line staff in designing the record-keeping process so that it is integrated into inspection, clean-up and enforcement activities.

⇒ An established commitment to, and process for, continuous improvement.

7.2.3 Tools for Targeting Outreach

Two of the social indicators we tested — #17, Public Attitude Surveys, and #20, User Perception — are designed as broad gauges of public awareness and sentiment. For reasons discussed in Sections 6.17 and 6.20, we did not find these indicators particularly useful in evaluating program effectiveness. However, they were useful in assisting SCVURPPP to target future public education resources.

By implementing Indicator #17, the Program was able to establish, or reaffirm in some instances, the Program's primary target audiences, key messages, and most effective modes of communication to reach target audiences. The indicator also provided the Program with profiles of residents' awareness and behaviors that contribute to urban runoff pollution. The indicator also reaffirmed Santa Clara Valley residents' support for expending public funds to educate people and businesses about urban runoff pollution. This information is useful in helping the Program to formulate work plans and budgets with more certainty that the public will value and support these efforts. Finally, the indicator provided the Program with critical information on the public's levels of awareness of watershed issues and allowed the Program to gauge how well a future campaign will be received.

Indicator #20 particularly useful in identifying the public's misconceptions, which in turn, will aid in targeting future education and outreach programs. For example, area residents continue to perceive large industrial or manufacturing companies as the major contributors to water pollution, and attribute far less responsibility to private residents. Future efforts could be improved by using this information as a platform to educate the public about the sources of urban runoff pollution and the collective impact the general public possesses for stormwater pollution.

#20 particularly useful in identifying the public's misconceptions, which in turn, will aid in targeting future education and outreach programs. The results of this indicator also reinforced the Program's 1996 conclusions regarding the natural features that are perceived to make the most important contributions to the Valley's quality of life.

8. Conclusion

An evaluation of the effectiveness of a stormwater program must account for:

⇒ The specific requirements applied to the programs as described in Section 402(p) of the Clean Water Act, USEPA's stormwater regulations, and the requirements of the states.

⇒ The complex nature of watersheds and the response of streams and other water bodies to land use within their watershed.

⇒ The natural and human history of watersheds, including the legacy of logging, mining, agriculture, ranching, and other non-urban impacts.

⇒ The multifaceted effects of urbanization, including the changes to hydrology, flooding, drainageways, and water quality, as well as the damming and diversion of stream flow, that typically accompany agricultural and urban development,.

⇒ An understanding of sources, fate, transport, and effects of pollutants throughout the watershed.

⇒ The relationship between BMP implementation and watershed effects, including reductions in pollutant loads.

⇒ The problems of natural and random variability, as well as uncertainty in measurement, associated with environmental sampling.

⇒ Variability in the needs, characteristics, and capabilities of local government, including the local social and political, as well as environmental, milieu.

⇒ The specific goals of the local stormwater program.

No single indicator, or combination of indicators, is likely to meet the needs of every stormwater program. Stormwater programs will need to choose indicators, and an approach to implementing them, that best suits their needs.

Most stormwater programs seem to emphasize two goals: meeting the requirements of their NPDES permit, and determining the status of beneficial uses in local waters. Many also seek to educate the public about stormwater pollution-prevention.

The results of this study suggest two categories of indicators: watershed-related indicators, which are best applied in the context of stakeholder-based watershed management planning, and program-related indicators, which provide feedback that can be used to focus and improve municipal stormwater pollution-prevention programs.

Table 8-1 summarizes our perspective regarding the usefulness of the indicators and the framework in which they should be applied..

8.1 Watershed-related Indicators

The usefulness of these indicators depends on their integration into a narrative that educates and motivates watershed stakeholders to protect and enhance stream beneficial uses. To develop such a narrative, the indicators must first be organized around a framework that provides a unifying theme. The development of that theme — and the process of focusing a watershed management plan around it — is best accomplished by watershed stakeholders working together. Our experience in the Coyote Creek watershed suggested that the most useful framework incorporates an understanding of how stream hydrogeomorphology — the flow of water and sediment, and the continual re-creation of in-stream structures by natural and human influences —relates to stream biological functions and the associated aquatic life beneficial uses.[10]

We were able to use the watershed-related indicators to characterize some of these watershed relationships in Coyote Creek. The indicator

[10] In particular, we would recommend the approaches described in Brinson, et. al (1985), Riley (1998), and Federal Interagency Stream Restoration Workgroup (1999). For specific application of a functional approach to Coyote Creek, see Buchan and Leidy (1999).

Table 8-1. Summary of Indicator Usefulness.

		Indicator	Usefulness for Level I – Problem Identification and Baseline Conditions	Key conditions and requirements for enhancing Usefulness in Level I Assessments	Usefulness for Level II – Assessment of Management Program	Key conditions and requirements for enhancing usefulness in Level II Evalutions	Additional or Alternative Indicators
Watershed Indicators	Physical & Hldrological	#24 – Growth and Development (Imperviousness)*	Useful	Use indicators within framework linking urban drainage patterns to impacts on stream hydrogeomorphic functions and habitat functions.	May be possible to use physical condition of streams and extent of drainage modifications as an indicator of success in Watershed Management.	Requires long-term data sets and consistent protocols. Most effective when used to measure specific temporal effects of land use change or watershed management actions.	Dam releases and flow diversions, amount or proportion of altered vs. natural channel, inventory of storm drain outfalls and design flows, extent of floodplain, extent of riparian area.
		#7 – Stream Widening and Downcutting	Limited				
		#8 – Physical Habitat Monitoring	Useful				
		#10 – Increased Flooding Frequency	Limited				
		#11 – Stream Temperature Monitoring	Limited				
	Water-Quality	#1 – Water Quality Monitoring	Limited	May be useful to illustrate relative degreee of influence of runoff on different stream reaches, but not necessarily linked to beneficial uses.	May be applied at site or catchment scale to supplement programmatic measures of BMP implementation	Sediment appears to be a more robust indicator than storm flows. Best used to monitor response to clean up of specific sites or catchments.	Continuous monitoring of dissolved oxygen during summer months. Consider other indicators of urban influence on stream sediments, e.g. visual observations or oil/grease.
		#2 – Toxicity Testing	Limited				
		#3 – Non-point Source Loadings	Not Useful				
		#4 – Exceedance Frequencies of Water Quality Standards	Not Useful				
		#5 – Sediment Characteristics and Contamination	Somewhat Useful				
	Biological	#12 – Fish Assemblage	Very Useful	Use established methods for data collection and analysis; refine selection of indices.	Use to correlate and confirm effects of physical and hydrological changes and changes in water quality.	Long-term consistent monitoring at selected sites. Select indices based on stakeholder goals and practicability.	Fish and macroinvertebrates seem to be the best biological indices because methods are established and links to stream function and beneficial uses are widely understood.
		#13 – Macroinvertebrate Assemblage	Very Useful				
Social Indicaotrs		# 18 – Industrial/Commercial Pollution Prevention	Very Useful	Conduct on-site interviews in context of site inspections.	Can test effectiveness of specific outreach messages.	Use to measure success of specific outreach campaigns.	Similar approach could be applied to other groups, e.g. mobile cleaners, landscapers, restaurant managers.
		#17 – Public Attitude	Useful	Use to gauge general awareness of watershed and pollution-prevention issues.		Measure behaviors instead of attitude. Focus on everyday activities that can affect water quality.	
		#20 – User Perception	Limited	Importance ascribed to pollution prevention and watershed issues is affected by social and economic conditions.			

Table 8-1. Summary of Indicator Usefulness.

	Indicator	Usefulness for Level I - Problem Identification and Baseline Conditions	Key conditions and requirements for enhancing Usefulness in Level I Assessments	Usefulness for Level II - Assessment of Management Program	Key conditions and requirements for enhancing usefulness in Level II Evalutions	Additional or Alternative Indicators
Programmatic Indicaotrs	# 21 – No. of Illicit Connections Identified/Corrected			Very Useful	Establish programmatic indicators to complement Performance Standards and use as part of continuous improvement process.	Consider appropriate programmatic indicators for public agency activities, new development, other program elements. Consider programmatic indicators for participation in watershed management process.
	# 22 – No. of BMPs Installed, Inspected, and Maintained			Somewhat Useful		
	# 23 – Permitting and Compliance			Useful		
	# 26 – Industrial Site Compliance Monitoring			Useful		
	# 19 – Public Involvement and Monitoring*			Limited		

results will be applied, and expanded upon, as SCVURPPP participates in a watershed management process to plan management of flow, in-stream activities, and preservation and enhancement of riparian areas. To be successful, this process must also integrate flood management planning and a review of how land development policies contribute to these goals.

As this watershed management process proceeds, it should be possible to plan the use of indicators to measure the success of elements in a watershed management plan, e.g., to measure conditions before-and-after changes in dam releases, in-stream restoration actions, or urban development along a specific reach.

8.2 Program-related indicators

Stormwater pollution prevention programs should adapt the program-related indicators to correspond to the their specific permit conditions and approved work plans. The indicators should combine reporting the programs' level of effort (e.g. number of businesses inspected, number attending outreach events) with measurement of variables directly related to that effort (e.g. improvement in pollution-prevention compliance, knowledge of pollution-prevention techniques).

The use of program-related indicators will be most effective when program managers and regulators have agreed on a policy of continuous improvement. This requires acknowledgement that "maximum extent practicable" is different for each locality and changes over time.

As part of the continuous improvement process, the indicator results should be openly discussed in meetings that include municipal staff, regulatory agency staff, and interested parties.

8.3 Linking Watershed Management and Stormwater Pollution Prevention

Development of stormwater environmental indicators stemmed from the desire to redirect NPDES-permitted stormwater pollution prevention programs to focus on receiving water body quality and the beneficial uses that the community desires for that water body.

The results of this project confirm that the myriad effects of urbanization on water bodies cannot be adequately addressed within the limits of the NPDES-permitted programs. Municipal stormwater programs cannot, by themselves, develop and implement plans to preserve and enhance urban watersheds. These tasks require a watershed management approach.

Municipal stormwater pollution prevention programs, like other municipal programs, are most effective when they are guided by a specific plan, with objectives, tasks, timelines, and budgets for each plan element, and a process for periodic evaluation and adjustments. The programs will contribute most effectively to watershed management when they combine ongoing participation in the stakeholder process with development of specific work plans — i.e., when they define specific tasks within the general stakeholder effort that the municipal program is best qualified to implement.

During the planning stages, stormwater program contributions to the stakeholder effort may include conducting studies, managing data, acting as fiscal agents, managing joint projects, and facilitating stakeholder meetings. As the stakeholder process builds a common understanding of how urbanization has affected uses in the local water body — and builds consensus on objectives and actions to preserve and enhance those uses — changes to the municipal program may include targeting specific sources, areas, or pollutants.

In this way, stormwater pollution prevention programs can develop, define, and measure the effectiveness of their contributions to watershed management.

This project has confirmed SCVURPPP's working definition of a successful stormwater pollution prevention program as one that:

⇒ meets the obligations stated in its NPDES permit and management plan;

⇒ makes decisions openly and is responsive to contributions and new ideas from regulators and the public;

⇒ is continuously improving;

⇒ is actively involved in broad, stakeholder-based efforts to control pollution and to protect and enhance beneficial uses of local waters.

9. References

Barsamian, L. 1999. *Notice of Violation: discharging pollutants to waters of the United States without a permit.* California Regional Water Quality Control Board, San Francisco Bay Region, Oakland, California.

California Regional Water Quality Control Board for the San Francisco Bay Region (1986). *Water Quality Control Plan for the San Francisco Bay Region.* (Basin Plan).

CH2MHill and EOA, Inc. (1987). Nonpoint Source Evaluation Action Plan.

City of San Jose. 1995. *City of San Jose Urban runoff Management Plan Annual Report 1994 – 1995.* Environmental Enforcement Division, Environmental Services Department, San Jose, California, 70pp.

City of San Jose. 1996. *City of San Jose Urban runoff Management Plan Annual Report 1995 – 1996.* Environmental Enforcement Division, Environmental Services Department, San Jose, California, 70pp.

City of San Jose. 1997. *City of San Jose Urban runoff Management Plan Annual Report 1996 – 1997.* Environmental Enforcement Division, Environmental Services Department, San Jose, California, 70pp.

City of San Jose. 1998. *City of San Jose Urban runoff Management Plan Annual Report 1997 – 1998.* Environmental Enforcement Division, Environmental Services Department, San Jose, California, 70pp.

Claytor, R.A. and Brown, W.E. (1996). *Environmental Indicators to Assess Stormwater Control Programs and Practices, Final Report.* Center for Watershed Protection, July 1996.

California Regional Water Quality Control Board San Francisco Bay Region (1990). Permit No. CA 0029718, Order No. 90-094.

California Regional Water Quality Control Board San Francisco Bay Region (1995). NPDES Permit No. CAS029718, Order 95-180.

California Regional Water Quality Control Board San Francisco Bay Region. 1992. "Guidance for Who Needs an Industrial Storm Water Permit." Memorandum to Interested Parties from Thomas Mumley.

California State Water Resources Control Board. 1995. Annual Report for Storm Water Discharges Associated with Industrial Activities, 1994 – 1995. State Water Resources Control Board, Sacramento, California.

Duke, L.D., and Bauersachs, L.A. 1998. *Compliance with storm water pollution prevention regulations by metal plating industry facilities.* Journal of the American Water Resources Association. 34(1): 1-12.

Duke, L.D., K.P. Coleman, and B. Masek. 1999. "Widespread failure to comply with U.S. storm water regulations for industry, Part I: Publicly-available data to estimate number of potentially regulated facilities." Environmental Engineering Science.

Duke, L.D., and K.A. Shaver. 1999. Widespread failure to comply with U.S. storm water regulations for industry, Part II: Facility-level evaluations to estimate number of regulated facilities. Environmental Engineering Science.

Fairbanks, Maslin, and Maullin. *1999 Public Opinion Survey, Final Summary Report.* Prepared for the Santa Clara Valley Urban Runoff Pollution Prevention Program, September, 1999.

Habitat Restoration Group. 1995. Spreader Dams Fisheries Study 1994 Annual Report: Summary of Field Work, Nov ember 1993 through October 1994 and Five-Year Project Summary 1989-1994. Prepared for the Santa Clara Valley Water District, March 1995.

Harrington, J.M., Ode, P., Montalvo, A., Post, D., Sheehy, C. and M. Dawson. 1999. Biological and Physical/Habitat Assessment of California Water Bodies - Russian River Index of Biological Integrity (RRIBI) for First to Third Order Tributary Streams. California Department of Fish and Game, Office of Spill Prevention and Response, Water Pollution Control Laboratory. May 1999.

H.T. Harvey and Associates and Coyote Creek Riparian Station. 1995. Coyote Creek Reach 1A 1994-1995 Monitoring Report. Prepared for the Santa Clara Valley Water District, San Jose, California. 17pp and appendices.

Kinnetics Laboratories, Inc. (KLI), 1999. Quality Assurance Project Plan for the Stormwater Environmental Indicators Demonstration Project. Part II: Coyote Creek. Santa Clara Valley Urban Runoff Pollution Prevention Program, Sunnyvale, CA.

Leidy, R. 1981 (Unpublished data). USEPA Wetlands Division. Personal communication, September 1999.

Rensselaerville Institute, 1995. Report on Stormwater Indicators Meetings Conducted April-June 1995 by the Rensselaerville Institute as part of a cooperative agreement with EPA. In Appendix A to Claytor and Brown (1996).

Santa Clara Valley Urban Runoff Pollution Prevention Program (1997). Urban Runoff Management Plan. September 1, 1997. Sunnyvale, CA.

SCVWD. 1999 (Unpublished). Anderson Reservoir temperature data (1996-99). Don Daves, personal communication.

State Water Resources Control Board. 1997. *Industrial Activities Storm Water General Permit.* State Water Resources Control Board, Sacramento, California.

StatSoft, Inc. (1999). Electronic Statistics Textbook. Tulsa, OK: StatSoft. WEB: http://www.statsoft.com/textbook/stathome.html

Sylvester, M.A. 1986. Water Quality and Flow of Streams in Santa Clara Valley, California, 1979-81. USGS Water-Resources Investigations Report 84-4196. Prepared in cooperation with the Santa Clara Valley Water District. USGS, Sacramento, CA.

Woodward-Clyde Consultants (1990). Loads Assessment Results and Implementation Program, (3 volumes).