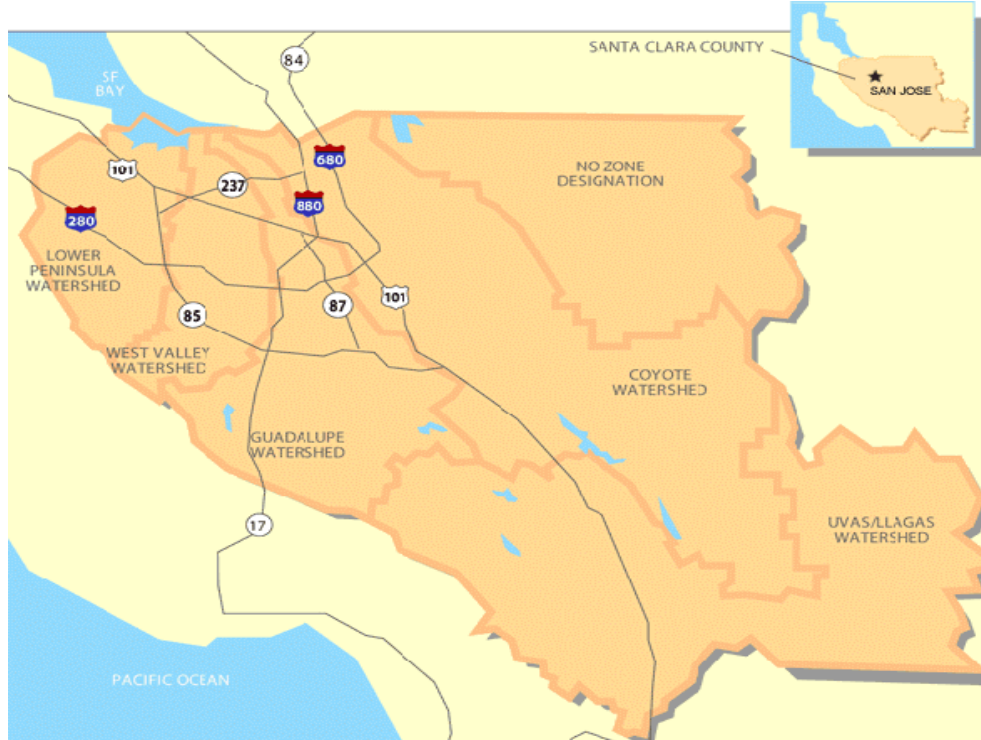


DEVELOPING WATERSHED INDICATORS FOR SANTA CLARA COUNTY:
A Report to the Santa Clara Valley Water District
for the 2003 Watershed Stewardship Grant Program

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“We play in water, fish in it, bath in it, and drink it...We are mostly water and have an affinity for it that transcends our ability to describe it in mere words.”

- David Orr

Section 1. Introduction

Clean water is crucial to sustaining life. Not only are clean water supplies essential to human health and activities, but they are critical to sustaining all aquatic and amphibian species as well as all terrestrial flora and fauna. One key to clean water is the protection of watersheds, the drainage basins through which water runs before it collects in streams, rivers, lakes, bays and groundwater systems. Conditions in watersheds are major determinants of the level of pollutants, such as sediments, excess nutrients, and toxic compounds, that end up in our nation's waters. Monitoring watersheds for problems that can reduce water quality entails using indicators, which are measures that inform us of the condition of watersheds. Good indicators of environmental health are able to show trends over time that indicate human impacts to resources. Once these impacts are detected, action can be taken to prevent further degradation of the resource and, perhaps, even restore environmental health. As part of our national quest to protect water resources, indicators of watershed health are being used as valuable tools for monitoring and ultimately protecting water quality.

Unfortunately, environmental indicators monitored by the EPA show that watersheds are in poor condition throughout the US. The EPA's Index of Watershed Indicators reports that:

- 15% of our watersheds nationally have relatively good water quality;
- 36% have moderate problems;
- 22% of the watersheds have more serious water quality and;
- 27% do not have enough information to be characterized.

In addition, one out of every 15 watersheds nationally is highly vulnerable to further degradation (US EPA, 2002).

Recognizing the importance of watershed indicators, the Silicon Valley Environmental Partnership (SVEP) included such an indicator in their 1999 report, Silicon Valley 1999 Environmental Index. This report included a number of indicators of the environmental health of the area and was designed to “document the progress Silicon Valley has made toward restoring a healthy natural environment and charting those areas where declines in our natural environment must be reversed if we are to achieve a sustainable community.” For watershed health, the report authors included the US Environmental Protection Agency (EPA) assessment of watershed health in Silicon Valley as one indicator of water quality in Santa Clara County. The EPA uses a suite of water quality and watershed condition measures (discussed in Section 3) that are then collated into a single score for watershed health. These measures are assessed using three general levels of health: better, less serious and more serious (see Appendix A). This general format did not provide the detail necessary to track changes in water quality and watershed condition over time for the County. Because of their generality, EPA watershed condition indicators were not included in the up-dated Silicon Valley Environmental Index in 2003. Instead, three new indicators were used in their place: percentage of drinking water in compliance with drinking water standards, underground fuel leaks, and hazardous chemical leaks. While excellent surface and groundwater indicators, these measures do not provide a picture of watershed health.

Both SVEP and the Santa Clara Valley Water District (Water District) recognized the need for developing quantitative indicators of watershed health for Santa Clara Valley, a realization that resulted in the Water District’s 2003 Watershed Stewardship grant award to SVEP. To assist with watershed indicator development, SVEP formed a partnership with the Department of Environmental Studies at San Jose State University. The Chair of the Department and the non-profit Environmental Resource Center (ERC) in the Department have worked with SVEP over the past year on watershed indicator development.

This grant has resulted in several products, the first being the complete development of a watershed indicator focused on lower Coyote Creek, using riparian bird diversity (the number of different bird species using streamside forests and vegetation) to assess watershed health. A powerpoint presentation of this indicator has been placed on the ERC website (<http://www2.sjsu.edu/orgs/erc/> under “Student Project”) and is attached in Appendix B of this report. While this indicator is an excellent metric for assessing watershed health, the fact is,

watersheds are complex and require a number of different quantitative measurements if condition is to be assessed.

The second product from the grant is this report, which:

- reviews watershed indicators used by organizations to determine which of these indicators could be used to monitor watershed condition in Santa Clara County,
- examines two measures of Silicon Valley watershed conditions that could potentially be developed into indicators, and
- suggests other watershed indicators that could potentially be developed for Silicon Valley.

Section 2. What are Watershed Indicators?

Indicators play an integral role in our daily lives. Gauges on an automobile dashboard indicate the speed, gasoline level, and temperature of the engine. A visit to a doctor will require a test for pulse rate, weight level and cholesterol level to indicate our health. Just as pulse rate is an indicator of our health, so environmental indicators reveal the condition of our natural resources. Environmental indicators are used to track the quality of a resource area over time to observe whether conditions are improving, degrading or stabilizing. These data have been used establish acceptable levels of environmental health for many resource areas, such as air and water quality standards. Ultimately, data collected from monitoring conditions can lead to changes in our behavior that will benefit the environment.

Trained personnel in government, non-profit organizations, and local citizen's groups monitor watershed condition using a variety of indicators with various degrees of efficiency. The results of these programs, whether they are science based or student project oriented, are potential sources of information for developing watershed indicators. Examples of government and citizens groups have collected data on watershed condition in Santa Clara County include:

- Government: US EPA, US Geological Service, Regional Water Quality Control Board, Santa Clara Valley Water District, Cities of Palo Alto, Sunnyvale and San Jose.
- Non-profit: Acterra, Santa Clara Valley Audubon Society, San Francisco Bay Bird Observatory, Silicon Valley Toxics Coalition.

Indicators used to assess watershed health can be as simple as observing the water depth of rivers or as complex as the analysis of water chemistry. The EPA, for example, uses diverse indicators of watershed health, such as pollutant concentrations, wetland loss, and urban run-off potential. Whether simple or complex, single measures are seldom used to determine the health of a watershed; in reality a combination of indicators is the norm to decipher the vital signs of the health of a watershed in its entirety. Several qualities are required for a factor to be a good measure of watershed condition and water quality:

- The indicator must be linked directly with watershed/water quality conditions and must be sensitive to changing watershed conditions over time.
- At least 5 years of quantitative (numerical) data are needed in order to reveal changes in conditions.
- Existing data must have been collected with technically valid procedures that produce reliable data.
- There must be a link between the indicator and possible remedial actions.

Section 3. Organizations Monitoring Watershed Health--Global to Local

SVEP and the Water District would like more indicators of watershed health to be included in future updates of the Silicon Valley Environmental Index. In searching for measures that could potentially be turned into Santa Clara Valley indicators, we examined the indicators used by several organizations to monitor watersheds on an international, national and local level.

World Research Institute

The World Research Institute (WRI) is a non-profit organization engaged in environmental research and policy organization worldwide with four major goals: 1) to protect earth's living systems, 2) to increase access to information, 3) create sustainable enterprise and opportunity and 4) reverse global warming. The WRI is also involved in developing indicators for watersheds and uses 15 indicators “that characterize watersheds in terms of their ecological value, current condition, and vulnerability to potential degradation from human activities” (WRI 2002). Indicators used by the WRI include the following:

- Primary Watersheds (http://pdf.wri.org/watersheds_p1_19.pdf)
- Freshwater Fish Species and Endemism (http://pdf.wri.org/watersheds_p1_20.pdf)

- Endemic Bird Areas (http://pdf.wri.org/watersheds_p1_21.pdf)
- Aridity (http://pdf.wri.org/watersheds_p1_22.pdf)
- Population Density (http://pdf.wri.org/watersheds_p1_23.pdf)
- Water Availability (http://pdf.wri.org/watersheds_p1_24.pdf)
- Modified Landscape (Cropland and Developed Areas)
(http://pdf.wri.org/watersheds_p1_25.pdf)
- Cropland Irrigation (http://pdf.wri.org/watersheds_p1_26.pdf)
- Existing and Proposed Major Dams (http://pdf.wri.org/watersheds_p1_27.pdf)
- Remaining Original Forest Cover (http://pdf.wri.org/watersheds_p1_28.pdf)
- Extent of Original Forest Cover Lost (http://pdf.wri.org/watersheds_p1_29.pdf)
- Area Affected by Water Erosion (http://pdf.wri.org/watersheds_p1_30.pdf)
- Urban Population Growth (1995-2000) (http://pdf.wri.org/watersheds_p1_31.pdf)
- Tropical Deforestation (1980-1990) (http://pdf.wri.org/watersheds_p1_32.pdf)
- Protected Areas (http://pdf.wri.org/watersheds_p1_33.pdf)

The indicators are displayed using GIS maps for each individual set of data (in parenthesis above); the maps give an overall display of global patterns of the health of watersheds. Although the data provided do not give actual numbers of the extent of the impacts on watersheds, the maps are very compelling providing a visual overview of the health of watersheds worldwide.

US Environmental Protection Agency

The US Environmental Protection Agency (EPA) has developed an Index of Watershed Indicators (IWI) to assess the health of watersheds nationwide. As a federal enforcement agency, the EPA can regulate the impacts that occur as a result of human actions. The IWI has divided its indicators into two distinct types: condition and vulnerability indicators. The condition indicators reveal existing water quality in watersheds nationwide while the vulnerability indicators are designed to provide an indication of where pollution arises in watersheds as well as other potential problems that impact watersheds. The 15 condition indicators include the following:

- Assessed Rivers Meeting all Designated Uses Established by State or Tribal Water Quality Standards (305(b)). This indicator uses information reported from the Clean

Water Act section 305(b) on the percentage of waters within watersheds that meet all the requirements of this act.

- Fish & Wildlife Consumption Advisories. This indicator provides recommendations to restrict the consumption of fish or game that may contain contaminants.
- Indicators of Source Water Quality for Drinking Water Systems. This indicator combines 3 data sets to provide an update on the condition of public drinking water systems from rivers, lakes/reservoirs and ground waters systems.
- Contaminated Sediments. Fish tissue residue data, sediment toxicity and sediment chemical analysis are combined in this indicator to decipher the potential risk posed to humans.
- Ambient Water Quality Data. This indicator examines four toxic pollutants; copper, chromium (hexavalent), nickel and zinc (STORET) to observe percentage exceedences for national criteria levels over a six year period (1990 - 1996).
- Ambient Water Quality Data. This time four conventional pollutants--ammonia, dissolved oxygen, phosphorous and pH--are observed for percentage exceedences for national criteria levels over a six-year period (1990 - 1996).
- Wetland Loss Index. This indicator uses the US Fish & Wildlife Service National Wetland Inventory and the National Resources Conservation Service National Resource Inventory to determine the percentage of wetland loss over a historic period from 1870 - 1980 and then more recently from 1986 - 1996.

The eight vulnerability indicators are:

- Aquatic/Wetland Species at Risk. Using data from the Nature Conservancy/State Heritage Database this indicator provides data on the occurrences of species at risk in watersheds.
- Pollutant Loads Discharged above Permitted Discharge Levels - Toxic Pollutants. This indicator examines discharges of toxic pollutants over a one year period as a percentage above or below discharges as permitted by the National Pollutant Discharge Elimination System.
- Pollutant Loads Discharged above Permitted Discharge Levels - Conventional Pollutants. This indicator examines discharges of conventional pollutants over a one

year period as a percentage above or below discharges, as permitted by the National Pollutant Discharge Elimination System.

- Urban Runoff Potential. This indicator uses the percentage of impervious surface areas to gauge the impacts of runoff on watersheds.
- Index of Agriculture Runoff Potential. Data from the Natural Resources Conservation Service and the National Resources Inventory is combined to provide an index for the following: a nitrogen runoff potential, sediment runoff and pesticide runoff.
- Population Change. Census Bureau data is used for this indicator to monitor population growth and the potential impacts associated with urbanization.
- Hydrologic Modification. This indicator uses data from the Corps of Engineers to examine the impact of dams and the associated activities that result from watershed impoundment.
- Estuarine Pollution Susceptibility Index. Data from the National Oceanic and Atmospheric Administration is used to gauge the susceptibility of estuaries to pollution based on physical characteristics (US Environmental Protection Agency 2002).

The Bay Institute

The Bay Institute is a non-profit research, education and advocacy organization involved in restoring and protecting the fragile ecosystems of the San Francisco Bay area and its adjoining watersheds. The Bay Institute publishes a San Francisco Bay Index comprised of eight indices, each of which is composed of numerous measures. The indices are listed on an “ecological scorecard”, essentially a report card, that gives a grade and score for each index and then provides a short term/long term prediction of environmental condition in terms of its viability (improving, declining or stable). The eight indices are:

- Habitat Index - an index measuring the amount of habitat loss or restoration occurring.
- Freshwater Inflow Index - a measure of the amount of freshwater inflow into San Francisco bay from the adjoining watersheds.
- Water Quality Index - a measure of toxic sediments and storm runoff.

- Food Web Index - a measure of plankton levels that form a major food basis and the number of alien species present.
- Shellfish Index - a measure of crab and shellfish commercial harvests.
- Fish Index - a measure of fish populations.
- Fishable-Swimmable-Drinkable Index - a measure of fish eating warnings, beach closures and drinking water violations.
- Stewardship Index - a measure of water conservation, pollution limits, monitoring and restoration in progress.

Acterra

Acterra is a non-profit organization based in Palo Alto that plays a leading role in stewardship, restoration and awareness of environmental issues in the South Bay. One of their major projects is the San Francisquito Watershed Council, which is involved in restoring the health of the San Francisquito Creek and its tributaries. Projects include removing trash and invasive plant species, planting native species and modifying barriers that prevent native fish species especially the endangered steelhead trout (*Oncorhynchus mykiss*), from migrating up and down this watershed. Acterra has just recently started a “Citizen Streamkeepers” group to monitor activities along the watershed. Streamkeepers are trained to use indicators on a regular basis as each streamkeeper monitors their own portion of the watershed. A total of 5 indicator classes (multi-metric indices) with a number of specific measures are used as follows:

- Biological: Animals – an index that includes non-native species (6 species), native, threatened and endangered (3 species), native species becoming less common (5 species), and benthic macroinvertebrates (2 species).
- Biological: Plants – an index that includes trees growing in mid-channel, amount of revegetation, and presence of invasive exotic plants (15 species).
- Chemical – an index that includes 11 indicators of chemical impacts.
- Physical – an index that includes 8 indicators of physical impacts.
- Social – an index that includes 9 indicators of social impacts.

Section 4. Potential Watershed Indicators for Santa Clara County

After reviewing indicators used by other groups to monitor watersheds, we investigated data available in Santa Clara Valley. Our goal was to find measures that could potentially be developed into indicators to help characterize the health of our watersheds. As noted earlier, for a measure to be a good indicator of watershed health, the measure must link directly to watershed/water quality, be sensitive to changing conditions, have at least 5 years of quantitative (numerical) data, be collected with technically valid procedures and be amenable to remedial action. We chose two measures that met or could meet these standards.

Dissolved Oxygen (DO)

“DO levels are considered the most important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life” (Water on the Web). Dissolved oxygen levels are mainly a result of two oxygen sources: by plant photosynthesis and from direct absorption from the atmosphere. “Oxygen concentrations are much higher in air, which is about 21% oxygen, than in water, which is a tiny fraction of 1 percent oxygen” (Water on the Web 2004). The concentration of dissolved oxygen in a stream is dependent on several factors: 1) temperature - oxygen is more easily dissolved in cold water as compared to warm water, 2) water movement - fast flowing streams tend to have a higher concentration of DO than stagnant bodies of water, 3) day/night cycles - photosynthesis only occurs in green plants during the day hence DO levels are highest during the day when plants release oxygen and lower at night when respiration occurs and 4) suspended solids - oxygen is more readily dissolved into water with suspended solids, hence the reason why salt water tends to have lower concentrations of DO than fresh water (Acterra 2004).

The amount of dissolved oxygen in a stream is expressed as a concentration and that concentration in a stream “is the mass of oxygen gas present, in milligrams (mg) per liter (l) of water, which can also be expressed as parts per million (ppm)” (Acterra 2004). “Dissolved oxygen can range from 0-18 parts per million (ppm), but most natural water systems require 5-6 parts per million to support a diverse population” (Science Junction, NC State University 2000). When the concentration of dissolved oxygen falls below normal levels it can result in the loss of aquatic life. “A decrease in the dissolved oxygen levels is usually an indication of an influx of some type of organic pollutant” (Science Junction, NC State University 2000).

Not only is DO an important measurement of water quality, but it is easily measured with readily available and accurate field monitoring units. This ease of measurement one reason this parameter is so commonly used to assess water quality. However, it is important to realize that a number of factors result in DO changes and it is essential to understand those factors before ascribing low DO levels to poor watershed conditions. For example, lower DO levels in summer are natural, due to higher air temperatures. However, if human activities have removed streamside vegetation, then water temperatures will be unnaturally high and DO dangerously low. Such a condition can be remedied by planting streamside trees and understory. By understanding the *causes* of low DO levels, we are able to determine whether remedial action is necessary and what that action might be.

One source of DO data in Silicon Valley is the City of Palo Alto, which has been actively engaged in monitoring the streams of that city. Specific parameters they measure include: temperature, specific conductance, dissolved oxygen concentration, oxygen reduction potential, conductivity, resistivity, salinity and total dissolved solids. Sampling locations in Matadero creek, Adobe/Barron creeks and the Palo Alto flood basin are regularly monitored to observe the health trends as part of a pollution prevention program. The data collected are analyzed to observe trends over time and then displayed in graphical format.

The City of Palo Alto has been collecting DO data in Palo Alto creeks since April 1993 and other organizations are in the process of starting this data collection using dissolved oxygen. For example, the Stevens/Permanente Creek Watershed Council will begin measuring DO levels in August, 2004 and the Silicon Valley Toxics Coalition has initiated a similar project on the Guadalupe River. If these two organizations take regular readings of dissolved oxygen levels similar to the City of Palo Alto over the next 5 years, together these data this will provide an ideal watershed indicator encompassing much of Santa Clara County providing a trend over time.

Figure 1 gives an example of the dissolved oxygen data collected by the City of Palo Alto from April 2003 to February 2004. There is an obvious change in DO levels from late spring, summer and early fall when DO levels are in the 4.5 – 6 mg/L range compared to the remainder of the year when the levels reach 9 –12 mg/L. These DO levels are fairly normal for creeks in this location and nearly always remain above the 5mg/L level. As the University of Minnesota's excellent Water on the Web site states, "levels above 5 milligrams per liter (mg O₂/L) are

considered optimal and most fish cannot survive for prolonged periods at levels below 3 mg O₂/L. Levels below 1 mg O₂/L are often referred to as *hypoxic* and when O₂ is totally absent *anoxic* (often called anaerobic which technically means *without air*)” (Water on the Web 2004). While the Palo Alto DO levels appear very healthy, it is important to evaluate other factors that may impact DO such as levels of pollution, the decomposition of organic matter, and loss of riparian vegetation.

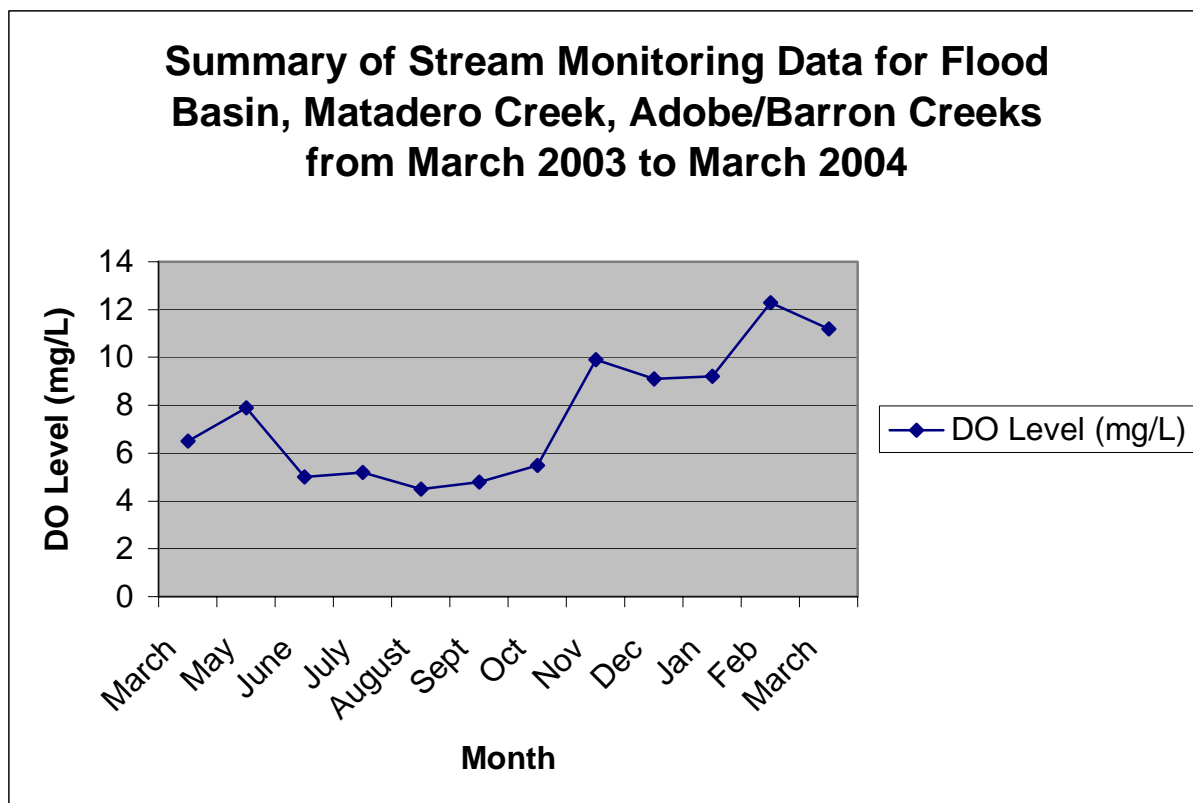


Figure 1. City of Palo Alto Dissolved Oxygen Data

Freshwater Clams

Freshwater clams “have tremendous potential for advancing community awareness of toxics in the environment . . . they will filter hundreds of gallons of creek water through their bodies, extracting food and toxins such as deadly PCBs. Luckily, they are resistant to PCBs and so can survive exposure as they function as inexpensive biological monitoring devices” (Silicon Valley Toxics Coalition 2004). Not only can clams be monitored for PCBs, they can also be monitored for highly toxic organic and heavy metal contaminants, brominated flame-retardants

and mercury (Silicon Valley Toxics Coalition 2004). To monitor for pollutants using clams, native clams or non-native species contained in plastic nets are placed in a water body for a period of time, during which they are filtering the water for food. In the process of filter feeding, the clams collect pollutants in their tissues. After a set period of time, the clams are removed from streams and their body tissues are analyzed for the presence of pollutants such as PCBs and mercury.

In Santa Clara County, PCBs and mercury are a serious concern in local waters. PCBs are a suite of 209 human-made compounds used for a variety of purposes, especially as flame-retardants and in transformers. These chemicals have been in wide use since the 1940s and have been escaping into the environment. They are extremely persistent compounds that take decades to breakdown and are known to cause a wide range of problems, including declines in wildlife populations. Human exposure to PCBs can result in the following:

- Developmental Effects – “Several recent studies suggested that children born to mothers who ate PCB-contaminated fish during their pregnancies may have had an increased risk of developing subtle (i.e., not easily observable) nervous system delays (e.g., abnormal reflexes, motor immaturity, deficits in memory, learning, and IQ), which in some cases persisted into adolescence” (ATSDR 2002).
- Cancers – “Some human studies provide suggestive evidence that PCBs are carcinogenic based on indications of PCB-related cancer in areas such as the liver, biliary tract, intestines, and skin” (ATSDR 2002).

Mercury is also a major problem in Santa Clara County, especially in the Guadalupe watershed. The huge Almaden Quicksilver mine, operated the 1800s and 1900s to extract cinnabar, is leaching mercury into the Guadalupe River in significant concentrations. This pollutant poses risks to wildlife in and along the Guadalupe River and out into the South San Francisco Bay, into which the River drains. Human exposure to mercury can result in a number of physical problems, especially brain damage as “methylmercury (CH₃Hg⁺) from fish consumption... affects the central nervous system, and in severe cases irreversibly damages areas of the brain” (U.S. Geological Survey 2001).

The US Geological Survey has monitored saltwater clams (*Macoma baltica*) in the South Bay for decades, and these quantitative data may be valuable in developing a watershed indicator using clams. A non-profit Santa Clara County organization involved in using clams as

biomonitors is the Silicon Valley Toxics Coalition (SVTC). Their studies are centered on the Guadalupe River watershed because the Regional Water Quality Control Board has found that fish in this watershed “have mercury contamination 5 to 10 times the levels found in Bay fish. PCBs in the Guadeloupe River during the winter have been shown to be 10 times greater than in the Central Bay and North Bay. This contamination is at levels exceeding those considered safe for human consumption” (Silicon Valley Toxics Coalition 2004).

SVTC plans to train high school teachers and their students on how to place and collect the clams in the Guadalupe River. They began this project to collect data on PCB and mercury levels in 2000 with a pilot study using Pioneer and Oak Grove High School students. Clams were placed and collected by the students and the tissues were analyzed by the City of San Jose. At the time of this report, it was not clear to us if quantitative data have been collected since 2000, but we will follow up with SVTC to see if there are data that could be used to create an indicator.

Section 5. Other Potential New Indicators of Santa Clara Valley Watershed Health

While DO and clam data appear to be good choices for new indicators, data may exist on other parameters that would be important to include as indicators of watershed health. Although we did not have time to investigate the potential data sources on the following parameters, they should be examined as they are important metrics of watershed health:

- Stream flow and water depth;
- Spread of non-native invasive species in the watersheds;
- Hydrological modification (channelization, dam removal or placement, etc.);
- Watershed restoration projects undertaken.

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APPENDIX A

Silicon Valley 1999 Environmental Index
Water Quality: Watershed Health in Serious Condition

Available on the Silicon Valley Environmental Partnership Website at: www.svep.org

APPENDIX B

A New Silicon Valley Watershed Indicator:
Birds as Indicators of Watershed Health in Silicon Valley
(developed by Philip Higgins)

Available on the Silicon Valley Environmental Partnership Website at: www.svep.org