# Understanding the Human Influence on the San Francisco Bay-Delta Estuary Ecosystem - The Toxic Substances Hydrology Program and USGS Place-based Studies Program Provide Complimentary Approaches and Results

By James S. Kuwabara, Frederic H. Nichols, Kathryn M. Kuivila, and Jeanne S. Dileo [1]

## ABSTRACT

The San Francisco Bay-Estuary Toxic Substances Hydrology (Toxics) Study is unique among estuarine studies in its long-term approach to quantitatively defining the processes that affect contaminant transport and distribution in major urbanized estuaries. These studies create the scientific foundation from which specific, management oriented problems may be addressed. The necessary balance between maintaining this scientific foundation and responding effectively to critical management issues is demonstrated by the complementary nature of Toxics and USGS Place-based studies in San Francisco Bay. Examples of this programmatic linkage are provided that span wide spatial and temporal scales.

## INTRODUCTION

For nearly three decades, the U.S. Geological Survey (USGS) has methodically developed a unique network of interdisciplinary and interdependent studies in the San Francisco Bay-Estuary, one of the most economically and ecologically important estuaries in the United Stated States (Conomos, 1979; Hollibaugh, 1996). Sustained progress through these long-term studies has maintained the USGS in a leadership role in responding to shorter-term (that is, less than 5 years), regional management issues, as well as in transferring information about fundamental processes that affect the transport of toxic substances in all major estuaries. Since its inception in 1991, the San Francisco Bay-Estuary Toxic Substances Hydrology (Toxics) Study has provided critical support to this role. A clear example of the application of long-term studies supported by the San Francisco Bay Toxics Study to detailed issues regarding resource management is the complementary nature of the Toxics Study to the USGS Place-based Studies Program in San Francisco Bay. Since 1995, the USGS Place Based Studies Progam [formerly the "Integrated Natural Resource Science (INATURES) Program"] funding has been used to augment Toxics studies for additional research, monitoring, and assessment studies that focus on critical management issues and to improve the accessibility of scientific information produced by USGS about the estuary.

[1] In Morganwalp, D.W., and Buxton, H.T., eds., U.S. Geological Survey Toxic Substances Hydrology Program--Proceedings of the Technical Meeting, Charleston, South Carolina, March 8-12, 1999--Volume 2--Contamination of Hydrologic Systems and Related Ecosystems: U.S. Geological Survey Water-Resources Investigations Report 99-4018B.

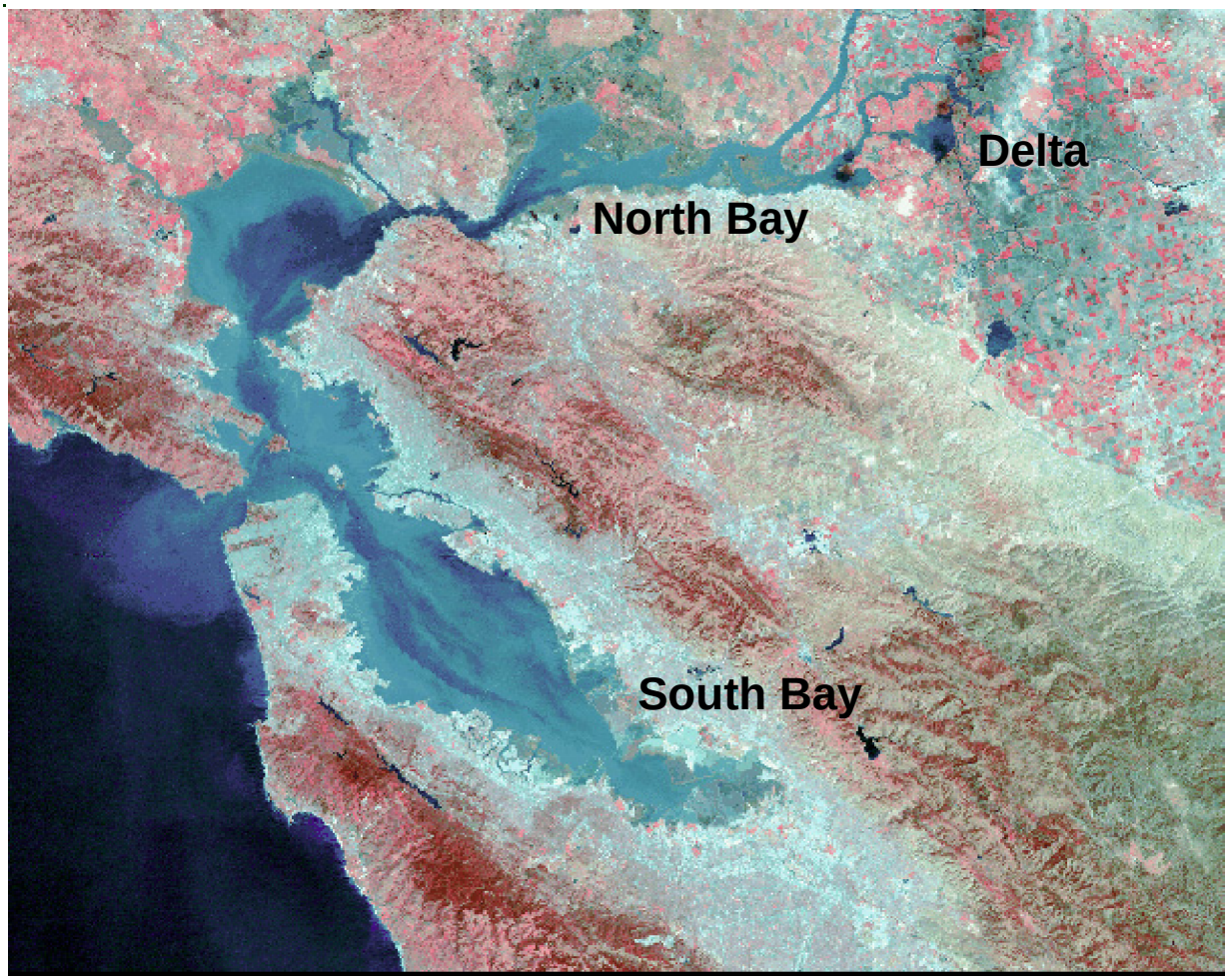



**Figure 1.** Landsat photograph (processed by Pat Chavez and his group, USGS, Flagstaff, AZ) depicting how, like most major estuaries, San Francisco Bay represents a complex integration of circulation patterns that generate a wide range of ecosystem types.

## TEMPORAL-SCALE DISTINCTIONS

Processes controlling the transport of inorganic and organic toxic substances and associated biological response are particularly complex in an estuarine setting (fig. 1). They operate from sub-second (e.g., certain complexation and redox reactions) to decadal (e.g., sediment quality changes, and basin-scale meteorological effects) time scales. The ability to examine the interdependence of these fundamental processes within an estuarine laboratory is unique to the Toxics Program. Given the short-term management-oriented goals of the USGS Place-based Studies Program, trends over seasonal and shorter time scales can be intensively observed and then placed within the context of longer term trends established by sustained Toxics studies. Both the Toxics and the USGS Place-based Studies Programs currently support the development of sediment-transport, and two- and three-dimensional numerical models that build on our present knowledge. Existing models have been applied to provide easily-accessible "real-time" descriptions of current and wind patterns as tools for spill response, navigation, and recreation (fig. 2). In the San Francisco Bay/Delta system, water-resource demands generate continual interest and need on the part of regional managers and the general public for unbiased scientific information of the highest quality that describe relationships among flow, circulation, contaminant distribution and effects, and habitat alteration.

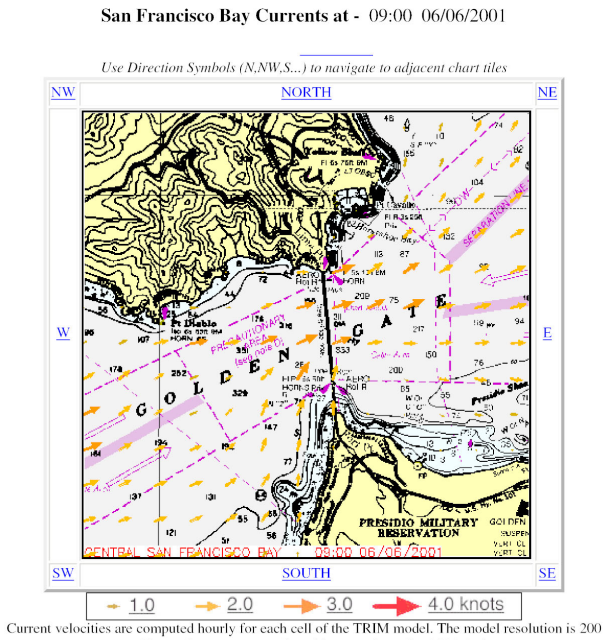



**Figure 2.** Population growth surrounding major estuaries generates new challenges for management of environmental quality. Hydrodynamic studies over more than two decades in San Francisco Bay have developed sophisticated yet practical models that provide "now-casting" (real-time) information about wind and circulation patterns (Cheng and others,; http://sfports.wr.usgs.gov/sfports.html).

## SPATIAL-SCALE DISTINCTIONS

Contaminants enter the estuary in municipal and industrial sewage, urban and agricultural runoff, and weathering processes. There is currently a strong interest in quantifying the linkage between fluxes of these contaminants and the health and abundance of biological resources in the estuary. Within the San Francisco Bay Toxics Study, the estuary is viewed as an interaction between several "subecosystems" which operate distinctly, are controlled by different processes, and are faced with different problems. Those distinctions between interacting subecosystems, the Delta, the northern component of San Francisco Bay (North Bay) and southern component (South Bay) are the basis for major study themes in our Toxics Workplan. For example, research elements associated with the Delta examine the "Influences of Riverine Inputs, Local Land Use and Managed Flows" (fig. 3). Work in the North Bay (including San Pablo and Suisun Bays) focuses on long-term transport of sediment and toxic substances, and associated biological response by benthic and planktonic organisms (fig. 4). In the South Bay, where municipal point dischargers dominate freshwater inflow during the summer and fall dry season, "Interactions between Toxic Substances, Phytoplankton and Nutrients" is the theme for biological response, modeling, and benthic flux studies (fig. 5).

As a result of anthropogenic modifications to the San Francisco Bay region since the California Gold Rush 150 years ago, historic tidal marshes have been levied and freshwater flow into the estuary has been diverted to support agriculture and population growth in California. Dredging practices have generated primary effects on dredged and disposal sites as well as secondary effects on flow patterns and

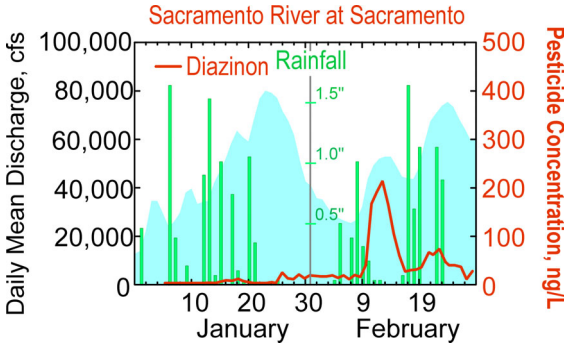
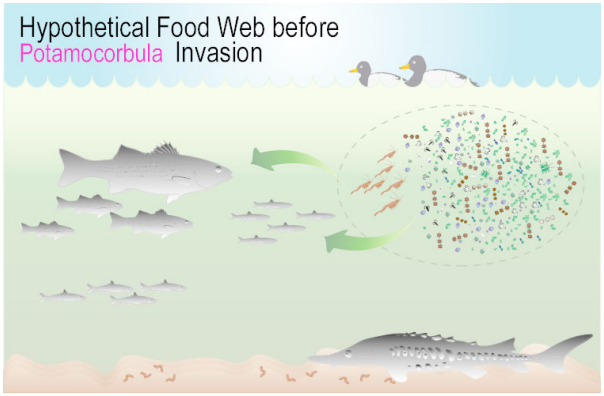



**Figure 3.** Intense application of pesticides and herbicides in the Central Valley of California obviously has important positive implications on the agricultural productivity of our country. Conversely, inputs of these chemicals into the Delta and North Bay during winter flushing events can also generate a toxicological response. Current collaborative work examines the effects of multiple stressors when exposure to elevated pesticide/herbicide concentrations can be coincident with elevated heavy-metal and suspended sediment concentrations, in addition to changes in salinity (National Research Program and California District, 1998).



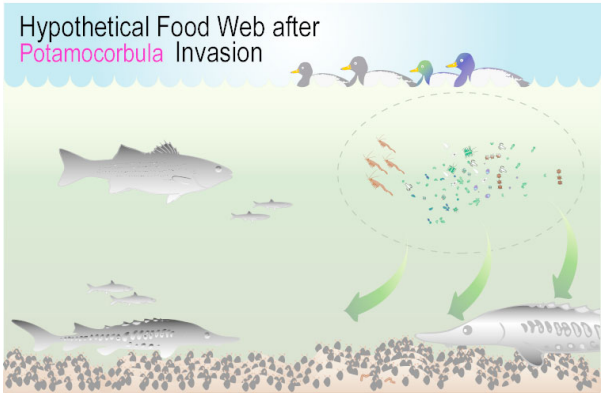




**Figure 4.** Cartoons depicting how aquatic systems like San Francisco Bay can be dramatically affected by the proliferation of invader species. Our sustained studies of the estuary's water column and benthos quantitatively describe how the transfer of toxic substances and energy between major biological groups can signifcantly change in response to the rapid domination of an invader species like the Asiatic clam, *Potamocorbula amurensis* (Thompson and others, 1998).

water-quality gradients. The programmatic effort of the USGS Place-based Studies Program in the San Francisco Bay-Estuary has addressed questions in three areas: (1) the relations among freshwater flows, suspended sediments, and contaminants (including biological effects); (2) sedimentologic and contaminant factors related to wetland restoration (fig. 6); and (3) the development of new tools and procedures to make existing and new information more widely available via the Web (Nichols, 1998). Beginning in FY1999, the USGS Place-based Studies Program activities in San Pablo and Suisun Bays will be focused on two areas relevant to restoring ecosystem health and improving water management: (1) the relations between freshwater inflows, sediment movement, and contaminant effects; and (2) the hydrology and ecology of abandoned salt-evaporating ponds.

Work supported by the Toxic Substances Hydrology Program and the USGS Place-based Studies Program is also complemented by ongoing and upcoming studies within other collaborative programs administered by the Geological Division like Global Change, and the Marine and Coastal Geologic Surveys Programs.

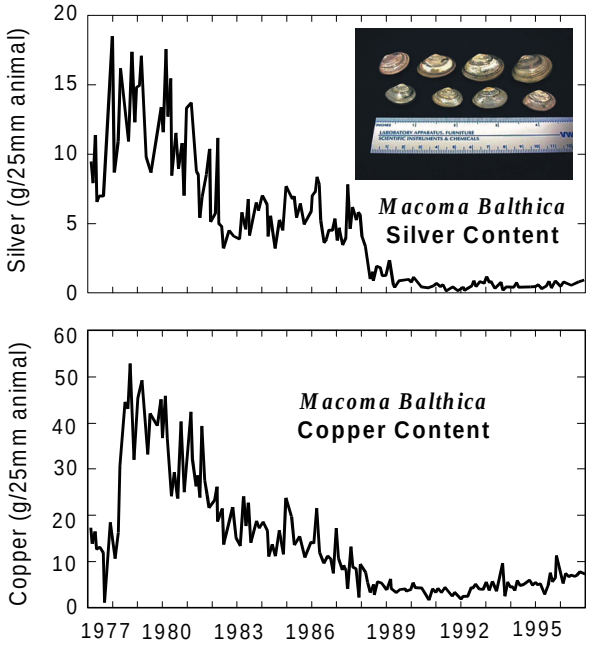



**Figure 5.** A significant fraction of the freshwater input to the southern component of the bay constitutes receiving waters from municipal water-treatment facilities. A unique long-term study of the condition of benthic organisms in the South Bay has motivated and monitored the positive effects of a series of improvements in sewage treatment practices over past decades. These two slides depict decadal-scale improvement in silver and copper bioaccumulation (Hornberger and others, 1999b).

For more detailed information on the Toxic Substances Hydrology Study and the USGS Place-based Studies Program in San Francisco Bay, please visit the following Web sites:

http://toxics.usgs.gov
http://sfbay.usgs.gov.

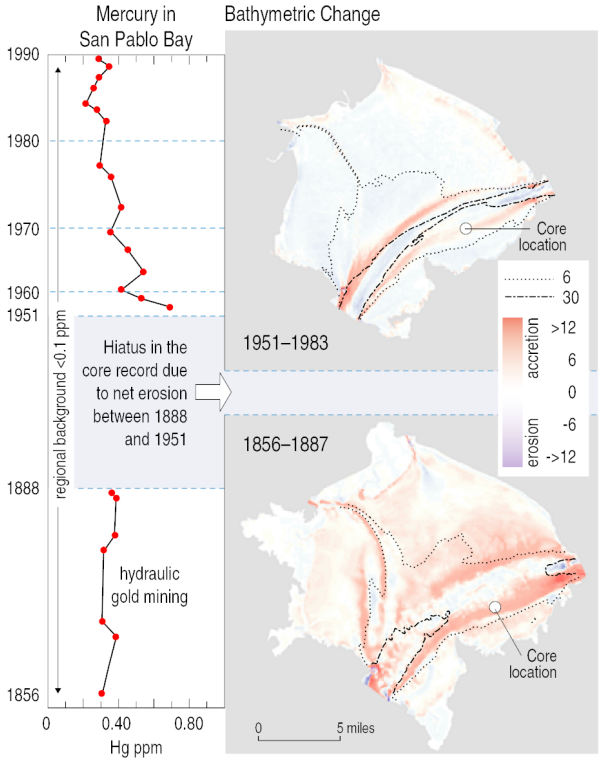



**Figure 6**. Studies of bathymetric changes in the estuary, resulting from anthropogenic practices (for example, levying and dredging), modify the relative areal coverage of different ecosystem types. The USGS Place-based Studies Program in San Francisco Bay examines how historical trends in contaminant deposition (shown here for sediment-associated mercury) have been affected by changes in wetland morphology and sediment distribution patterns (Nichols, 1998; Hornberger and others, 1999a; Fuller and others, 1999; Smith, R.E. and Jaffe, B.E., written communication, 1999).

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## AUTHOR INFORMATION


James S. Kuwabara, Frederic H. Nichols, and Jeanne S.Dileo, U.S. Geological Survey, Menlo Park, California (e-mail: kuwabara@usgs.gov, fnichols@usgs.gov, jdileo@usgs.gov)

Kathryn M. Kuivila, U.S. Geological Survey, Sacramento, California (e-mail: kkuivila@usgs.gov