BAY AREA WATERSHEDS SCIENCE APPROACH

VERSION 3.0

THE ROLE OF WATERSHED SCIENCE TO SUPPORT ENVIRONMENTAL PLANNING AND RESOURCE PROTECTION

PREPARED BY THE WATERSHED SCIENCE TEAM
SAN FRANCISCO ESTUARY INSTITUTE

September 1998

BAY AREA WATERSHEDS SCIENCE APPROACH

VERSION 3.0

THE ROLE OF WATERSHED SCIENCE TO SUPPORT ENVIRONMENTAL PLANNING AND RESOURCE PROTECTION

September 1998

San Francisco Estuary Institute

1325 South 46th Street
Richmond, CA 94804
http://www.sfei.org

Version 3.0 supersedes Version 1.0 (December 1996), Version 1.5 (June 1997) and Version 2.0 (July 1997)

ACKNOWLEDGMENTS

This version 3.0 of the Bay Area Watersheds Science Approach (WSA) and the accompanying example were authored by the Watershed Science Team at SFEI, led by Joshua N. Collins, Ph.D., Laurel Collins, and Rainer Hoenicke, Ph.D. Laurel Collins supervised all field work.

The illustrated example was made possible by the help of volunteer field assistants, including Peter Alexander, Brian Amador, Paul Amato, Elise Brewster, Ed Bowman, Nancy Brownfield, Steve Cochrane, Jordan DeStaebler, Robin Grossinger, Dale Hopkins, Preston Holland, Michelle Holland, Richard Kauffmann, Liz Lewis, Brett Harvy, Jill Marshall, Lisa Michelli, John Nicoles, Mike Rigney, James Sillamen, Kerri Steenwerth, and Martin Trso.

Technical support for graphics and computerized Geographic Information Systems (GIS) was provided by SFEI staff, including especially Zoltan Der, Mike May, and Christina Wong.

The (WSA) will continue to be revised based upon the suggestions of watershed managers and scientists in the Bay Area, and the SFEI Committee of Science Advisors. Written comments for previous versions of the WSA are available through SFEI, which takes full responsibility for the WSA. Comments about this version of the WSA should be directed to Josh Collins at SFEI.

We thank the East Bay Regional Park District for permission to explore Wildcat Canyon Regional Park, Tilden Regional Park, and the Wildcat Creek Trail.

The Bay Area Watershed Science Approach and the accompanying illustrated example were funded by grant # 96-2781 from the David and Lucile Packard Foundation.

TABLE OF CONTENTS

PLEASE NOTE: A sample of WSA results for Wildcat Creek watershed in Contra Costa County, Ca, is available from SFEI.

BAY AREA WATERSHEDS SCIENCE APPROACH

PREAMBLE

WHY IS WATERSHED MANAGEMENT IMPORTANT AND HOW DOES IT RELATE TO THE ESTUARY?

The values of the San Francisco Estuary are numerous. The Estuary is an immense natural resource and the biological centerpiece of America's fourth largest metropolitan area. The Estuary is needed to receive runoff from nearly half of California's landscapes. Freshwater from the Estuary is diverted to serve 18 million people and 4.5 million acres of farm lands. Five hundred million gallons of treated wastewater are discharged into the Estuary each day. The Estuary is the center of a unique natural community that includes two-thirds of the state's salmon, nearly half of the Pacific coast waterfowl and shorebirds, and sixteen rare, threatened, or endangered fauna.

But what is the relation of watersheds to the values briefly listed above? Every one of these values is influenced, controlled, or caused by the watersheds contributing to the Estuary. Without that tributary inflow the Estuary would collapse as an ecosystem, unable to accommodate the expected wastes of industry, agriculture, and urbanization. The watersheds - their soils, vegetation, geology, and land uses - largely determine the quality and quantity of incoming freshwater, sediment, and dissolved materials. The intimate relation of the Estuary to its contributing watersheds, and its dependency on the quantities and types of inflows, makes it obvious that knowledge about the sources of these inflows and their conditions is imperative. The watersheds are, in fact, a land extension of the Estuary. Protection of the Estuary relies upon the careful management of its attending watersheds.

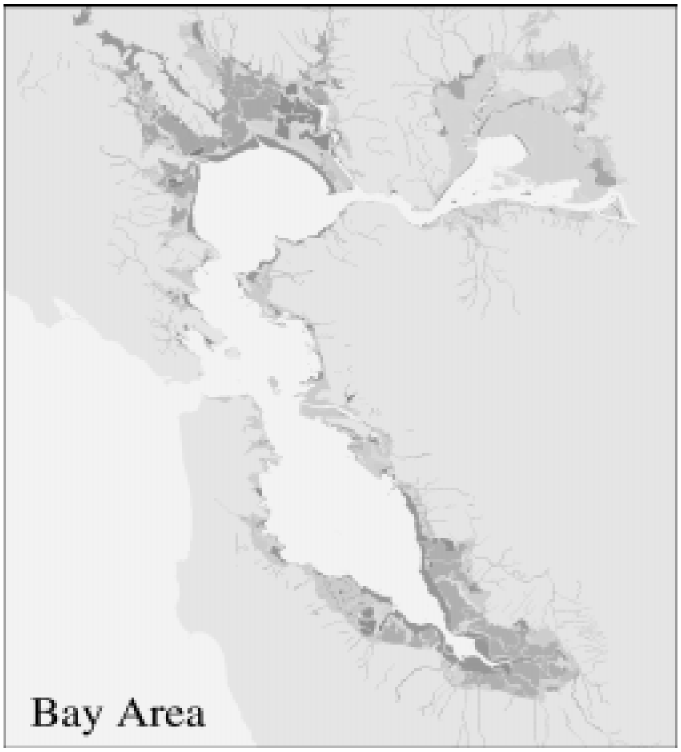
But protection of the Estuary is not the only compelling reason for watershed management. The watersheds have important values unto themselves. The rivers and streams and their immediate margins are local focal points in the regional aesthetic. They are political and practical boundaries, and they are sources of drinking water and irrigation. They are the arteries through which move rainwater, sediment, and nutrients critical to the good health of the land. They support natural communities of significant cultural, recreational, and commercial value. The valleys, hillslopes, and ridges are where we build, for better or worse. Watershed management is needed to protect whatever life the land and water can support.

For these reasons, an approach to improve our understanding of watersheds has been initiated by the San Francisco Estuary Institute. An outline of the approach is presented, and a sample of results is available from SFEI. It shows the amazing diversity of subject matter contributing to even a preliminary understanding of watershed condition and function.

Such information is needed for every watershed entering the Estuary. The SFEI Watershed Science Approach illustrates the useful knowledge that watershed analysis may produce and points a direction in which watershed management might contribute to societal views.

Luna B. Leopold
SFEI Committee of Science Advisors

BAY AREA GEOGRAPHY



The Golden Gate Watershed includes all the lands that drain to the San Francisco Estuary. It is a simple construct based upon the geography of watersheds: everybody lives in one; water flows downhill; watersheds are basic units for land management. The Estuary can be delineated by the maximum possible extent of the tides inland of the Golden Gate, in the absence of any levees or dikes that might constrain the tides. As sea level rises, the Estuary moves upstream and inland.

The Bay Area is one region of the Golden Gate Watershed. It consists of the waters of the Estuary plus the attending watersheds between the Golden Gate and the Delta. Parts of the Bay Area are called the South Bay, the Peninsula, the East Bay, the Central Bay, the North Bay, and Suisun. Some of the most distinguishing landmarks are Mt. Diablo, Mt. Hamilton, Mt. Tamalpais, Mt. Saint Helena, Livermore Valley, Santa Clara Valley, Napa Valley, Suisun Slough, the Napa River, the Petaluma River, the Guadalupe River, Suisun Bay, Suisun Marsh, Carquinez Strait, San Pablo Bay, San Francisco Bay, the Golden Gate, the Gulf of the Farallones, Yerba Buena, Alcatraz, Angel Island, the San Andreas Fault, and the Hayward Fault.

The Bay Area is the most urbanized region of the Golden Gate Watershed. It is the center for commerce and industry. Great amounts of fuel, power, water, and goods move daily through the Bay Area. It also provides critical support for a unique natural community, including salmon and waterfowl that migrate along the Pacific coast. Vital flows of materials and energy sustain life in the Bay Area and connect it to the rest of the world.

GEOGRAPHIC SCOPE

This is an approach to watershed science for the lands draining to the San Francisco Estuary downstream of the Delta. For the purposes of this approach, a watershed or basin is defined as all the lands that drain to a common place. Any discrepancy between this geomorphic definition of watersheds and various administrative definitions used in the Bay Area should be rectified.

WHAT IS WATERSHED SCIENCE?

In the most general sense, watershed science is the integral sum of individual scientific disciplines that contribute to a better understanding of the physical, biological, and social relations among terrestrial and aquatic environments.

RATIONALE FOR A WATERSHED SCIENCE APPROACH

The public needs to know whether watershed health is getting better or worse, and why. This need is recognized by numerous state and federal policies and programs relating principally to the Clean Water Act, Coastal Zone Management Act, Endangered Species Act, Rivers and Harbors Act, California Environmental Quality Act, and the Basin Plan of the San Francisco Bay Regional Water Quality Control Board. Through these policies and programs numerous local agencies manage one or more aspects of watershed health, such as land use, water supply, flooding, pollution, erosion, fire, endangered species, and other living resources.

Despite the existing efforts by government to manage various aspects of watersheds, there is no local or regional overall assessment of their condition. No single agency is in charge of watersheds as a whole. A regional approach of watershed science is needed to coordinate among the various efforts of government to assess and report on the health of local watersheds.

WHY SFEI IS INVOLVED

SFEI was established in 1994 through the San Francisco Estuary Project of the U.S. Environmental Protection Agency to foster the development of the scientific understanding needed to protect and enhance the San Francisco Bay-Delta Estuary. SFEI is meeting this challenge with regional monitoring and research programs for bays and wetlands. Recognizing the need for scientific support of watershed management, and the need for regional coordination of such support, SFEI has produced this Watersheds Science Approach.

Based upon the SFEI science programs for bays and wetlands, the role of SFEI in watershed science will involve regional coordination of data collection, management, interpretation, and reporting. In all these regards, coordination does not mean the control or conduct of all work. Rather, it means the central role of organization among equal partners to achieve a common goal, that being a regional watershed research and monitoring program.

It should be acknowledged that all aspects of this Watershed Science Approach are scientific and not political. SFEI is uniquely qualified as a science organization to coordinate regional science because SFEI has no private or political interests in the results.

OVERVIEW OF THE WATERSHEDS SCIENCE APPROACH

The Watershed Science Approach (WSA) is an outline of fundamental scientific work in the field and office to help describe historical and existing watershed conditions, revise watershed management goals and objectives, and monitor future changes in a watershed.

The WSA can be summarized as the following three phases.

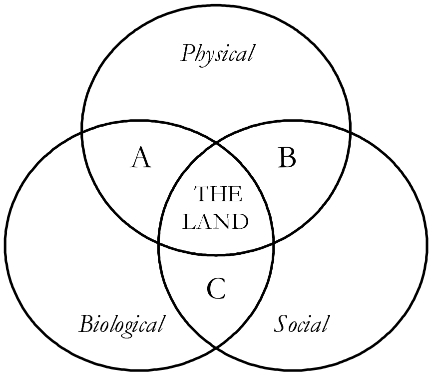
1. *Develop an understanding of the environmental past, the present, and change.*
2. *Based upon the understanding of change, help quantify the future goals and objectives for watershed health.*
3. *Monitor progress toward the goals and objectives, and monitor the risk that they might not be achieved.*

Phase one involves scientific inventories, meaning sets of qualitative or quantitative statements or both that, when considered as a whole, allow a watershed to be visualized, and by these statements can be compared over time, and with other watersheds.

Phase two involves interpretation of the inventories leading to an understanding of the relative effects of natural processes and human operations on changes in watershed form and function. This is a critical step of science support to set realistic goals and objectives for watershed management.

Phase three involves scientific monitoring as a scheme of successive inventories through time to assess progress or regress relative to the management goals and objectives. Monitoring begins with the first inventories, and continues indefinitely, with modifications to account for changes in public concerns and issues, and to reflect new scientific understanding.

Three Scientific Perspectives on Watershed Health



Multiple views can be useful in watershed science. For example, the physical and biological views (A) are needed to describe habitat. The physical and social views (B) are needed to define flooding and landslide hazards. The biological and social views (C) are needed to define water quality and sediment toxicity. The land is everything viewed from all three perspectives.

Each step of the WSA involves the physical sciences, biology and ecology, and sociology. These different scientific perspectives are complementary. Each perspective contributes to a more complete view of watershed health, although one perspective or another may sometimes dominate.

The goals and objectives of watershed management tend to change. They change within a watershed over time, and they vary among watersheds, in response to changes in scientific understanding and public attitudes (Appendix I). For example, pollution may be the major concern for some watershed managers, while other managers are more concerned about flooding, fire, erosion, land use change, or the conservation of natural resources. Each of these concerns exists to some degree in every watershed in the Bay Area, and each concern has important physical, biological, and social aspects. A regional program of local watershed science is needed to address these concerns.

According to the WSA, the physical sciences provide the most fundamental view of watershed health. Physical factors comprise a dynamic, physical template for the support of all living resources, including people. The form and functions of a watershed are primarily controlled by physical factors. An understanding of these factors is therefore essential to protect and enhance local watersheds.

The WSA regards erosion and the supply of surface water as the most important physical factors of a watershed because they affect every environmental concern of watershed managers. For example, rainfall and runoff control groundwater recharge. Runoff is the primary cause of erosion. The accumulation of eroded sediment in channels decreases their flow capacity and thereby increases local flood hazards. The quality and quantity of surface water and sediment strongly influence the distribution and abundance of plants and wildlife. Drainage and other engineering properties of the land affect local land use. An understanding of erosion and water supply is therefore essential to protect and enhance local watersheds.

The WSA emphasis on basic data extends to the biological and social perspectives. With regard to watershed biology, the WSA suggests that the most basic data are lists of species and maps of major plant communities and habitat types. With regard to sociology, the basic data are counts of people by age, level of income, and length of residency. There is also a basic need for many kinds of social maps, including maps of home languages, maps of average per capita income, land use, agency jurisdictions, schools and other social services, infrastructure, etc. These are the basic kinds of data that allow the biology and sociology of a watershed to be characterized, and that shed light on relationships between the physical conditions of a watershed and the life it supports.

The WSA is tailored to the particular characteristics of Bay Area watersheds. It reflects the need for information about intermittent as well as perennial streams, about the effects of drought and deluge, and about rural as well as urban watersheds.

There is much to be learned about how to conduct watershed science in the Bay Area. Enough is known to begin a regional program, but the watersheds are not well understood at this time, there is no firm institutional or financial support, and not all aspects of the science are equally well supported by experience. This means that every application of the WSA is a learning opportunity.

It is unlikely that the WSA will be fully implemented throughout the Bay Area at one time. The costs may be inhibitory, and comparable assessments can be produced among local watersheds over time. It is more likely that scientific information about watersheds will accumulate through comparable, but more or less independent WSA projects. To help start local projects, the WSA includes guidelines for choosing starting places (Appendix II).

The need to develop a regional understanding of watershed health based upon local assessments puts a premium on regional coordination. The keys to coordination are shared descriptions of watershed conditions. The WSA therefore includes a watershed typology, and a regional computer-based Geographic Information System (GIS). The watershed typology (Appendix III) can help watershed scientists, managers, and the public organize their thinking about watersheds. The regional GIS is called the Bay Area EcoAtlas (Appendix IV). It is being developed as a public-access, on-line source of maps, photos, data, and reports that can be used to visualize, analyze, and exchange information about watersheds. The EcoAtlas will be extended into local watersheds through implementation of the WSA.

Many partners are needed to implement and improve the WSA. To maximize support for watershed science, and to maximize its social value, the WSA should involve partnerships that transcend different levels of government, scientific disciplines, and sectors of society.

The public should participate in the WSA. Public involvement is both practical and ethical. The inventories and monitoring may not be possible without the participation of trained volunteers. Management goals and objectives must be based upon public discourse that is informed by scientific information. To help foster public involvement in watershed science, the WSA calls for the establishment of local watershed health clinics, called Riparian Stations (Appendix V), to organize volunteers for data collection, and to distribute the results of local watershed assessments.

To what extent the WSA needs to be taken into every local watershed remains to be discovered. Some portion of the learning should be transferable from one watershed to another, thereby reducing the work load for developing a regional watershed assessment. But every watershed is managed, and every manager has some needs for science support.

Implementation of the WSA should lead to a regional watersheds monitoring and research program. The purpose of the regional program should be continued learning about watershed form and function, and routine monitoring of changes in the regional picture of watershed health. This will require some amount of ongoing empirical science among watersheds that represent conditions throughout the region. A network of "benchmark watersheds" should be created, whereby one or more watersheds in each county will be routinely monitored, using the WSA. Each county should be involved to assure the vertical integration of watershed science and management throughout the different levels of government, leading to better public understanding of watershed health.

A critical part of any regional watershed science program will be scientific review. One of the more important functions of a science review group will be to assist SFEI and the watershed science community with data interpretation. It is expected that a science review group will be established within the next few years to help summarize or integrate the findings of the first generation of WSA projects. Until then, science review will be provided by the technical advisory committees created for each project, and by the Committee of Science Advisors for SFEI.

PRACTICAL BENEFITS OF THE WATERSHEDS SCIENCE APPROACH

The WSA can help identify and protect the beneficial uses of water.

Watershed management seeks to balance water use for domestic, industrial, municipal, and agricultural consumption; recreation; aesthetic enjoyment; navigation; and the protection and enhancement of natural resources. Successful watershed management therefore requires a detailed understanding of these various beneficial uses.

The WSA can help meet this requirement through the inventories of past and present beneficial uses, leading to assessments of their impairment and potential for recovery. For example, the WSA can reveal the extent to which nature or people have impaired fish habitats by channel aggradation (loss of spawning habitat), changes in water temperature (impaired water quality and food resources), or other physical stressors (such as bank erosion, channel obstructions, etc.). There are many comparable examples of how the WSA can help identify and protect beneficial uses.

The WSA can improve flood management.

Watersheds have two basic physical functions: they move water and sediment downhill. Natural channels adjust to any change in water or sediment supply. This fact has profound implications for flood management. For example, upstream erosion can lead to downstream aggradation of the stream bed, causing a loss in flow capacity, and an increase in flood frequency.

The WSA can help improve flood management by providing a map of sediment sources, estimates of sediment supply rates from these sources, and an analysis of their primary causes. The WSA can also help flood management by improving the understanding of water sources. For example, runoff and discharge vary among tributaries within a watershed; not all tributaries contribute equally to downstream flow. The WSA can reveal which tributaries make the largest contributions to watershed discharge, to what extent rainfall or runoff explain the variation in discharge among the tributaries, and to what extent the differences in runoff relate to land use.

The WSA can improve pollution control.

Chemical pollutants and contaminants are conveyed downstream through a watershed in suspension, solution, or attached to sediment. The drainage system of a watershed is a spatial template for the distribution and abundance of pollution. Excess sediment and undesirable species of aquatic plants or wildlife are also regarded as forms of pollution in some watersheds.

The WSA can help pollution control by providing accurate maps of drainage networks, including natural channels, pipes, tunnels, ditches, canals and so forth, as the system that conveys pollution. These maps, in combination with maps of soils, geology, land use, infrastructure, and human demographics, comprise a spatial template for water quality monitoring. For example, by sampling above and below confluences, and at the outfalls of storm drains, or above and below metal-baring geologic strata, pollution sources can be more closely targeted for management actions. Simply stated, the WSA can help turn non-point sources of pollution into point sources, and thereby improve pollution control. The WSA can also provide empirical data on relations between sediment and water supplies that are needed to develop, validate, and calibrate numerical models of pollution.

The WSA can improve the performance of ecological restoration projects.

Successful projects to restore river and stream habitats are designed to convey the local supplies of water and sediment. Otherwise, the channel adjusts itself to accommodate these supplies. As the channel adjusts, the array of habitats will be altered, perhaps leading to project failure. It is also necessary to set restoration goals that are likely to be achieved, based upon the ecological history of the project site and its surroundings. What is possible and appropriate to restore usually varies within and among watersheds.

The WSA can help improve the performance of restoration projects in a variety of ways. It can reveal potential project sites, identify past and present beneficial uses at these sites, and identify risks of project failure imposed by surrounding conditions. It can also provide estimates of the amounts of sediment and water that the project must convey. For example, the WSA can help determine if a potential restoration site is likely to degrade or aggrade, or experience much variability in water supplies or sediment supplies. The WSA can also provide the hydrological design criteria for channel form, in cross-section an plan view.

The WSA can improve the understanding of local watersheds.

Every watershed supports a community of people who share their watershed as a place of work or residence. But scientific understanding of watersheds has not been provided to the public in a meaningful way. Most of the public and the local agencies do not have a picture of local environmental change. They do not know what ecological resources have been lost or gained this century or even this decade, and therefore they do not have a realistic sense of the past, present, or potential beneficial uses of their watersheds. One consequence is that existing watershed management programs are not as well supported by the public as they should be.

To help improve the public understanding of local watersheds, the WSA calls for public reports of watershed assessments, and the establishment of local, community-based watershed health clinics, termed "Riparian Stations" (see Appendix V). The Riparian Stations form partnerships among watershed residents, government agencies, and science institutions to train and organize volunteers for watershed science. Volunteers can help conduct some aspects of a watershed research and monitoring program, and they can help develop and distribute information about local watersheds .

ANNOTATED OUTLINE
BAY AREA WATERSHEDS SCIENCE APPROACH

The following outline for watershed science assumes that the goals and objectives for watershed management should be based upon comprehensive inventories of past and present conditions of the watershed, focusing especially on the relationships between sediment and water supplies.

According to the recommended approach, watershed science is separated into three phases. Phase 1 consists of field reconnaissance and inventories. Phase 2 involves data interpretation and reporting. Phase 3 involves monitoring. All three Phases may overlap in some regards. Inventories of past and present conditions can proceed together.

It should be noted that monitoring in Phase 3 may not involve all aspects of the inventory of Phase 1. What is monitored will depend upon the management goals and objectives. Monitoring programs might therefore differ among local watersheds. It is imperative, however, that different programs use the same or comparable methods to monitor the same parameters. Quality assurance and control plus on-going science review will be required for results that are meaningful and useful.

Standard protocols may be required for many aspects of watershed inventories and monitoring, including data collection, data management, and reporting. There are existing, suitable protocols for some of the recommended measures of hydrology, geomorphology, ecology, and sociology. Each WSA project should begin with an assembly of the existing protocols, and the identification of others that are needed.

To the extent possible, local watershed residents should be involved in all aspects of this WSA. Citizen volunteers can decrease the cost and increase the positive social value of watershed science. It is expected, however, that all phases of the WSA must be supervised in the field and office by experienced professionals trained in the diagnosis of watershed conditions based upon their own expert investigations. Watershed science is ideally accomplished by professionals and local volunteers working together as watershed science teams.

The following outline and its accompanying illustration will continue to be adjusted to reflect the advice of watershed managers, changes in scientific understanding, and new experience gained through local implementation of the Bay Area Watersheds Science Approach.

PHASE 1: RECONNAISSANCE AND INVENTORIES

The work of Phase I will produce a general picture of watershed conditions based upon existing information, a synoptic field reconnaissance, and detailed inventories of water and sediment supplies. A team of three people is needed for the field work. Untrained volunteers can participate in the field work, but a trained, experienced geomorphologist is needed for sketch-mapping, identifying important geomorphic features, estimating heights and distances, and managing the work load. It will be seen from the kinds of data listed below that the duration of Phase 1 is at least one field season long, and will not end when Phase 2 begins.

Phase 1 Office Work

Physical Sciences Perspective

- Develop a digital, photographic base map showing the watershed boundaries, drainage network, and contours at scale not less than 1:12,000. Trees should be distinguishable.
- Digitize the perimeter of the watershed, and of each component basin.
- Compile all available environmental maps, including the FEMA maps of flood hazard, county soils maps, maps of geology, landslides, geologic faults, seismic events, etc.
- Assemble all data on rainfall and stream flow for the watershed, including local rainfall records produced by watershed residents.
- Estimate the extent of sewered areas, and the extent of areas served by a central water supply, based upon available maps.
- Calculate the average dry season base flow for each stream gage site, and the average monthly precipitation for each rain gage site.
- Tabulate the annual floods, and construct a flood frequency curve, based upon the data on the gaging stations that might describe the basin. This may later be amplified by a curve of a partial duration array.
- For each of the major discharge events, tabulate the daily discharge for each day of the runoff event so that the total runoff volume may be computed. For each storm, compute the accumulated runoff in inches.
- For each of the dates of runoff events chosen from the runoff analysis, tabulate the daily rainfall at each station during the storm event.
- Plot the accumulated runoff with time and the daily rainfall in inches, showing on the same graph the rainfall and runoff. Compute the runoff coefficient for the storm.
- After that the major storm events have been analyzed, their historical effects should be studied, to determine which event caused major damage and where. This can be related to the base map to see what topographic element was inundated (terrace or floodplain).
- Plot the longitudinal profile of the main stem channel and its tributaries based upon the blue line on 1:24000 quadrangle sheets, unless superior maps are available.
- Using recent and historical stereo aerial photography at scale not less than 1:12,000, map the active and inactive landslides, and map the extent of gullying and headward extension of the drainage network. Plan to verify the maps with field work.

Phase 1 Office Work (Continued)

Social Perspective

- Conduct one or more public meetings in the watershed to announce the science effort underway and to solicit participation.
- Begin to construct a list of local environmental problems or issues as presented by local watershed interests. This information can be solicited during the public meetings. Reference the problems to the base map.
- Begin to compile a list of land owners or tenants who may need to be contacted to provide access to the watershed.
- Assemble all available data on the number of people living in the watershed and their household languages, per capita income, ages, etc. Reference this information to the base map as attribute files in the GIS.
- Compile or construct maps of the locations of schools, churches, and other public service centers such as fire stations, police stations, and community farms and gardens.
- Compile or construct maps of jurisdictional boundaries, including cities and counties, school districts, open space districts, etc.
- Compile all available maps and accompanying reports on basic local government services and programs, including street sweeping schedules, household refuse pick-up schedules, curb-side recycling schedules, etc.
- Compile available maps and reports on the locations and characteristics of discharges, including the outfalls of POTW's, storm drains, and other point-sources of runoff.
- Using the base map and digital road maps, estimate the amount of area of roads and other impermeable substrates for each tributary drainage system, including the storm drains. Estimating the area of roads will be straight-forward. But the estimates of other areas may require spatial sampling with high resolution photography to compute the average amount of impermeable substrate per unit of area of each tributary basin.
- Compile information about the drainage areas of storm drains, land use zonation, locations of septic systems, paddocks, golf courses, recreational fields, and known toxic sites for each tributary drainage system.

Biological Perspective

- Compile lists and maps of species of plants and wildlife living in the watershed. There will be a need to develop a typology of plant communities and major habitats.
- Compile maps and reports on ecological restoration projects. It will be especially useful to compile any maps that together show changes in the distribution or abundance of habitats over time.
- Initiate an historical ecology project based upon the "Historical Ecology How-To" manual for developing maps of the native and agricultural landscapes, flood history, fire history, and changes in the drainage network. The manual is available from SFEI.

Phase 1 Field Work

Physical Sciences Perspective

- With the best available map or aerial photograph in-hand, and/or a GPS (Geographic Positioning System), drive around the watershed and walk as much of the drainage network as feasible. It is necessary to have an expert reconnoiter as much of the watershed as possible at the start of the field work.
- During the reconnaissance, make sketches of cross-sections of the channel and terraces, with estimated heights and distances, for obvious reach types of the mainstem channel and for major tributaries above their confluences with the mainstem. Reaches might be delineated by the confluences of natural channels, by bridges, long culverts, etc.
- Beginning at the bottom of the watershed, inventory the bank, bed, and terrace conditions of the main stem channel and selected tributaries, using the protocols established through the other WSA projects. Tributaries should be selected to represent the range of channel order, major land uses, dominant vegetation, geology, slope, and aspect within the watershed. The inventory should be conducted during low flow. The inventory protocols are available from SFEI.
- The channel inventory will provide a continuous record of bank and terrace erosion; bed aggradation and degradation; the locations, sizes, and causative agents of pools; locations and causes of debris jams; locations and common species of large woody debris, locations, types, and conditions of bank revetments and grade control structures; locations, sizes, and conditions of bridges and culverts, sizes and locations of all pipe crossings and outfalls; extent of riparian forest and perennial reaches.
- Establish cross-sections as necessary to show longitudinal changes in bankfull width, bankfull depth, and flood prone area.
- All major erosional features within the channel will be classified as having either mostly natural causes, mostly human causes, an equal combination of natural and human causes, or unknown causes. The identification of causes will follow the guidelines developed for the other WSA projects. The guidelines are available from SFEI.
- The reaches will be classified according to three schemes (see Appendix III). They will be classified as either sediment source reaches, transport reaches, or storage reaches; they will be classified as perennial, intermittent, or seasonal; and by the Rosgen scheme, which requires estimates of sinuosity, flood-prone width, geomorphic bankfull level, and average particle size on the channel bed.
- Use annotated photography or video to document visible conditions at selected cross-sections and noted features.
- The maps of landslides and gullying will need to be verified in the field. It may not be necessary to verify all features, if the most questionable ones are shown to be correct.
- Classify the landslides in four ways. First, determine if the slide is active or inactive. Then classify each landslide as either a debris flow, debris avalanche, earthflow, or slump. Then determine if the feature reaches any part of the drainage network. For each feature that reaches the drainage network, classify its primary causes as mostly natural, mostly human, a combination of natural and human causes, or unknown.
-

- *Phase 1 Field Work (Continued)*

  Biological Perspective

  - The species lists of plants and wildlife should be augmented with field observations. Begin a systematic survey of in-stream and riparian plants and wildlife. During this first phase of the WSA, the surveys should not involve much trapping or sampling. There will be a need for people familiar with the local flora and fauna to lead the surveys, which should include urban as well as suburban and rural reaches of the river or stream.

  Social Perspective

  - Note the places of obvious use by people and what the uses are.
  - Note the places where people commonly enter or exit the riparian corridor.
  - Report any crimes or clear regulatory violations to the proper authorities.
  - In the process of mapping and putting data into the GIS, the location and possibly the level of ground water of all public and private wells should be sought.
  - Keep a record of people who are met during field work, and explain the project to them.
  - Seek to involve local watershed residents in data collection.

PHASE 2: INTERPRETATION AND REPORTING

The reconnaissance and inventories of Phase 1 are elaborated upon in Phase 2, resulting in an assessment of change in watershed form and function, with a discussion of the relative influence of natural processes and human operations. With this information at hand it is possible to visualize what are the sediment-water relations and what data are going to be needed to manage the relations.

Phase 2 is concluded with a report of the inventories and their interpretation, meaning scientific analyses of change from the perspectives of physical science, biology, and sociology. The scientific perspectives will not provide any assessment of change as good or bad. For example, Phase 2 will not yield any assessment or finding of legal fault, regulatory non-compliance, or failed watershed management. Phase 2 is intended to improve management goals and objectives by providing information about historical changes in watershed form and function.

There may be a need to return to the field for verification of some of the findings from the inventories conducted in Phase 1, or to continue data collection for some aspects of the inventories. But Phase 2 will mostly involve office work.

Phase 2 Office Work

Physical Sciences Perspective

- Using the inventories of the channels, their banks, and their terraces, estimate the net amounts and rates of bank and terrace erosion and channel degradation or aggradation. These quantitative estimates will be derived from the field measurements and historical records. For example, there will be a need to determine the dates of historical floodplain abandonment based upon archeology, dendrochronology, and old photos showing bank and terrace heights. These estimations are not meant to produce a sediment budget, but to compare the major sediment sources in terms of minimum volumes per study period.

Phase 2 Office Work: Physical Sciences Perspective (Continued)

  - Based upon the inventories of Phase I, develop a graph of channel bankfull width, bankfull depth, and bankfull cross-sectional area as a function of upstream drainage area. Compare these curves to the published regional curves for the Bay Area.
  - By comparing all kinds of historical and modern information about the physical form and function of the watershed, describe the historical changes in the plan form and cross-section of the channel; changes in the bed form and substrate type; changes in the drainage network; changes in the location and total length of sediment source reaches, transport reaches, and storage reaches; changes in dominant sediment sources; and changes in the rates of erosion.
  - To the extent possible, based upon al available information about past and present land use, climate change, infrastructure, and so forth, estimate the proportion of change in sediment sources, runoff and watershed discharge, erosion rates, and bed elevation that can be mostly attributed to human operations. State which operations are probably most responsible for these changes. If there is not enough evidence to infer the causes of the changes observed, then construct hypotheses that can be used to test for causes.
  - Construct one or more conceptual models in words and diagrams to illustrate the expected relationships between climate, land use, and the supplies of water and sediment that might explain the changes that are characteristic of the watershed.

- *Biological Perspective*
  - The lists of species should be annotated to indicate special status species, including legally protected species, and species of special concern or interest to the California Native Plant Society, Trout Unlimited, or the Audubon Society.
  - Construct a matrix that shows the functional relationships between the species and the major habitat types in the watershed, including intertidal flat, tidal marsh, freshwater wetlands, rivers or streams, riparian forest, prairie, and other major plant communities. Habitat functions include foraging, resting, migration, and breeding.
  - Based upon a comparison of all historical and modern materials, develop a table of change in acreage of the major habitat types.

- *Social Perspective*
  - Based upon the historical research, and using the GIS, quantify the changes in acreage of agriculture and urban development for each tributary watershed for three periods of time: the historical or native period (generally ending before 1830), the agricultural period, and the modern period of urbanization. The latter two periods will bracket different years for different watersheds.
  - Compile the demographic data and tax assessor's parcel map with the base map in the GIS, to develop a community profile of watershed residents for each major tributary and storm drain. These profiles will be used in outreach and education.
  - Plan and Hold at least one public meeting in the watershed to explain the findings of Phase 1 and Phase 2.

Phase 2 Office Work: Social Perspective (Continued)

- Prepare a public report on the major changes in the form and function of hillslopes, terraces, floodplains, and channels, with a discussion of the probable relative influences of natural processes and human operations. This should be a short report with abundant illustrations, such as conceptual models, drawings, graphs, and photographs.

- Foster a process to set local, shared, quantitative, goals and objectives for watershed management. The goals and objectives should be statements of how much of what kinds of ecological and other support functions should be provided by the watershed. In this regard, the purpose of watershed science is to advance public debate. To meet this purpose, it will be necessary to maintain a program of expert diagnosis and prognosis in the context of newly defined issues and concerns. Diagnosis requires that the data must be organized, tabulated in a uniform way, and interpreted. Again this must be done by skilled practitioners.

PHASE 3: CONTINUING INVESTIGATIONS AND MONITORING

In Phase 3, recommendations are developed and implemented to monitor watershed ecology, land use, water and sediment relations, water quality, and restoration projects. Protocols are available from SFEI for some aspects of this work.

The monitoring program outlined below focuses on the sediment-water relations as the most fundamental aspect of watershed form and function. The program should be elaborated to address ecology, water quality, land use, and other aspects of watershed health, as necessary to monitor progress toward management goals and objectives. There needs to be a team of technical advisors and watershed managers to help choose indicators of watershed health and management success.

The schedule for monitoring will vary among the parameters being monitored. There should be continuous monitoring of rainfall and flow at selected, permanently gaged stations, with annual summaries of the data by storm event. The synoptic inventories of physical, ecological, and social conditions, as conducted in Phase 1, should be inventoried periodically, perhaps every 5 years. In addition, there should be occasional surveys of erosion on hillslopes, following very wet winters, large earthquakes, wildfires, etc. Ecological restoration projects, housing projects, public works projects, and other major landscape alterations will require their own monitoring programs.

Implementation of the WSA will help to focus basic and applied research. The conceptual models called for in Phase 2 will help organize the research questions.

Phase 3 Monitoring

Physical Sciences Perspective

- Establish a set of reference reaches. This is a procedure that requires special talent and experience owing to the variability in channel form among different basins. Each reference reach should have a total length that is at least equal to thirty channel widths. The reference reaches should represent the range of channel order, major land uses, dominant types of vegetation, geology, slope, and aspect within the watershed. The protocols for establishing reference reaches are available from SFEI.

- *Phase 3 Monitoring: Physical Sciences Perspective (Continued)*
  - Make sketch-maps of the typical cross-sections and the plan form of each reference reach, showing its sinuosity, bankfull height and width, terrace height and width, landmark trees, and other distinguishing features. It is imperative that the terraces be identified and differentiated from the bankfull stage. This apparently simple job requires training and supervision.
  - A detailed survey of longitudinal profile is needed in some reaches. This will help determine how to interpret the past and future changes in channel degradation and aggradation.
  - For each reference reach, choose a cross-section for which a flow rating curve is developed and a water level gage is established. Where a continuous-reading gage is not practicable, a peak stage wire gage should be installed. There are many fine details of gage installation that must be considered. For example, the section must be surveyed and velocity measurements made by orange peel floats or other means during actual flow events. Again, technical teams must be available to instruct the observer as to how to measure and record.
  - It is necessary to establish permanent bench marks at the ends of the cross-sections which later will be tied together into a network having a common datum.
  - The re-survey of cross-sections is essential to show change in channel capacity and other functions of channel cross-section. Likewise, a re-survey of bank condition, landslides, and longitudinal profile will be especially useful following wet seasons or droughts. These data can be essential to explain local aggradation or degradation of the channel, and the performance of channel or hillslope engineering. Interpretation depends on the technical teams, and should be reviewed.
  - From the field maps of apparent bank condition, places may be chosen to monitor bank erosion. Once a month in the rainy season will usually be an adequate frequency of measurement but several years of record are desirable. At the chosen places, the parameters needed to make quantitative forecasts of the erosion rate should be measured according to the Rosgen stream classification system. These parameters include height of bank, stratification, root binding, and flow distribution.
  - Establish a network of rainfall gages that provide daily measures of rainfall for each major tributary basin. Local watershed residents should be encouraged to volunteer to monitor rainfall.

Biological Perspective

  - Ecological monitoring should focus on the habitats and natural resources of highest concern. These will usually include species that have been identified in the goals and objectives for local watershed management. It can be expected, however, that ecological monitoring will focus on fishes, amphibians, birds, the riparian plant community, and the quantity and quality of major habitats. Regional protocols for monitoring these species and others aspects of watershed ecology need to be selected or developed by the regional community of watershed scientists.

-

- *Phase 3 Monitoring: Biological Perspective (Continued)*
    - For each reference reach, initiate a program of quantitative surveys for plants, fish, amphibians, and birds. There may also need to be surveys of macroinvertebrates as food resources, pests, disease vectors, or indicators of habitat quality.
    - The ecological monitoring should be integrated with the efforts by local Mosquito Abatement Districts and public health departments to monitor pestiferous species and vectors of human disease.
    - There should be a continuation of the historical ecology project, with expanding involvement of local educators and other watershed residents.
    - Sampling programs for ecological resources should be spatially stratified based upon the maps of habitats and the conceptual models developed during Phases 1 and 2. It will be essential that the plan minimize the variance of sample data by addressing the supplies of water and sediment as factors that control the distribution, abundance, and health of species and their habitats.

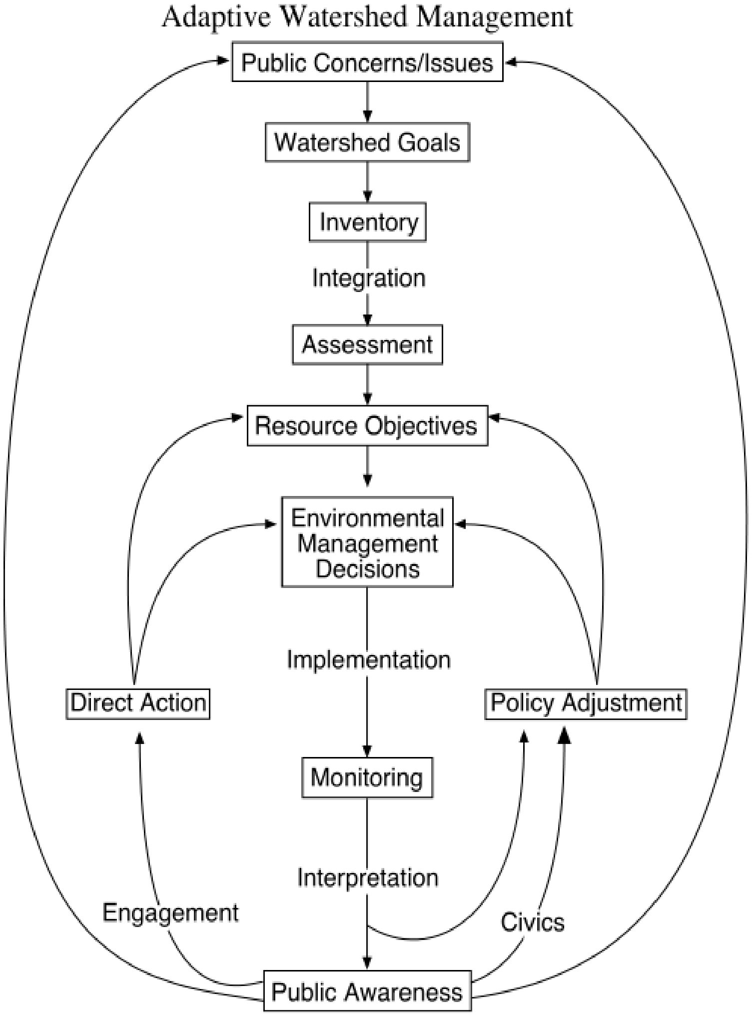
Social Perspective

- Plan and hold at least one public meeting to discuss the need for a monitoring and research program.
- There should be list maintained of the various aspects of local watershed health that being monitored, who is conducting this work, and where the data reside.
- Water quality is a dominant concern for some watershed managers. Begin to develop stratified sampling schemes for water quality. The primary sampling strata will be self-evident from the inventories and assessments of Phases 1 and 2. The drainage network of channels and storm drains should be regarded as a basic spatial template for water quality monitoring. For example, samples from above and below stream confluences and the insertion points of storm drains will be especially useful to spatially delimit pollution problems. Water quality at any point in the watershed should be regarded as a product of upstream natural processes and human operations.
- Produce modern and historical views of watershed form and function as outreach and educational materials. The demographic profiles initiated during Phase 1 should be useful to define the audiences.
- The GIS of maps and related information will need to be maintained. There should be an effort to involve volunteers to update the maps.
- There should be a Riparian Station or similar organization for the coordination of watershed science and education within the watershed.

APPENDIX I

MODEL FOR ADAPTIVE MANAGEMENT OF WATERSHEDS

SFEI does not intend or expect to manage watersheds, or to develop watershed management plans. However, SFEI recognizes that a program of regional watershed science should fit into a framework for watershed management. Ideally, the framework would indicate how the policies and programs within and among agencies at all level s of government would support and respond to science. But no such framework exists at this time. SFEI has therefore drafted a model framework for local or regional watershed management that explicitly includes watershed science.



The SFEI model for adaptive watershed management is presented here as an annotated flowchart. The terms in bold annotation represent management outcomes (flowchart boxes). The italicized terms pertain to processes (flowchart arrows). Based upon the Bay Area Watersheds Science Approach, the role of SFEI would be mainly restricted to inventories, integration, assessment, monitoring, and interpretation, with lesser involvement in public awareness. SFEI recognizes that many comparable flowcharts are possible, and that this flowchart should evolve to reflect the preferences and experiences of local watershed managers.

Public Concerns or Issues create the need for practical watershed science and management. In every major watershed, residents voice concerns about local declines in watershed health. Common concerns relate to flooding, fire, pollution, and declines in recreational opportunities. The concerns and issues need to be clarified as the program of watershed science begins. Clarification does not necessarily mean that all concerns are equally addressed, or that the issues are resolved. It means that the concerns and issues are clearly stated and understood by most of the watershed interests.

Watershed Goals are broad statements that reflect the dominant public concerns and issues, and represent the majority expectations of the existing watershed residents for the health of their home watershed. The setting of overall goals is an important early step toward knowing the need for scientific information.

APPENDIX I CONTINUED

Inventories are sets of qualitative or quantitative statements or both that when considered as a whole allow a watershed to be visualized, and by these statements can be compared over time, and with other watersheds. While the level of understanding about local watersheds is adequate in some cases to protect people from wildfire and flooding, the understanding is not adequate to protect whole watershed ecosystems with reasonable certainty. At this early stage of our understanding about local watersheds, programs for watershed science should emphasize the completion of local inventories of past and present conditions relative to the supplies of sediment and water.

An inventory of historical conditions is useful for a variety of reasons. Watershed residents do not generally appreciate their influence on their home watersheds because their residency is too short to provide them with a sense of local environmental history and change. Residents do not generally recognize that they share the history of their home watersheds. An inventory of past conditions is therefore a way to "come to terms" and to "find common ground" for watershed residents who are engaged in even the most contentious debates about watershed concerns and issues. Furthermore, many people enjoy the discovery of their past, which includes the history of their home watersheds.

Integration means the use of independent sets of numerical or cartographic data to produce new information. For example, comparisons of maps of past and present conditions can reveal new information about the locations of remnant habitat patches and changes in the distribution of habitats. Rainfall and stream flow data can be used to calculate runoff coefficients.

Assessments are based upon the watershed inventories. They lead to explanations of the relative influences of natural processes and human operations on historical changes within the watershed. The result is a better understanding of how existing concerns and issues have evolved, a better public appreciation of the watershed approach to solutions for environmental problems, and a justifiable selection of environmental conditions that can and should be improved. Watershed assessments also provide estimates of the limits of what watershed management can achieve as solutions to environmental problems. The assessments provide a picture of local ecological potential.

Resource Objectives are quantitative statements that describe what environmental conditions should be achieved and sustained by watershed management. The objectives should be broadly shared by the watershed residents and government agencies. The most probable sources of risk that the objectives will not be achieved should also be identified.

Environmental Management Decisions translate the resource objectives into specific activities or instruments that individually or together have a measurable influence on local watershed conditions, relative to the objectives, or that significantly affect the risk that the objectives will not be achieved. These decisions must be communicated effectively to the watersheds residents.

Implementation means that management decisions are carried out in ways that can be assessed in terms of their environmental and economic costs and benefits.

Monitoring is a scheme of successive inventories through time that describe changes in a watershed, including the ordinary diurnal, seasonal, or annual variations due to natural causes and human operations. Monitoring begins with the initial inventory of present conditions. It continues indefinitely, with modifications to account for changes in public concerns and issues, and to reflect increases in scientific understanding. Monitoring programs must assess the efficacy of watershed management.

APPENDIX I CONTINUED

The resource objectives and the identified sources of risk have special meanings in the context of monitoring. Each resource objective is a performance indicator for watershed management. The progress or regress of management is measured as the condition of the watershed relative to the resource objectives. The sources of risk are stressor indicators. They are monitored to forecast management problems and to help account for success.

Interpretation at this position in the flow chart means clear measures of progress or regress, relative to the watershed goals and objectives, based upon the monitoring results. The measures must be provided to all participants in watershed management, including the watershed residents.

Public Awareness must be generally increased to achieve local and regional goals and objectives. More public awareness is required for watershed residents to support watershed management. Most of the objectives will not be achievable without adjustments in the behavior of watershed residents, and they must understand the need to adjust their behavior. Increases in public awareness will improve the definition of public concerns and issues, causing them to be more consistent with the scientific understanding of the watershed, and in this way improve watershed management. It is therefore incumbent upon watershed managers to develop and maintain public awareness programs that engage the local community.

Civics means that watershed residents are personally involved in the watershed management decisions to help achieve the shared resource objectives.

Policy Adjustments and mission shifts may be required to achieve the goals and objectives, and to adjust the policies, programs, and projects in response to changes in scientific understanding and public attitude.

Engagement means that watershed residents feel personally responsible for conditions in their home watersheds. Public Awareness programs should emphasize the important, positive influence that individual residents can have on their watersheds.

Direct Action by watershed residents can include staffing public awareness programs, participating in ecological restoration projects, and helping with environmental monitoring. Volunteer monitoring is especially important. Trained volunteers may be essential to meet local and regional monitoring needs. Volunteer monitoring has the added benefit of connecting watershed residents to their home watersheds through the development of scientific information that serves as the foundation for watershed planning and protection. Direct action by watershed residents is perhaps the most meaningful objective of watershed management.

APPENDIX II

GUIDELINES TO CHOOSE A STARTING PLACE

The Bay Area Watersheds Science Approach (WSA) is designed to provide a sound foundation of basic science to support local watershed management, and to assess watershed conditions throughout the region. The WSA can be applied to any size watershed, and it invites participation by local watershed residents.

Any group or partnership of local watershed interests can implement the WSA. The following general assumptions and specific criteria are provided to guide the selection of a starting place. These guidelines complement the Watershed Science Approach.

General Assumptions

1. ***The first practical objective is to get started on watershed science that will be continued from one local watershed to another in a systematic way with local support.*** The initial work should engender collaboration, cooperation, and coordination among local interests, the concerned public, and appropriate agencies at all levels of government. These watershed science partners should work together to select a starting place, with the intent to set shared management goals and objectives, and to monitor progress toward the goals.
2. ***Implementation of the WSA starts with an exchange of science and technology among the local watershed science partners, SFEI, and other sources of expertise.*** According to the WSA, the role of SFEI will be to help implement the plan in local watersheds through transfer of the EcoAtlas, and training local interests in data collection, data management, analysis, and presentation. After watershed science gets started, then SFEI will provide continuing services mainly for data quality control and assurance, data exchange, and interpretation in a regional context.
3. ***Implementation of the WSA starts with an historical ecology project, an inventory of existing information, local EcoAtlas development, and a description of water and sediment supplies .*** The historical ecology project is needed to understand the relative influences of natural processes and human operations on watershed conditions, and to illustrate common ground or shared understanding for all watershed interests. The historical ecology project begin in Phase 1 of the WSA as a part of an inventory of existing information on local physical factors, ecology, and sociology. The EcoAtlas will serve as a local communications and management tool. The description of water and sediment sources and supplies will serve as a spatial template for monitoring.
4. ***The starting place should provide a clear example of conclusive watershed science within one year***. The watershed science partners will need to show early success to generate the momentum to keep going. Early success will mean a shared understanding of the past and present, local use of the EcoAtlas to illustrate the shared understanding, and an administrative plan to extend the science into other watersheds. Funding constraints should be managed through the selection of a starting place, and not by paring down the approach or by redefining success.

APPENDIX II CONTINUED

Specific Criteria

1. ***The starting place should not be where contentious debate about any particular issue or problem will restrict the demonstration of watershed science.*** The starting place should be a venue for creating partnerships for the development and exchange of basic science and technology that is necessary to address any watershed issue or problem.

2. ***The starting place should not extend above a major impoundment, such as a reservoir for public water supply or flood control.*** Major reservoirs obviously affect watershed form, function, and management. The response of a reservoir to upstream events and processes is a special topic that should be addressed after basic watershed science gets started.

3. ***The starting place should encompass a complete drainage system not much larger than 10 square miles.*** A system of this size is usually required to observe relationships among sediment sources and storage reaches; to observe variations in runoff or flow as functions of aspect, land use, road density, geology, plant cover, and drainage area; and to estimate the levels of human and financial resources needed to implement the WSA.

4. ***The starting place should help reduce the cost of getting started.*** The following conditions suggest the suitability of a starting place. The upper two sets of conditions, dealing with local, non-governmental interest groups and volunteers, are probably most important for reducing costs.

Good	Better	Better	Best
There is a local interest group	*that includes all pertinent local agencies*	*and non-governmental organizations*	*and wants science support.*
There is a local volunteer monitoring organization	*that focuses on watershed health care*	*and has strong links to public education*	*and pertinent local agencies.*
The stream is gauged	*and there is a daily record of discharge*	*for ten or more years*	*that is up-to-date.*
There is a local Geographic Information System (GIS)	*in ArcInfo™ (or ArcView™) or MapInfo™*	*that includes modern infrastructure*	*and tax assessors' maps.*
There is recent aerial photography	*at scale 1:12,000 or larger*	*that is digital (or can be)*	*and geo-rectified.*
There is a local legacy of environmental studies	*that includes a written natural history*	*and the history of fire and flooding*	*and the history of land use.*

APPENDIX III

WATERSHED TYPOLOGY

Regional coordination of watershed science will require that watershed scientists and managers adopt a common watershed typology. The typology should include a shared definition of watersheds, an agreed upon system of watershed classification, and a common vocabulary to describe the basic, physical character of a watershed. Otherwise there will be abundant miscommunication and little assured agreement about watershed management goals and objectives.

The following watershed typology has been developed as part of the Bay Area Watersheds Science Approach (WSA). It is rudimentary but exhaustive in its address of watershed types and their prominent landscape components. This typology is scientific and not administrative or political. It is likely that the watershed typology will be elaborated to reflect new information about the forms and functions of local watersheds.

Watersheds or basins are defined as lands that drain to a common place. The emphasis is on surface drainage, rather than groundwater flow. As physical systems, watersheds consist of hillslopes, valleys, and drainage networks. Some watersheds in the Bay Area also enclose baylands.

Baylands are lands between high and low tide.

Diked baylands are protected from the tide by levees, tide gates, or other water control structures.

Hillslopes and Valleys comprise the terrestrial parts of watersheds. There are no fixed rules for delineating the boundary between a valley and its neighboring hillslopes.

Drainage networks are defined as all the channels and drains that convey runoff downstream through a watershed.

Channels are open to the air along their length. Ditches and gutters are kinds of channels.

Drains are closed to the air along their length. By this definition, Culverts are short drains.

Diversion Channels or Ditches convey flow from one watershed to another.

> Channels and drains are classified by order. To define channel order, the following convention will be followed. Starting from the top of the watershed, the first channel encountered that has no tributaries is termed first-order. This will be among the smallest channels in the drainage network. Two or more first-order channels that come together (i.e., are confluent) form a second-order channel. Two or more second-order channels that come together form a third-order channel, and so forth. Channel order can only increase downstream.

Reaches are segments of a channel. They are defined as the length of a channel between landmarks. The landmarks can be natural confluences, bridges, culverts, station markers on a survey, etc.

APPENDIX III (CONTINUED)

Reach Classification

The WSA uses four classification systems for reaches.

1. With regard to the spatial or temporal pattern of surface flow:
    - *perennial reaches* have flow on the channel surface all year during most years.
    - *intermittent reaches* are in some parts perennial and elsewhere the surface flow ceases for some part of most years.
    - *seasonal reaches* only have flow on the ground surface or in a drain during a particular season of most years.

2. With regard to the movement of sediment:
    - *source reaches* mostly supply sediment to the drainage network.
    - *transport reaches* mostly move sediment from one part of a drainage network to another.
    - *storage reaches* mostly store sediment.

3. With regard to geomorphic form, the Rosgen classification is used.

Watershed Classification

The WSA classifies watersheds in three ways.

1. With regard to their connection to the Estuary:
    - *bayshore watersheds* enclose channels that have direct connections to the Estuary.
    - *perennial bayshore watersheds* enclose perennial channels that have direct connections to the Estuary.
    - *inland watersheds* enclose channels that do not have direct connections to the Estuary.

2. With regard to size, watersheds are classified by the largest order channels they enclose.

3. With regard to the degree or kind of management:
    - *storm drains* are watersheds having drainage networks consisting mostly of buried pipes or tunnels.
    - *impounded watersheds* have man-made reservoirs that interrupt the flow of water and sediment through the drainage network
    - *diverted watersheds* have all or some portion of their flow diverted to another watershed.
    - *expanded watersheds* receive diverted flow from other watersheds.

APPENDIX IV

DESCRIPTION OF THE BAY AREA ECOATLAS©

Visit the Bay Area EcoAtlas at the SFEI web site at http://www.sfei.org

The Bay Area EcoAtlas is managed by SFEI as a set of scientific maps, images, and environmental data to support regional environmental planning and management. The EcoAtlas represents the integration of many kinds of information from numerous sources. It provides the most detailed regional views of past and present conditions available at this time. It is also a base map to study possible future landscapes, and a map-based index for environmental data and their sources.

The EcoAtlas is a growing concern. Planning is ongoing to assure its accuracy, maximize its availability to the public, and enable reputable sources to add local or regional information. It is envisioned that anyone will be able to use the EcoAtlas to exchange local and regional environmental information. It is hoped that the EcoAtlas will enhance the regional sense of place and purpose.

SFEI has copyrighted the EcoAtlas to help maintain its credibility among government agencies as a common platform for environmental planning and protection. SFEI will endeavor to make the EcoAtlas available to the public as quickly as possible, while maintaining high standards of accuracy.

The credibility of the EcoAtlas is provided through the review of its contents by local and regional environmental scientists and managers. Hundreds of people have spent tens of thousands of hours compiling the evidence of past and present conditions that are presented in the EcoAtlas.

The main technology behind the EcoAtlas is a computerized Geographic Information System (GIS) centered at SFEI. In the GIS, maps consist of one or more coverages, and each coverage consists of one or more features or places. The GIS provides a common system of geographic coordinates for all the maps and images contained in the EcoAtlas. This allows the maps and their component coverages to be selectively viewed and quantified, and it allows one coverage to overlay another. The GIS also provides electronic links between coverages and databases. This allows access to data through interactive maps.

The EcoAtlas is produced in three editions. The GIS Edition includes all the maps and images in GIS format, plus the metadata needed to use the maps and images in another GIS, outside of SFEI. The Graphics Edition includes the maps and images formatted for electronic reproduction, and it includes software for computer-based viewing of the maps and images. The Science Edition includes everything in the other editions, plus environmental data that are electronically linked to the maps and images. There are plans to further develop the EcoAtlas for the on-line exchange of scientific information about the Bay Area.

EcoAtlas maps and images can be ordered from SFEI as original plots on paper or mylar, as photographic slides, acetate overlays, or electronic files.

While a wealth of information about the historical and modern landscape of the Bay Area has already been compiled in the EcoAtlas, as much or more environmental information will be available in the future. SFEI is developing protocols to allow information to be up-loaded into the EcoAtlas from reputable and qualified sources outside of SFEI.

Appendix IV (Continued)

Descriptions of EcoAtlas Coverages and Images

Historical Coverages

Complete:

Zero Tide Contour
3 Fathom Contour
Tidal Marsh Ponds
Salt Ponds
Vegetated Shoreline
Upland/Bay Shoreline
Moist Grasslands
Sandy Beaches
Tidal Lagoons
Wet Fans, Spring Runs
Sausals (Willow Groves)
Topography

Intertidal Flats
High Tidal Marshes
Low Tidal Marshes
Muted Tidal Marshes
Major Tidal Channels
Minor Tidal Channels
Grasslands with Vernal Pools
Dunes
Rivers and Creeks
Riparian Forests
Lakes and Upland Ponds
Bay Fill

In Progress

Zones of Freshwater Influence (on tidal marsh plan form)
Major Terrestrial Plant Communities
Tidal Reaches of Creeks and Rivers

Modern Coverages

Complete

Zero Tide Contour
3 Fathom Contour
Salt Ponds (by salinity regime)
Diked Marshes
Diked Grazed Baylands
Ruderal Baylands
Rivers and Creeks
Land-Use Zonation
USGS 7.5 minute Quadrangles
Moist Grasslands
Developed Bay Fill

Intertidal Flats
High Tidal Marshes
Low Tidal Marshes
Diked Farmed Baylands
Managed Marshes
Lakes and Upland Ponds
Riparian Forests
Roads and Railroads
Digital Elevation Models (DEM's)
Grasslands with Vernal Pools
Undeveloped Bay Fill

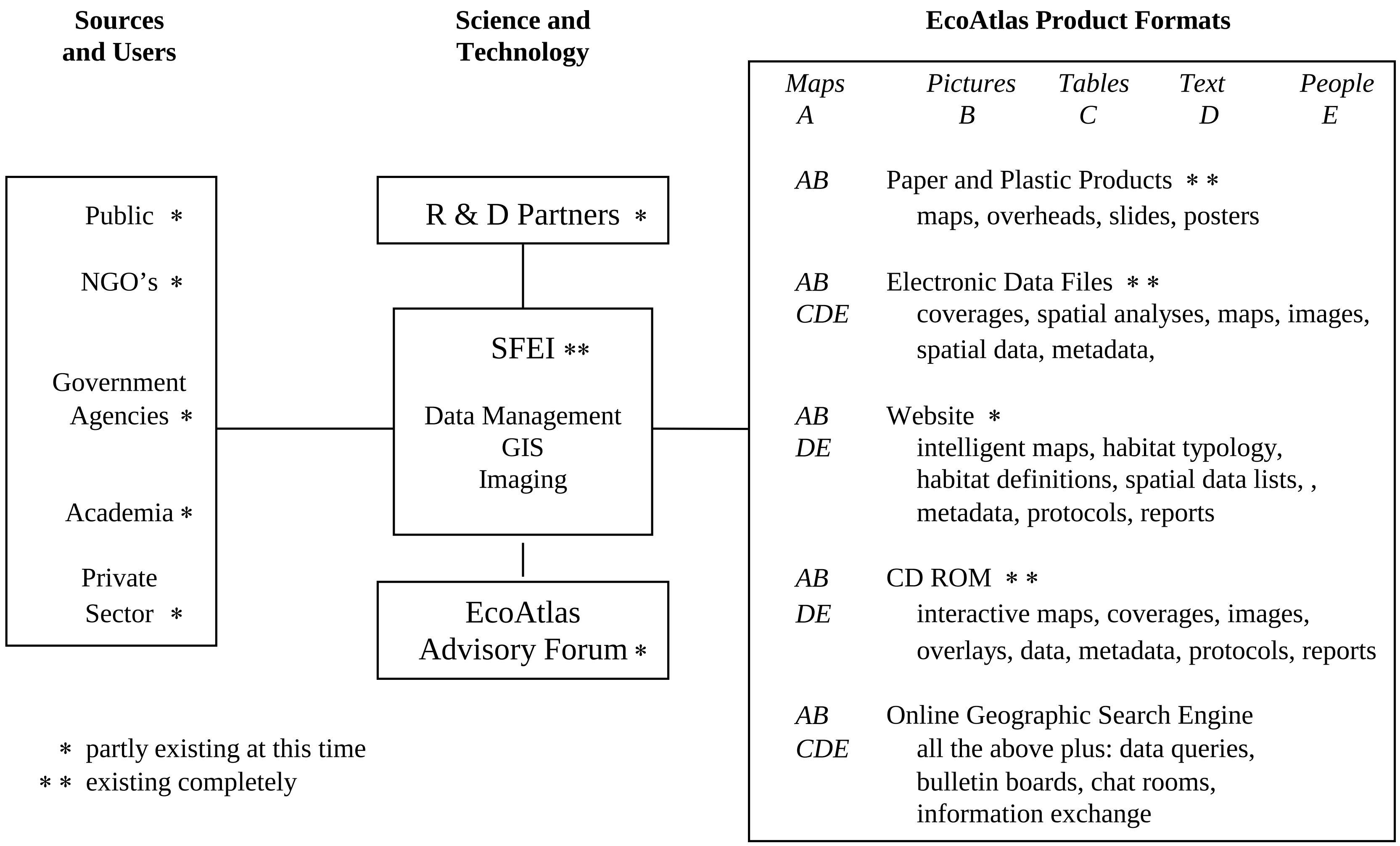
Regional Aerial Photography (1:24,000 and 1:58,000)

In Progress

Watershed Boundaries
Adjacent Freshwater Flow Inputs

The Bay Area EcoAtlas © will expand into watersheds with local detail through implementation of the Watersheds Science Approach.

Proposed EcoAtlas Structure



Sources and Users

Public ∗

NGO's ∗

Government Agencies ∗

Academia ∗

Private Sector ∗

Science and Technology

R & D Partners ∗

SFEI ∗∗

Data Management
GIS
Imaging

EcoAtlas Advisory Forum ∗

EcoAtlas Product Formats

Maps	*Pictures*	*Tables*	*Text*	*People*
A	*B*	*C*	*D*	*E*

AB	Paper and Plastic Products ∗ ∗ maps, overheads, slides, posters
AB *CDE*	Electronic Data Files ∗ ∗ coverages, spatial analyses, maps, images, spatial data, metadata,
AB *DE*	Website ∗ intelligent maps, habitat typology, habitat definitions, spatial data lists, , metadata, protocols, reports
AB *DE*	CD ROM ∗ ∗ interactive maps, coverages, images, overlays, data, metadata, protocols, reports
AB *CDE*	Online Geographic Search Engine all the above plus: data queries, bulletin boards, chat rooms, information exchange

∗ partly existing at this time
∗ ∗ existing completely

APPENDIX V

DESCRIPTION OF RIPARIAN STATIONS

Visit the Coyote Creek Riparian Station at http://www.coyotecreek.org

The evolving approach to watershed management in the Bay Area features public participation through local watershed health clinics called Riparian Stations. It is envisioned that each Riparian Station would be a local center to coordinate volunteer monitoring and related environmental education. Watershed residents could come to their Riparian Station for natural history programs, watershed science education and training, and to help produce and distribute information about their home watershed.

Riparian Stations would be practical neighborhood links to watershed planning and management. Ideally, English would not be a language requirement, and local watershed residents would not have far to travel to their Riparian Station.

Computer capability at a Riparian Station might include word processing, graphics, Geographic Information Systems (GIS), Global Positioning Systems (GPS), and connection to the Internet. Each Riparian Station would have access to the Bay Area EcoAtlas© (see Appendix IV).

At this time, there are five Riparian Stations in the Bay Area: the Coyote Creek Riparian Station in Santa Clara County, the Napa Resource Conservation District in Napa County, the Sonoma Ecology Center in Sonoma County, the Lindsay Museum in Contra Costa County, and the Bay Model in Marin County. It is essential to the overall health of watersheds in the region that these examples of community-based watershed health care are nurtured, and that similar examples are established elsewhere in the region. There are dozens of local institutions and groups of citizens interested in forming Riparian Stations. New Riparian Stations might be affiliated with churches, schools, or offices of local agencies, including for example Mosquito Abatement Districts and Flood Control Districts. Some Riparian Stations might have substations within minor watersheds. Some substations might be private residences. There should eventually be a network of stations throughout the Bay Area.

The kinds and amount of activities within a Riparian Station will probably vary among local watersheds and over time. In almost every case, volunteer data collection by watershed residents will have to be augmented with professional work to monitor some of the more arcane parameters of watershed form and function. The less trained public would not be responsible for interpretation of technical data, or for integrative health assessments. These concerns notwithstanding, the Riparian Stations can be central places of transfer of science and technology among academia, government agencies, non-governmental organizations, and local watershed residents.