ABSTRACT
WATER QUALITY ISSUES IN NORTHERN CALIFORNIA: INTERNSHIPS AT THE BUREAU OF LAND MANAGEMENT, SUSANVILLE & MEC ANALYTICAL SYSTEMS INC., TIBURON

by Leela A Sequeira

My internships in Northern California focused on different aspects of my concentration in water resources. They provided me with professional work experience in the government and private consultancy fields. My first internship dealt with testing water quality in streams to determine compliance with the non-degradation policy of the Clean Water Act. As a part of this internship, I was able to participate in the collection, analysis, database creation and start a spatial GIS layer for water samples collected. The second internship dealt with testing water column and sediment toxicity for a maintenance-dredging project at Oakland Harbor. This internship introduced me to environmental testing of dredged sediment and the toxicants of concern in Oakland Harbor Area.
WATER QUALITY ISSUES IN NORTHERN CALIFORNIA: INTERNSHIPS

AT THE BUREAU OF LAND MANAGEMENT, SUSANVILLE

&

MEC ANALYTICAL SYSTEMS INC., TIBURON

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1. INTRODUCTION

In order to fulfill the research requirement for a Master of Environmental Science at the Institute of Environmental Sciences (IES), Miami University, I completed two internships for a total duration of six months. My focus during these internships was on water quality in Northern California. These two internships gave me a practical and hands-on experience toward the courses I took for my area of concentration, “Water Resources.” My first internship dealt with the nutrient, sediment levels and fish habitat in surrounding perennial streams, while the second was on the toxicity of dredge material on invertebrates in a sediment and water column.

The first internship was at the Bureau of Land Management in Susanville, Northern California. The aim of the project during this three-month internship was to gather baseline or additional data on stream water quality and check if they were in accordance with the non-degradation policy of the Clean Water Act. This entailed gathering and analyzing samples, entering results in a database linked to GIS, which can later be used to run a model.

For my second internship, I worked on an aquatic toxicology project. This project entailed carrying out a review on dredging projects, environmental testing methods and laws, besides carrying out the testing of the dredged material.
2.0 BUREAU OF LAND MANAGEMENT: FIRST INTERNSHIP

2.1 Introduction

The Bureau of Land Management (BLM) supports approximately 3.6 million acres of public land in Northern California and Northwestern Nevada. This land supports 200 miles of perennial streams (Figure 1). These streams provide water to ranchers, wildlife, recreation, and agriculture, besides maintaining the region’s arid ecosystem.

Figure 1. Public land with water quality stations managed by the BLM Eagle lake field office

BLM manages a wide variety of resources and uses on public land. Some of the uses include livestock grazing, controlling wild horse and burro populations, timber cutting, fish and wildlife habitat, low volume roads for recreation, mineral mining and protection of archaeological, paleontological, and historical sites. Most of these uses impact the water quality of streams in the area, causing adverse ecological effects and
long-term damage. Thus, proper management of uses on public land is important in protecting water quality and the ecology of the region.

2.2 Effect of water quality on land uses and vice versa

There are four main water quality constituents that degrade water quality and hinder beneficial uses in the region. Constituents that adversely affect fishery habitat are increases in temperature, increases in sediment, and reduction in dissolved oxygen. Waterborne pathogens could have various adverse effects on warm-blooded animals drinking the water, and even some possible adverse effects to human through contact such as recreational activities.

Depending on the land use and the methods used during these activities the impact on water quality can vary. Best management practices help reduce environmental impacts and should be followed closely. In Northern California the main land use and their impacts on water quality are as below.

Livestock grazing

Livestock grazing has a large impact on the native ecosystem of Western North America. Because grazing has gone on for a long time in this region, its impact on the landscape tends to go unnoticed. Approximately 165 million acres or 94% of BLM land in the western states are used to graze cattle (Fleischner 1994). Cattle grazing negatively impact the ecosystem and the water quality of the region if not managed properly.

Impacts of grazing vary with animal density and distribution, but cattle show strong preference to moving in herds to certain areas (Figure 2)(Gillen et al. 1984).
Figure 2. Herd of cattle impacting the water quality of the stream.

Areas such as meadows are preferred to highland plains. Cattle graze selectively, causing the density and biomass of certain plant species to decrease (Belsky & Blumenthal 1997). Another adverse impact to the plant communities is the spread of exotic species by livestock. Livestock help in the dispersal of exotic plant seeds in fur and dung; they open up habitat for weedy plant species, and reduce the competition of exotic species by eating the native plants.

Selective grazing indirectly induces changes in animal populations by changing their habitat structure or making them visible to predators. Bock et. al. (1993) found that migratory land birds preferred grazed lands to intermountain shrub steppe (Fleischner 1994).

Microbial crust is characteristic of arid and semi-arid areas. These crusts are fragile and easily damaged by grazing livestock. The microbial crust assists in nutrient cycling by performing a major share of nitrogen fixation in these areas (Fleischner 1994). Early seral vegetation is another visible disruption caused by grazing on the ecological succession. New Mexico, which changed from grassland to creosote bush desert due to extensive grazing over a long period of time, is an example of grazing transforming the physical landscapes of areas (Fleischner 1994).
The removal of soil litter during grazing causes both physical and biological effects. Roughness coefficients are reduced in watersheds, causing more surface runoff, soil erosion, and mass flooding. It is proven that grazing reduces water infiltration due to soil compaction and even causes stream bank sloughing (Fleischner 1994). Riparian areas are very productive areas in the western arid areas, since they provide breeding, wintering, and migration habitat for fish and other wildlife. Livestock grazing impacts are magnified in riparian areas and affect the water quality. Grazing reduces streamside vegetation, which in turn reduces the shade-producing canopy and increases the water temperature. Livestock alter the channel substrate, widening the channel and disrupting the relation of pools to ripples. Trampling in the streambed increases turbidity and suspended sediments in the water column (Report 208, Fleischner 1994).

**Wildlife**

Wildlife populations are controlled by hunting and by loss of habitat. Therefore, their impacts on the water sources are rare and isolated events. Wildlife, except deer, elk and buffaloes, have good watering habitats that do not cause fecal or bacterial pollution to the water.

**Wild horses and burros**

Horses and burros impact the water resources and land in the same way as livestock. They tend to concentrate around water sources and often wade and defecate in them.

**Silviculture**

Forestry operations have the potential to adversely affect water quality if best management practices are not used. Several water-quality characteristics are degraded in water bodies receiving drainage from forest activities (Mostaghimi et al. 1999). Forest management practices, even upland forestry activities, while seemingly removed from the wetlands and water bodies, can impact water quality and hydrology through runoff, erosion, stream flow, infiltration, or other means. Sediment concentrations in receiving water bodies increase due to active erosion of the surrounding area. This in turn increases the stream temperatures. The removal of shade trees following harvesting of stream
banks increases the amount of solar radiation reaching the water surface and can cause a significant increase in water temperature by 5°C or more (Brown & Binkley 1994). Oxygen is less soluble in water at high temperature and cause stress to the aquatic life. Accumulating organic debris elevates the biochemical oxygen demand and depletes the amount of dissolved oxygen available to fish (Brown 1985). Inputs of large woody debris can be substantially increased if harvesting occurs on the bank immediately adjacent to a stream channel, or if logging slash is dropped into a stream. Transportation of woody debris by streams can increase stream bank erosion, channel depth, and alter fish habitat.

Recreation

The major recreational activities that have an impact on water quality are big game and upland game hunting, fishing, and off-road vehicle operation, while visiting historical sites is less significant (USDI 1980). Big game hunting and fishing affect water quality indirectly. This is because sometimes people use road vehicles to get to good hunting and fishing locations.

Off-road vehicle operation

Off road vehicle operation is dispersed through the area and is usually associated with some other use, such as hunting (USDI 1980). Construction activities of building low volume roads for motorcycle trails expose previously protected soil, accelerating erosion processes. The problem of using low volume roads is the compaction of soils, causing a decrease in water infiltration and increasing runoff and peak flow rates (Snyder C 1976). Increased runoff can lead to erosion of the road surface or drainage channels leading from the road to nearby watercourses. Eroded sediments can adversely affect upland streams, damaging the aquatic ecosystem or increasing the risk of flooding. Roads can also be a source of other environmental contaminants, such as oil and petroleum spills or herbicides (Harrison R 1976).

2.2.1 Importance of water quality parameters

pH (units)

The pH of distilled water at 25°C is 7 units pH. Water with a pH lower than 7 is acidic, while water with a pH higher than 7 is alkaline. Unpolluted groundwater and
water from rivers ranges between 6 to 8.5 units, while water at thermal springs has a lower pH (Hem, 1989). Streams with a lot of aquatic organisms have pH fluctuations. These fluctuations in pH are caused because aquatic organisms take up dissolved CO$_2$ during the day and release CO$_2$ at night (Hem1989).

**Importance of pH**

pH plays an important role in geochemical equilibrium and the solubility of elements (Hem 1989). When the pH is low, the water is acidic and it begins to react with the surrounding substrate. Acidic water reacts with limestone substrate, forming hard water, which is expensive to soften (USEPA 1997). Depending on the pH in streams, heavy metals found in trace quantities can be selectively extracted causing toxic conditions and are available for uptake by aquatic plants and animals (Report 208). NH$_3^0$ is highly toxic to fresh water fish and the amount of NH$_3^0$ to the total ammonia species (NH$_4^+$ + NH$_3^0$) depends on water temperature and pH (Basin Plans 1994).

**Conductivity (mS/cm)**

Electrical conductivity is the ability of a substance to conduct an electrical current. Specific electrical conductance is “the conductance of a body of unit length and cross section at a specified temperature” (Hem 1989). The presence of ionic species in water, such as chloride, nitrate, sulfate, and phosphate anions (negatively charged ions), or sodium, magnesium, calcium, iron, and aluminum cations (positively charged ions), make water conductive. Natural water has both ionic and undissociated species. This makes it difficult to establish a clear relationship between conductance and the concentration of dissolved solids in water (Hem, 1989). Conductivity is directly related with water temperature and is corrected for when analyzing data collected in the field (USEPA 1997). Conductivity is also affected by the geology of the region through which the water flows. Areas with granite have low conductivity because granite is comprised of inert materials that are not easily dissolved.

Natural waters have a specific conductance of less than 1 micromhos (metric system) or microsiemens (SI system). The EPA reports that the range of conductivity in American rivers is between 50 to 1500 µmhos/cm. Inland streams with a conductivity
range of 150 and 500 μhos/cm are reported to support good mixed fisheries (USEPA 1997).

**Importance of conductivity**

Streams have a basal range of conductivity. Measuring conductivity helps provide a baseline for comparison with future measurements and helps detect additional discharges from sewer outflows or runoff from fields. The additional discharges change the range of conductivity in a stream, in turn harming the aquatic life (USEPA 1997). Conductivity can affect the water quality used for irrigation or drinking.

**Water Temperature (°C)**

Water temperature is an important indicator in monitoring water quality because the rates of both biological and chemical processes in a stream depend on it (Hem 1989). Water temperature is affected by weather changes, lack of stream bank vegetation, and the introduction of pollutants. Water temperature is linearly related to air temperature when short time scales, such as daily measurements, are used (Mohseni and Stefan 1999).

**Importance of water temperature**

Water temperature is critical to the health of aquatic microorganisms, invertebrates, and vertebrates. Stream temperatures outside the optimal range for certain aquatic organisms cause stress, hinder reproduction, or can even kill them. Increases in temperature decreases the dissolved oxygen levels and increases the rate of organic decomposition. Important parameters, such as the rate of metabolism and photosynthesis, sensitivity of organisms to toxic materials, parasites, and diseases are dependent on water temperature. Changes in baseline temperatures of a stream are a good indicator of something amiss in the system (Hem 1989, USEPA 1997).

**Dissolved Oxygen (mg/l)**

Dissolved oxygen is the amount of oxygen present in a stream. It is measured in milligrams of oxygen per liter of water. Oxygen enters the water through the processes of photosynthesis and diffusion. Dissolved oxygen levels in water bodies fluctuate daily and seasonally, and are dependent on the air temperature. The lowest dissolved oxygen levels
are recorded just before sunrise while the highest levels are at midday (USEPA 1997). The equilibrium concentration of dissolved oxygen in water is a function of water temperature and pressure (Hem 1989). Air temperature is inversely related to dissolved oxygen (USEPA 1997).

**Importance of dissolved oxygen**

All aquatic organisms need dissolved oxygen to survive. Low levels of dissolved oxygen stress aquatic organisms making them more susceptible to disease and toxic substances (Hem 1989). Dissolved oxygen helps microorganisms break down organic molecules into simpler, more stable end products, such as carbon dioxide, water, phosphate and nitrate (Dunne et al. 1978).

**Turbidity (NTU)**

Turbidity is a measure of water clarity (Hem 1989). Turbidity is measured in Nephelometric Turbidity Units (NTU). Suspended material in water, such as soil particles, algae, and microscopic aquatic organisms, decrease the passage of light in water, making the water turbid and undesirable for drinking. Some sources of turbidity are erosion, urban runoff, waste discharge, excessive algae growth, and trampling of streambeds. During precipitation, sharp increases in turbidity levels are observed in streams. This is mainly due to runoff from impervious surfaces or compacted soil that increases stream banks and channel erosion rates. Dry weather can also result in increasing stream turbidity levels if the flow is too low for a good sample to be collected or if the stream is a water source for grazing animals that trample the streambed while drinking.

**Importance of turbidity**

Suspended solids in water absorb heat and increase water temperature. Thus turbidity has a direct relationship with suspended solids and water temperature. Suspended solids decrease the amount of light in the water decreasing the rate of photosynthesis and the efficiency of fish to catch their prey. Other detrimental effects of turbidity on fish are clogging of their gills increasing their susceptibility to disease, and
affect development during egg and larval stages. Turbidity is a useful indicator in
detecting increasing erosion of developing watersheds (USEPA 1997).

**Fecal Coliform**

Fecal coliform are bacteria that live in large numbers in the intestines of man and warm- and cold-blooded animals. They are relatively harmless and are associated only with the fecal material of warm-blooded animals.

**Importance of fecal coliform**

The presence of fecal coliform bacteria in water indicates that it is contaminated with the fecal material of man or other animals. This in turn implies that the water may be contaminated by pathogens or disease producing bacteria or viruses, which can also exist in fecal material. A few examples of these waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A.

**Nitrate (mg/L)**

Nitrate are the most vital elements to plants and animal nutrition. The main source of nitrates is synthetic fertilizers. Nitrates are transported through the unsaturated zone between the ground surface and the water table. Evidence of nitrates leeching from soil is observed in streams near highly agricultural regions (Hem 1989). In shallow groundwater areas, leeching of nitrates during precipitation from livestock corrals is observed (Durum in Hem 1989). The natural level of or nitrates in surface water are typically low (less than 1 mg/L); however, in wastewater effluent from treatment plants, it can range up to 30 mg/L(USEPA 1997).

**Importance of nitrates**

When excess nitrates are present in water bodies, they cause hypoxia in water bodies and eutrophication, and are toxic to mammals at concentrations higher than 10mg/l. While nitrates themselves are not toxic, nitrites are toxic. Water with high levels of nitrates when consumed by livestock enter their rumen and are converted to nitrites by rumen bacteria prior to entering the bloodstream. These nitrites then convert the oxygen-
carrying hemoglobin into a brown pigment called methemoglobin. Methemoglobin does not carry oxygen and causes cyanosis in animals.

**Phosphorus (mg/L)**

Phosphorus is the other vital element for plant and animal nutrition. In aquatic systems, phosphorus occurs as organic phosphate and inorganic phosphate. Plants use phosphorus in the form of inorganic phosphate, while animals use either form (USEPA 1997). Phosphorus attaches itself to sediment and is transported to streams and lakes along with runoff from agricultural fields (Hem 1989).

**Importance of phosphorus**

When found in high concentrations in streams, it indicates animal metabolic waste is present in the water. Most fresh water bodies are limited by phosphorus. Excess phosphorus causes eutrophication (Hem 1989) and low dissolved oxygen (USEPA 1997). Low levels of oxygen can kill certain fish and invertebrates (USEPA 1997).

**Trace Elements (Boron, Sulfate, Chloride)**

**Boron**

Boron is found in trace quantities in most water bodies. It is a typical constituent of granite and pegmatite rocks. It is highly resistant to chemical attack (Hem 1989). Streams in areas with high geothermal activity and thermal hot springs have high concentrations of boron (Hem 1989). Boron can be found in sewage and industrial waste as it is used as a cleaning aid. The volatility of boron species causes it to be an environmental concern in areas where geothermal energy is used for industries (Hem 1989). The EPA suggested “no-adverse-response level” (SNARL) for boron in drinking water is 0.6 mg/L, while the California state action level for boron is 1.0 mg/L. This disparity in levels is due to the different analyses on the data by various agencies (CEPA 2000).

**Importance of boron**

It is important to test for boron in water because in concentrations as low as 1 mg/L, it is harmful to both plants and animals (Hem 1989). Based on a review done by
the Central Valley Regional Water Quality Control Board, the most sensitive beneficial use (agriculture, aquatic life and municipal supplies) may be impacted by boron concentrations in the range of 0.5 to 2.0 mg/L (CEPA 2000). Rainbow trout are negatively affected by boron concentrations in the range of 0.75 to 1 mg/L (CEPA 2000).

**Sulfate**

The sources of sulfates are both anthropogenic and natural. Some natural sources of sulfur in streams are from weathering rocks, volcanic gas, and biochemical or biological processes. Anthropogenic sources of sulfur in streams enter mainly through acid rain. It is noted that water from geothermal areas is usually high in sulfur concentrations (Hem 1989). Some forms of sulfate are more toxic than others (Idaho freedom 2000). The most toxic form of sulfur is hydrogen sulfide. Levels as low as 0.1 ppm of hydrogen sulfide are considered toxic (Idaho freedom 2000).

**Importance of sulfate**

Sulfur is a major element involved in the episodic and chronic acidification of surface water (Wigington et al. 1993). Acidification of water causes detrimental effects on aquatic life and the equilibrium of elements in solutions. Water intake is affected by sulfate levels above 500 ppm for calves and 1000 ppm for cattle (Idaho freedom 2000).

**Chloride**

Some sources for chloride are disinfectants and biocide used in purification of water. A high concentration of chlorine in water indicates a sewage discharge into the water body (US EPA 1997). This parameter was not important for my project as there were no sewage discharge points on the streams I monitored.

**Importance of chloride**

When chlorine reacts with organic matter in water it forms chloroform and trichloroethylene, which cause kidney, liver, and nervous system damage, and birth defects. High chlorine levels also interfere with the osmoregulation in the early stages of fish development (Kaneko et al. 2002).
2.3 Laws and Regulations
2.3.1 Reason for complying with standards

A committee on water quality criteria was appointed in 1950 by the state of California. This committee examined methods to get information on the levels of constituents in water that affect specific uses of the water (Ward 2001). In 1963, McKee and Wolf presented a study on the effects on water uses of different concentration of water quality constituents, which led debates on the types of standards used and the criteria within a particular standard. Before the Federal Water Quality Act (PL 89-234) of 1965, individual states, municipalities and interstate agencies had the right to manage and pursue water quality management for which the Federal government would provide technical and financial support.

2.3.2 Derivation of standards

In July 1961, the Federal government suggested that water quality standards and criteria should be used to manage water quality. It was noted that this effort would be time consuming and classifications would be hard to change once made therefore it was not mandatory for agencies to comply, although standards were deemed legal if they were promulgated based on classification of water use. This act was based on the theory that constantly improving water quality should guide the water use classification and standard. By 1965, PL 89-234 was passed mandating that “all state water quality management efforts had to establish stream standards for all state waters, with means for the standards to be implemented and enforced.” To comply with PL 89-234, states began developing stream-monitoring plans. The National Technical Advisory Committee (NATC 1968) presented criteria for managing stream water quality to states. This committee defined criteria as “a scientific requirement on which a decision or judgment may be based concerning the suitability of water quality to support a designated use.” This definition was revised by the NAS/NAE (1973) and US EPA (1976) and the latest findings and judgments were used to define criteria.

In 1972, the Federal Water Pollution Control Act was enacted. This act was amended many times and, in 1977, this act was called the Clean Water Act (CWA). This
The Clean Water Act (CWA) was intended to "...restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Section 101). To accomplish the objectives, the act aimed to attain a level of water quality that "provides for the protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water" by 1983. It also aimed at eliminating the discharge of pollutants into navigable waters by 1985. The CWA addressed five main elements: (1) a system of minimum national effluent standards for each industry, (2) water quality standards, (3) a discharge permit program that translates these standards into enforceable limits, (4) provisions for special problems such as toxic chemicals and oil spills, and (5) a revolving construction loan program (formerly a grant program) for publicly-owned treatment works (POTWs).

This act required the EPA to set limits based on water quality to control pollution in waters designated by the states for drinking, swimming, or fishing. It also helped involve the public, US EPA, and Congress in evaluating the progress made in maintaining and restoring water quality (CWA, section 305 (b)). The act imposes limitations on pollutant discharges is the Nationwide Permit Program established under Section 402 and referred to as the National Pollutant Discharge Elimination System (NPDES). This means it was unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. Under CWA Section 313, “The President may exempt any effluent source of any department, agency, or instrumentality in the executive branch from compliance with any such a requirement if he determines it to be in the paramount interest of the United States to do so; except that no exemption may be granted from the requirements of section 306 or 307 of this Act” (CWA, section 313).

The State of California has more stringent water quality standards than the federal standards. In the State of California, the definition of beneficial use was broadened by the senate bill 107, California Wild and Scenic Rivers Act, passed in 1972. The act declared “that the use of water for scenic fisheries, wildlife and recreation purpose in connection with such water ways is a beneficial use.”

By 1981 the capabilities of treatment plants were improved by streamlining the municipal construction grants process. The State and EPA worked in a close partnership
on water quality issues, as the Clean Water State Revolving Fund replaced the
construction grant process, making (US EPA 2000).

One of California’s primary statutes governing water quality and water pollution
issues is the Porter-Cologne Water Quality Control Act of 1970 (Porter-Cologne Act). It
established the State Water Resources Control Board and the nine Regional Boards in
their current form within California Environmental Protection Agency. The State Board
sets statewide policy for the implementation of state and federal laws and regulations.
The Regional Boards adopt and implement Water Quality Control Plans (Basin Plans
1994) which recognize regional differences in natural water quality, actual and potential
beneficial uses, and water quality problems associated with human activities (Basin Plans
1994). The state board is empowered to adopt its own water quality plans by the Porter
Cologne Water Quality Control Act (§ 13170) (Basin Plan 1994). The act defines “water
quality objectives” as the allowable limits or levels of water quality constituents or
characteristics which are established for the reasonable protection of beneficial uses of
water or the prevention This act supersedes the Basin plan to the extent of any conflict,
since article 3 of the act directs the Regional Boards “to adopt, review, and revise Basin
Plans, and provides specific guidance on factors which must be considered in adoption of
water quality objectives and implementation measures”(Basin Plans 1994).

“The Basin Plan implements a number of state and federal laws (CWA
section 208), the most important of which are the Federal Clean Water Act
(P.L. 92-500 as amended), and the State Porter-Cologne Water Quality
Control Act (California Water Code § 13000 et seq.). Other pertinent
federal laws include the Safe Drinking Water Act, Toxic Substances
Control Act, Resource Conservation and Recovery Act, and Endangered
Species Act, and the Comprehensive Response, Compensation, and
Liability Act (CERCLA or “Superfund”), and Superfund Amendment and
Reauthorization Act (SARA). Other applicable California laws include the
Health and Safety, Fish and Game, and Food and Agriculture Codes”
(Basin Plans 1994).
One of the objectives in the basin plan is the nondegradation policy. On October 28, 1968, the state water resources control board adopted resolution no. 68-16, “Policy with respect to maintaining high quality waters in California” establishing a nondegradation policy for the protection of water quality. This objective referred to as the nondegradation policy states “whenever the existing water quality of the water is better than the quality of water established in this basin plan as objectives, such existing water quality shall be maintained unless appropriate findings are made under the policy.”

The Grazing Service and General Land Office were merged in 1946 to form the Bureau of Land Management (BLM) (Moskowitz and Romaniello 2002). The Bureau of Land Management became an active steward with the passing of the Federal Land Policy and Management Act of 1976 (FLPMA). FLPMA decreed, among other things, that flora, fauna, camping, hiking, access for off-road vehicles, water quality, and preservation now carried as much weight as mining, grazing, and timber harvesting. It identified areas of critical environmental concern. Since 1976, the BLM has been maintaining the water quality of the stream on public land that they manage. In 2000, an instruction memorandum (No. CA IM-2000-021) instructed the BLM field offices to participate in the development of a statewide Water Quality Management Plan (WQMP) for BLM lands. This plan has brought about constant monitoring of streams on BLM to check for compliance with state water quality standards.

2.3.3 Water quality standards

Surface water should meet both narrative and numerical standards set in the Basin Plans for a particular region in California. Some of the narrative standards are as follows:

- Waters shall not contain bio stimulatory substances that provide aquatic growth to the extent of adversely affecting water for beneficial uses.
- Surface waters shall not contain concentrations of fecal coliform exceeding log mean of 20/100 ml in a 30-day period nor shall it be more than 10 percent of samples collected in a 30-day period be more than 40/100 ml.
• All wetlands shall be free from substances attributed to wastewater or other discharges that produce adverse responses in humans, and plant, or lead to nuisances to aquatic life.

• When the designated beneficial use of a stream is for both warm and cold water temperatures the normal ambient pH levels shall not exceed 0.5 units.

• For naturally high quality of water, the concentration of material that can settle should not exceed 0.1 milliliter per liter.

• For warm designated waters, the water temperature should not be altered more than 5 degrees Fahrenheit. Waters designated cold should not be altered.

The basin plan also identifies water quality objectives for water bodies in the Susanville hydrological unit as listed in the table below:
Table 1. Water quality parameter ranges for stations in the Susanville hydrological unit

<table>
<thead>
<tr>
<th>#</th>
<th>Surface water body</th>
<th>Objective range in mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>TDS</td>
</tr>
<tr>
<td>1</td>
<td>Willow Creek at Merrillville Rd</td>
<td>310-335</td>
</tr>
<tr>
<td>2</td>
<td>Willow Creek at Co. Road 216</td>
<td>200-230</td>
</tr>
<tr>
<td>3</td>
<td>Willow Creek</td>
<td>40-45</td>
</tr>
<tr>
<td>4</td>
<td>Cheney Creek</td>
<td>70-75</td>
</tr>
<tr>
<td>5</td>
<td>Susan River above Willard Creek</td>
<td>60-75</td>
</tr>
<tr>
<td>6</td>
<td>Susan River at Lassen Street</td>
<td>95-105</td>
</tr>
<tr>
<td>7</td>
<td>Susan River near Litchfield at Hwy 395</td>
<td>185-250</td>
</tr>
</tbody>
</table>

Source: Basin plans for the Lahontan Region

Numerical Standards for Water Quality According to Its Use
The following tables have been taken from the US EPA website available at

http://www.epa.gov/safewater/standards.html
### Table 2. Primary drinking water standards

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (Unionized as N)</td>
<td>0.05 mg/L</td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>0</td>
</tr>
<tr>
<td>Chlorine as Cl₂ Max. Residual Disinfectant Level</td>
<td>4 mg/L</td>
</tr>
<tr>
<td>Turbidity</td>
<td>N/A</td>
</tr>
<tr>
<td>Air temperature</td>
<td>12-32.5°C</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.002 mg/L</td>
</tr>
<tr>
<td>Lead</td>
<td>0.05 mg/L</td>
</tr>
<tr>
<td>Fluoride</td>
<td>1.4-2.4 mg/L</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>10 mg/L</td>
</tr>
</tbody>
</table>

### Table 3. Secondary Drinking water

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>0.05 to 0.2 mg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>250 mg/L</td>
</tr>
<tr>
<td>Color</td>
<td>15 (color units)</td>
</tr>
<tr>
<td>Copper</td>
<td>1.0 mg/L</td>
</tr>
<tr>
<td>Corrosivity</td>
<td>Non corrosive</td>
</tr>
<tr>
<td>Fluoride</td>
<td>2.0 mg/L</td>
</tr>
<tr>
<td>Foaming Agents</td>
<td>0.5 mg/L</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3 mg/L</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.05 mg/L</td>
</tr>
<tr>
<td>Odor</td>
<td>3 threshold odor number</td>
</tr>
<tr>
<td>pH</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>Silver</td>
<td>0.10 mg/L</td>
</tr>
<tr>
<td>Sulfate</td>
<td>250 mg/L</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>500 mg/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>5 mg/L</td>
</tr>
</tbody>
</table>
Table 4. Cropland irrigation

<table>
<thead>
<tr>
<th>pH</th>
<th>4.5-9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dissolved Solids</td>
<td>700 mg/L</td>
</tr>
</tbody>
</table>

Table 5. Aquatic life standard

<table>
<thead>
<tr>
<th>pH</th>
<th>6.5-9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dissolved Solids</td>
<td>2000 mg/L</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.05mg/L (stream), 0.025 mg/L (lake)</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>Greater than 5 mg/L</td>
</tr>
</tbody>
</table>

Table 6. Wildlife and livestock standard

<table>
<thead>
<tr>
<th>pH</th>
<th>7-9.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Dissolved Solids</td>
<td>2500 mg/L</td>
</tr>
<tr>
<td>Nitrate</td>
<td>10 mg/L</td>
</tr>
<tr>
<td>Nitrate+ Nitrite N</td>
<td>100 mg/L</td>
</tr>
</tbody>
</table>

Table 7. Primary Body Contact Recreation standard

<table>
<thead>
<tr>
<th>pH</th>
<th>6.5-8.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>15-30 °C</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.05mg/L (stream), 0.025 mg/L (lake)</td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>log mean of 20/100 ml</td>
</tr>
<tr>
<td>Oil &amp; Grease</td>
<td>None</td>
</tr>
<tr>
<td>Chloride</td>
<td>1500mg/L</td>
</tr>
</tbody>
</table>

2.4 Methodology

To test the water quality of streams within the Eagle Lake field resource area, for compliance with the State water quality standards, I gathered field data and water samples at water quality stations with my supervisor and a coworker. Some of the water quality stations are well established and continuous monitoring of these stations helps
detecting trends. As a part of a two-member crew I helped establish 4 new water quality stations that would enhance the available information of streams on BLM property.

Figure 3. Station marked with a blue flag and an iron bar.

To establish a new water quality station I used the following criteria which are in compliance with the USGS methods to locate a sampling station (Wagner et. al. 2000):

- They have to be on a portion of the stream entering or leaving BLM property.
- For every station located where the stream enters BLM property there is another station located where the stream leaves BLM property.
- They should represent the stretch of stream running through BLM’s property at that general location.

For a visual indicator in the field an iron bar with a blue flag as in the figure 3 would be placed at a station. At each station air and water temperature, conductivity, pH, velocity and two water samples were taken. Over the period of three months I sampled approximately 36 sampling stations.

2.4.1 Sample Collection

One water sample taken was used for analyzing fecal coliform. The other water sample was taken using a DH 48 meter and was used for analyzing total suspended solids, and nutrients in the laboratory. For new water quality stations, cross sections and discharge measurements (Figure 4) were collected and entered into an Excel file.
Figure 4. (Left) Instrument for discharge a DH 48 meter, (Right) Cross section being taken on the Susan River in June.

The specification of equipment used was compared against those specified by the USGS for sampling the above parameters.

For temperature, a continuously recording thermo sensor manufactured by Onset was used. This instrument was placed in the stream in a spot where the water was flowing and could not be seen by people passing by to reduce the risk of being tampered (Figure 5). This complied with the USGS standard and had a range of \(-0^\circ\) to \(50^\circ\)C (\(32^\circ\) to \(122^\circ\)F) in water and \(-20^\circ\) to \(70^\circ\)C (\(4^\circ\) to \(58^\circ\)F) in air. Its resolution was \(0.02^\circ\)C at \(25^\circ\)C it had an accuracy of +/- 0.2\(^\circ\)C at \(25^\circ\)C and could read out to at least \(0.1^\circ\)C. The thermo sensor was certified at room temperature against NIST traceable reference and had no drift, making it a good instrument to use in the field.
As a check on the instrument, a YSI 556 temperature probe, that has USGS specification, is used during spot sampling as seen being used in figure 6.

To measure pH, a YSI 556 glass combustion sensor is used. This instrument is used records the pH of the water it is immersed in. It complies with the USGS specified range (0-14 units) and accuracy (0.1 unit) for a pH instrument. It has a resolution of 0.01 unit.
The YSI 556 probe used to measure conductance has a 4-electrode cell with auto ranging sensors. The USGS specification for temperature in a conductivity meter is the same as that in the meter used (-5°C to 45°C). The range accuracy of the YSI probe is +/-0.5% of reading 0.001 mS/cm, which is the specified range. The resolution provided by this probe is range dependent and between 0.001 mS/cm and 0.1 mS/cm. A steady state polarographic sensor in another YSI 556 probe that measures dissolved oxygen. The range on this instrument is 0 mg/l to 50 mg/l, which is greater than the 0.1 mg/l to 20 mg/l specified by the USGS. The accuracy of 5% or 0.3 mg/l, whichever is less, recommended by the USGS is met by the probe at dissolved oxygen ranges below 20 mg/l. The accuracy of the probe increases to +/- 6% when the dissolved oxygen range is between 20 and 50 mg/l.

Fecal coliform was tested from grab samples taken at each site and compared to a control using the membrane filter technique as in figure 7. By counting the number of colonies formed on the grid filter paper, which is immersed in agar and incubated for 48 hrs, determines the presences of fecal coliform in the water sample.

![Figure 7. Fecal coliform comparison between a control sample and a sample from Smoke Creek, CA.](image-url)
2.4.2 Evaluation for checking compliance

After the collection and analysis of water samples, I entered the results in an Access database. Another database in Excel is also made with a cross section of the stream and a photograph of the spot for retrieving the hobo deployed earlier in summer. An example of the spreadsheets I helped maintain is seen in figure 8.

![Figure 8. Example of an Excel sheet compiled after sample collection.](image)

I then linked the Access and Excel databases to an Arc View theme of water quality stations. This helped to represent the data spatially, since clicking on a station in Arc View would bring up the water quality data of that section. I ran some basic statistics on the nutrients, temperature, suspended solid and fecal coliform data collected from the water samples, looking for trends and correlations. A regression of the water and air temperatures for stations over the past three decades were directly correlated as expected. I then looked at net solar radiation data for my study area and tried to correlate it with water and air temperatures. This correlation indicated that there were other important factors, like stream bank cover and suspended sediment, to be considered in explaining the relationship. The dissolved oxygen and water temperature data showed the expected trend of being inversely correlated. I was unable to analyze or work on the data any further since my three month internship at the BLM was completed at this point.

A main challenge in analyzing the data was removing the noise from the data, since there are only one or two samples collected per site for each season every year.
Another concern was that some of the standard for certain streams in the Basin Plans were incorrect. Certain streams run dry in summer but in the Basin plans those streams are recorded as being perennial and therefore do not comply with the state standards. To overcome this problem, evaluation criteria were set up to test compliance. Listed below are the evaluation criteria:

- Are the results consistent at a station with the rest of the data collected that day?
- Is the same trend seen at the station over the years?
- Do the results make sense intuitively or with current science?
- What is the magnitude of difference seen in meeting compliance?
- Can rival theories be disputed?
- Does the model support the results?
- Can historical photographs justify improvements if numerical data is not available?

2.5 Conclusion

The goal of the project I worked on was to eventually be able to restore stretches of stream that are identified as regions not suitable for native invertebrates. My internship was for three months and I was unable to analyze the data in depth or make conclusions about the data I collected within during time. The database I created in Access is being used in house and is updated every season. To help identify the needs of the fish in the Lahontan Basin and further the project, I carried out a literature review on the fish assemblage in the Lahontan Basin. A recommendation for this project would be to increase the number of times a station is sampled. This would enhance the strength of the data collected.

2.6 Fish Assemblage of the Lahontan Basin in the Eagle Lake Resource Area

To help identify the needs of the fish in the Lahontan Basin, I carried out a literature review on the fish assemblage in the Lahontan Basin. Listed below are the names of fish (native and introduced) in the Lahontan basin region of northern California. These
species are either historically or currently recorded as being present in the water bodies under the Eagle Lake resource area. To protect the fish assemblage of this region, a short paragraph on each species habitat and breeding requirements follows the list. A habitat requirement for each species focuses on water quality parameters that are monitored and impacted by the Bureau of Land Management’s activities (BLM). These parameters are pH, temperature, sediment concentration, and conductivity. The effect of certain parameters on a species may not be included in the descriptions due to lack of information.

Table 7. List of Native Fish Species with scientific names.

<table>
<thead>
<tr>
<th></th>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Salmo clarki</em></td>
<td>Cutthroat Trout or Lahontan Cutthroat Trout</td>
</tr>
<tr>
<td>2</td>
<td><em>Catostomus platyrhychus (Cope)</em></td>
<td>Mountain Sucker</td>
</tr>
<tr>
<td>3</td>
<td><em>Coittus beldingi</em></td>
<td>Piute Sculpin</td>
</tr>
<tr>
<td>4</td>
<td><em>Catostomus tahoensis</em></td>
<td>Tahoe Sucker</td>
</tr>
<tr>
<td>5</td>
<td><em>Richoardsonius egregious (Girad)</em></td>
<td>Lahontan Redside</td>
</tr>
<tr>
<td>6</td>
<td><em>Rhinichthys osculus (Girad)</em></td>
<td>Speckled Dace</td>
</tr>
<tr>
<td>7</td>
<td><em>Gila bicolor (Girad)</em></td>
<td>Tui Chub</td>
</tr>
<tr>
<td>8</td>
<td><em>Salmo gairdneri</em></td>
<td>Rainbow Trout</td>
</tr>
</tbody>
</table>

Table 8. Fish introduced in the Lahontan Basin

<table>
<thead>
<tr>
<th></th>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Lepomis microlophus</em></td>
<td>Redear Sunfish</td>
</tr>
<tr>
<td>2</td>
<td><em>Salmo trutta</em></td>
<td>Brown Trout</td>
</tr>
<tr>
<td>3</td>
<td><em>Ictalurus nebulosus</em></td>
<td>Brown Bullhead</td>
</tr>
<tr>
<td>4</td>
<td><em>Micropterus salmoides</em></td>
<td>Largemouth Bass</td>
</tr>
</tbody>
</table>
Native Fish Species

1. Cutthroat Trout or Lahontan Cutthroat Trout, Salmo clarki

Cutthroat Trout is native to the Lahontan region, but in a current survey of aquatic species present in the Eagle Lake Field Resource Area, this fish was not seen (Willow Creek URA). In 1975, this fish was placed on the Federal List of Threatened Species (Coffin and Cowan 1995).

Breeding and habitat requirements

Female cutthroat trout spawn twice in a lifetime. Spawning occurs during spring in clear, cold riffles of streams. Spawning begins when daily temperatures range from 5.5°C to 7.2°C (42°F to 45°F) and peak at 6.6°C to 8.8°C (44°F to 48°F). The upper (safe) limit for gravid females and egg incubation is considered to be 11.11°C (52°F). Cutthroats do not spawn in lakes; instead they migrate about 60 miles upstream. The female usually fans a cluster of eggs in the gravel bed to lay her eggs and, once fertilized, they are covered with 5 to 7 inches of coarse gravel (Sigler & Sigler, 1987). These fish are unusually tolerant of both high temperatures (>27°C) and large daily fluctuations (up to 20°C). They are also quite tolerant of high alkalinity (>3000 mg/l) and dissolved solids (>10000 mg/l). They are intolerant of competition or predation by non-native salmonids, and rarely coexist with them (Behnke 1992, LaRivers 1962, Trotter 1987).

Threats

The most serious environmental hazard facing the cutthroat trout is competition with introduced species of fish, and hybridization with non-native trout. Other threats are the loss of habitat due to reduced water flow, degradation of water quality, and changes in stream configurations, (Coffin & Cowan 1995; Sigler & Sigler 1987). In some streams, fish densities are affected by the lack of wintering habitat and cover, such as brush, undercut banks, logs, boulders, jams, and debris (Sigler & Sigler 1987).
2. **Mountain Sucker *Catostomus platyrhychus* (Cope)

The Mountain Sucker is native to the region and has been recorded in the last inventory (Willow Creek URA). This species has a state status of special concern (Moyle et.al. 1995). Trout, birds, and mammals heavily prey upon mountain suckers, further reducing their populations (Sigler & Sigler 1987).

**Breeding and habitat requirements**

Spawning occurs in June and July when temperatures are between 11°C to 19°C (52°F to 66°F) (Moyle, P, et al. 1995). These fish dwell in riffles, preferring clear, cold waters of streams that have beds of sand, gravel, boulders or rubble. Some may even be found in turbid streams with mud, sand or clay bottoms. Adult or half grown mountain suckers prefer 0.5 to 1.8 meter deep water, with a slight current of approximately 0.1m/sec to 0.5m/sec (Decker 1989). The ideal habitats are areas with high algal growth and water temperatures between 12.7°C to 21.1°C (55°F to 70°F) (Sigler & Sigler 1987). Juvenile mountain suckers feed on a higher proportion of aquatic insects than the adults (Hauser 1969). Adults feed on algae, diatoms and some aquatic insects and invertebrates (Smith 1966). Recent studies done by Decker (1989) and Olson and Erman (1987) show that mountain suckers were abundant in pools, contrary to the previous studies by Snyder (1983) and Smith (1966). Olson and Erman (1987) noted that there was a positive correlation between the abundance of mountain suckers and the abundance of native species of fish such as the Tahoe sucker and speckled dace.

**Threats**

Other than being heavily preyed upon by birds, trout and mammals, high water temperatures (approximately 21°C or 70°F) can adversely affect the mountain sucker population. The construction of dams decrease habitat and increase the water temperatures affecting these fish. Mountain sucker populations become confined to tributary streams and become vulnerable to predators (Moyle et.al 1995).

3. **Piute Sculpin *Coititus beldingi***
This is another native fish that has been recorded as “seen” in the last inventory of aquatic species (Willow Creek URA). It is not on the State or Federal Endangered Species List.

**Breeding and habitat requirements**

Sculpin begin spawning in May or June when water temperatures range from $7.8^\circ\text{C}$ to $10.6^\circ\text{C}$ (Moyle et. al. 1995). They favor spawning in stream ruffles with rubble substrate (AFS, 2000). Their typical stream habitat is rocky riffle sections with clear cold water. Sculpin prey on aquatic insects like the larvae or nymph stages of stone flies (*Hesperoperla pacifica*), caddis flies (*Rhyacophila vaccua* or *Hydropsyche sp.*), and may flies (*Ephmerella grandis*) (Moyle et.al. 1995).

**Threats**

Habitat degradation is one of the main factors that threaten this fish. A stable, unpolluted habitat, including spawning area, is a prime need for this fish (Sigler & Sigler 1987).

4. **Tahoe Sucker *Catostomus tahoensis***

The Tahoe Sucker is a native nocturnal fish and seen in abundance due to its ability to adapt to a wide range of habitats (Sigler & Sigler 1987). It is closely related to the Owens Sucker, which is a state species of concern (Moyle 1995). The Tahoe Sucker is a bottom feeder and eats algae detritus and small invertebrates.

**Breeding and habitat requirements**

River spawning begins from March / April until July when stream temperatures are around $8.8^\circ\text{C}$ to $11.6^\circ\text{C}$ ($48^\circ\text{F}$ to $53^\circ\text{F}$). They have a high fecundity and can adapt to a range of habitats (Sigler & Sigler 1987).

**Threats**

Since this fish adapts well to a range of habitats, it is not endangered.

5. **Lahontan Redside *Richoardsonius egregious* (Girad)**

They are usually found in shallow areas of quiet waters. This fish is popularly used as bait in the Lake Tahoe area (Sigler & Sigler 1987).
Breeding and habitat requirements

Spawning occurs from late May to August and peaks in June, when temperatures are between 13.05°C and 23.88°C (55.55°F to 75°F) (Evans 1969, CEPA 2002). They are generally found in the lower courses of rivers, in quiet water at the head of pools. They avoid high gradient areas. In fall, when temperatures drop to less than 10°C (50°F), they leave the shallows and inhabit rocky bottom areas with water 10 feet to 60 feet deep (Sigler & Sigler 1987).

Threats

Any alteration in its habitat adversely affects this fish.

6. Speckled Dace *Rhinichthys osculus* (Girad)

The Speckled dace is widespread and abundant (Sigler & Sigler 1987). Speckled dace prey on small insects’ larva, and in turn are preyed upon by trout and large birds (Moyle et.al. 1995). In 1950, Nevada’s Fish and Game Department stocked this fish in the headwaters of the Humboldt River and in the Diamond valley area. La Rivers (1962) recognized this species as a native to the Truckee River.

Breeding and habitat requirements

Peak spawning for this fish is during June and July at temperatures near 18.3°C (65°F). They are found in a variety of habitats, ranging from an intermittent stream or outflows of desert springs to cold, swift moving mountain streams.

Threats

This fish is not endangered. Speckled dace are known to hybridize with Chubs *Iotichthy phlegethonis* (Sigler & Sigler 1987), a species under review for Federal Listing. Thus, speckled dace pose a threat to this rare species of Chubs.
7. Tuichub *Gila bicolor* (Girad)

The Tuichub is successful in a variety of habitats and responds to environmental variations by changing its color, size, shape, and at times even its morphology. There are two subspecies of Chubs in Tahoe: the Obesa, that feeds on invertebrates and other fish eggs, and the Pectinifer, which feed primarily on zooplankton. The Mohave Tui Chub is on the 1998 Federal and Californian list of Endangered Species (Lovich 1998).

**Breeding and habitat requirements**

These fish spawn from late April to late August, when temperatures range from 16\(^\circ\)C to 22.22\(^\circ\)C (62\(^\circ\)F to 72\(^\circ\)F). The peak spawning period is in June when temperatures reach about 15.55\(^\circ\)C (60\(^\circ\)F) (Sigler & Sigler 1987). The young remain in the heavy vegetation, close to shore, during the summer. In late spring and early winter, they move to shallower waters, and, by late fall, they dwell in deeper water (Sigler & Sigler 1987).

**Threats**

Like most other fish, water diversions such as dams are a threat to this fish’s habitat. Large populations of these fish are present in Pyramid Lake and Walker Lake. These populations are bound to decline if water diversions continue at the present rate, as the water becomes too alkaline for the Tuichub to live (Moyle 1995).

8. Rainbow Trout *Salmo gairdneri*

These fish are reared domestically. Domestic rainbow trout are relatively short-lived when released in the wild. This fish is listed on the State List of Special Concern. Juvenile rainbow trout feed on zooplankton and invertebrates. Adults feed on the young of Tuichubs (King 1963; Moyle unpublished data).

**Breeding and habitat requirements**

For spawning, the rainbow trout seeks out gravel bars in early spring when temperatures are 10\(^\circ\)C (50\(^\circ\)F) or higher. Optimum temperatures of 15.55\(^\circ\)C (60\(^\circ\)F) are ideal for rapid growth (Sigler & Sigler 1987). For survival during the summer, a maximum weekly average temperature of 19\(^\circ\)C (66\(^\circ\)F) is required while a short-term maximum temperature of 24\(^\circ\)C (75\(^\circ\)F) can be tolerated (Report 208, Moyle et.al.1995). The female trout are most productive when temperatures are between 12.22\(^\circ\)C to 13.33\(^\circ\)C.
(54°F -56°F) for at least half of the year (Moyle et al. 1995). These fish can acclimate to high temperatures if the water is well-oxygenated. Ideal habitat water temperature for this fish is 21.1°C (70°F) or cooler. Water with a pH of 7 to 8 is ideal for rainbow trout, but they can survive in waters with pH ranging from 5.8 to 9.6. The Eagle Lake rainbow trout has adapted to waters with a pH of 8.4 to 9.6 (Sigler & Sigler 1987).

**Threats**

The main threats to this fish are habitat destruction, hatchery rearing, over exploitation, disease, and competition with introduced species. Scouring and siltation cause oxygen depletions in water bodies and threaten redd and young rainbow trout. Occasionally, the spring stream flow regime pushes trout fry downstream into unfavorable habitat.

**Fish introduced in the Lahontan Basin**

1. **Redear Sunfish *Lepomis microlophus***

   Redear sunfish provide forage for largemouth bass and are desirable game fish for sport fishermen.

**Breeding and Habitat requirement**

They prefer clear ponds, lakes, and slow moving streams (0 to 10m/s), but can be found anywhere submerged vegetation is abundant. They are warm habitat dwellers and spawn when temperatures exceed 21.1°C (70°F) (Moyle, 1995). Spawning normally occurs in May or June, but may continue till September in places like Tennessee (Schoffman 1939). They use a variety of substrate to lay their eggs. The substrates used are sand, sandy-clay, limestone, mud and gravel with no vegetation. The alpha temperature threshold for 50% hatching is 18.3°C (Moyle et. al. 1995). Optimal temperatures for successful incubation and hatching are between 21°C and 24°C (Moyle et.al. 1995). In Florida, the amount of vegetation in the water influences the growth of redear sunfish. They are tolerant of high salinity levels and can survive in brackish water without discomfort. The dissolved oxygen requirement of this fish is similar to that of blue gill, which is at 5mg/l. They show the first sign of stress at 3mg/l, when they swim
to the surface. The pH range that these fish live in is between 6.3 and 9 units. They do well in low turbid water of less than 25 ppm. (Moyle et. al. 1995)

**Threats**

Redear sunfish populations can be inhibited by high levels of suspended sediment (Buck 1956 in Henley et.al. 2000). No other threats were observed for this species in Northern California.

2. **Brown Trout *Salmo trutta***

This is a non-native species introduced from Europe and Western Asia in 1883 (LTBMU 2002). During the last aquatic inventory, it was recorded as seen (BLM).

**Breeding and habitat requirements**

Brown trout start spawning in fall when temperatures are between 7.2° to 10° C (45°F and 50°F). They lay their eggs in shallow water on gravely riverbeds. Adult brown trout favor rubble or the bottom of deep pools of water. Optimum temperatures for the survival of this fish are between 7.2° C and 20° C (45°F and 68°F) (Moyle et.al. 1995).

**Threats**

Stream channelization, dredging, fishing and habitat destruction are some of the threats to brown trout populations (Sigler & Sigler, 1987).

10. **Brown Bullhead *Ictalurus nebulosis***

Brown bullheads were introduced in California in 1874 (Curtis 1949). This species is reported to be common in most warm waters of this state (Moyle 1976).

**Breeding and Habitat requirements**

They spawn in spring when the temperature is about 21° C to 25° C (69.8°F to 77°F) (Breder 1935) in clear, weedy streams. Adult brown bullheads prefer deep, weedy waters with sand, gravel, or muck substrates. They can live in waters with temperatures between 0° C to 36° C (32°F and 98°F), although optimum growth occurs at temperatures from 68 to 95°F (CDFG 2002). They are observed to be tolerant of relatively low oxygen levels (CDFG 2002). Their diet consists of crayfish, algae, fish eggs, insects, and leeches.
**Threats**

A decline in this population fish numbers has been observed over the years due to habitat loss. This fish is very sensitive to pollution. They do not do well with interspecies competition (LTBMU 2002).

**4. Largemouth Bass *Micropterus salmoides***

Largemouth Bass were introduced in California in 1874 (Skinner 1962), because of the tremendous demand for this species from sporting fishermen. Largemouth Bass are stocked through public agencies and individuals throughout North America (Robbins & MacCrimmon 1974).

**Breeding and Habitat**

Largemouth bass can tolerate temperatures near 26.66°C (80°F), although they do not tolerate low oxygen concentrations. The calculated maximum weekly average temperature for growth is 32°C (90°F) and the short-term maximum for survival of temperatures for growth is 32°C (98°F) (Report 208). The reported value for maximum weekly average temperature during spawning is 21°C (70°F) and the short-term maximum of embryo survival during the spawning season is 27°C (81°F) (Report 208). To preserve this fish, it is important to stabilize water levels during spawning, and reduction of competition from other bass. Other fish limit largemouth bass population abundance, since bass are heavily predated upon as embryo or fry.

**Threats**

Adverse water temperatures during spawning time, fluctuating water levels, nest desertion, parasite caused sterility, and food availability for the fry are the main decimation factors.
Table 10. Requirements of native fish found in the Lahontan Basin

<table>
<thead>
<tr>
<th>Species Native Fish</th>
<th>Habitat</th>
<th>Spawning Season/ Temperature Requirement</th>
<th>Spawning Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lahontan Cutthroat Trout</td>
<td>Cold/cool water</td>
<td>Spring: April - June, 5.5°C to 8.8°C</td>
<td>Gravel riffles</td>
</tr>
<tr>
<td><em>Salmo clarki</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Mountain Sucker</td>
<td>Variable</td>
<td>Summer: June-July, 11°C to 19°C</td>
<td>Gravel riffles</td>
</tr>
<tr>
<td><em>Catostomus platyrhynchus</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Cope)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Piute Sculpin</td>
<td>Cold water bottom dweller</td>
<td>Spring: May – June, 7.8°C to 10.6°C</td>
<td>Stream ruffles with rubble substrate</td>
</tr>
<tr>
<td><em>Coittus belding</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Tahoe Sucker</td>
<td>Variable</td>
<td>Spring - Summer: April – July, 8.8°C to 11.6°C</td>
<td>Gravel riffles</td>
</tr>
<tr>
<td><em>Catostomus tahoensi</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Lahontan Redside</td>
<td>Variable shallow areas</td>
<td>Spring – Summer: April – July, 13.0°C to 23.8°C</td>
<td>Near shore in shallow protected areas with mud, silt</td>
</tr>
<tr>
<td><em>Richoardsonius egregious</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Girad)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Speckled Dace</td>
<td>Variable shallow areas</td>
<td>Spring: June- July, 18.3°C</td>
<td>In shallow sand, gravel, or rubble substrate</td>
</tr>
<tr>
<td><em>Rhinichthys osculus</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Girad)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Tui Chub</td>
<td>Variable deep water</td>
<td>Spring – Summer: April- August, 16°C to 22°C</td>
<td>Near shore heavy vegetated area</td>
</tr>
<tr>
<td><em>Gila bicolor</em> (Girad)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Rainbow Trout</td>
<td>Variable</td>
<td>Spring: March – April, 10°C</td>
<td>Gravel riffles</td>
</tr>
<tr>
<td><em>Salmo gairdneri</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 11. Requirements of introduced fish found in the Lahontan Basin

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat</th>
<th>Spawning Season/ Temperature Requirement</th>
<th>Spawning Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown Trout <em>Salmo trutta</em></td>
<td>Cold/clear water</td>
<td>Fall: October-November 7.22 °C to 10 °C</td>
<td>Gravel riffles</td>
</tr>
<tr>
<td>Brown Bullhead <em>Ictalurus nebulosis</em></td>
<td>Warm water</td>
<td>Spring: May – June, 21 °C – 25 °C</td>
<td>Shallow vegetated areas</td>
</tr>
<tr>
<td>Largemouth Bass <em>Micropterus salmoides</em></td>
<td>Warm water</td>
<td>Spring: April-May/June, 14 °C – 24 °C</td>
<td>Gravel or below boulders in sand or mud</td>
</tr>
<tr>
<td>Redear Sunfish <em>Lepomis microlophus</em></td>
<td>Warm/clear water</td>
<td>Spring-Fall: May – September, 18.3°C – 21 °C</td>
<td>Shallow vegetated areas</td>
</tr>
</tbody>
</table>
3. MEC ANALYTICAL SYSTEMS INC.: SECOND INTERNSHIP

3.1 Introduction

My second internship, May 5th- August 5th 2003, was at MEC Analytical Systems (MEC) in Tiburon, California. MEC Analytical Systems is a professional, multidisciplinary environmental resources consulting firm that provides a complete range of in-house environmental services. These include study design, field sampling, biological laboratory analyses, quality assurance, data management and statistical analyses, environmental documentation, and preparation of clear and defensible documents and permits. MEC’s bioassay laboratory, Tiburon, California deals with sediment bioassays and compliance testing of Non Point Disposal Effluent Source (NPDES) permits.

During my internship at MEC Analytical, I worked on several projects. For this report I have gone into detail about one of the projects I worked on closely in the laboratory. The project was the evaluation of dredged sediment from Oakland Harbor. My responsibilities toward this project focused on laboratory work. I was a part of a group of three technicians that aided in the set up, termination, daily water quality monitoring, and noting observation of organisms for tests conducted. In addition to the laboratory work involved with this project, I conducted a literature review on the environmental testing regulations for dredged material. The results section for this internship has excerpts from the Oakland Harbor report written by my supervisor Mr. Bodensteiner. I used the same statistical tests when I did the data analysis for other projects that I worked on.

3.1.1 Overview

The Oakland Harbor federal navigation channel, located in San Francisco Bay (Figure 9), was approved for regular maintenance dredging by the U.S. Army Corps of Engineers, San Francisco District (USACE-SF). The harbor was maintained at 42 feet below Mean Lower Low Water (MLLW) till recently. In order to accommodate the latest deep draft container ships, the port found funding to deepen certain channels to - 50ft MLLW. This deepening will be done over a period of time. During this time, regular
maintenance of - 42 ft MLLW is implemented with a one-foot ‘over dredge’ tolerance. This makes the project depth -43 ft MLLW. The total volume of 314,913 cubic yards of dredged material was removed from the channel (USACE 2003). The USACE- SF authorized disposal of dredged material at the unconfined aquatic disposal at the San Francisco Deep Ocean Disposal Site (SF-DODS) and the in-bay disposal site, Alcatraz Island (SF-11) (Figure 10). Although this is a routine maintenance - dredging project, the sediment is evaluated for biological impact at its authorized site.

MEC Analytical Systems, Inc. conducted the bioassay tests to evaluate the dredged material for disposal at the authorized sites. A chemical and physical analysis of the material was performed as well. The sampling sites for collecting sediment core are specified in the sampling and analysis plan:-Oakland Harbor Channel Maintenance Dredging FY 2003 Sampling Plan 2003(USACE 2003), which is the first step in getting a dredging permit.

Figure 9. Aerial view of Project area for 2003 Oakland Harbor with dredge material evaluation sampling sites.
(Source: MEC, July 2003. “Results of Chemical, Physical and Biological Testing of sediment from Oakland Harbor”. Prepared for USACE- San Francisco Division.)
3.2 Dredge Material Testing Regulation

The EPA and USACE regulations require the testing for biological impacts caused by disposing dredge material in the ocean. Contaminated dredged material, if disposed in the bay without testing, can adversely affect the bay ecosystem. Sediment-dwelling amphipods and filter-feeding organisms are very sensitive to contaminants present in the water column or sediment. Once these primary level feeders are affected, the effects are rippled throughout the food chain. Bioavailability of contaminated sediment depends on the chemicals molecular weight and polarity. Metals in sediment are highly soluble in water and can be resuspended by underwater currents or human activities affecting filter feeders. Non-polar compounds (e.g., highly chlorinated polychlorinated biphenyls (PCBs)) have low aqueous solubility and a strong tendency to be associated with dissolved and particulate organic matter thus affecting sediment
ingesting organisms. Sediment bioassays are considered a direct and good method of assessing the effects of multiple contaminants on organisms (Baudo R et. al. 1990).

**3.2.1 Testing compliance**

To ensure the sediment in question is acceptable to be disposed it has to meet a limiting permissible concentration (LPC) in the water column. The LPC is the portion of dredged material suspended in the water column, which is in compliance with the marine water quality concentrations after mixing. For contaminants that currently do not have a standard, the LPC is 0.01 the acute toxicity levels after a 4-hour initial mixing period. The initial mixing expected at the selected disposal site is incorporated into the interpretation of results to offset changing variables experienced by organisms in the field (USEPA/ACE 1991).

For a bioaccumulation test, it is important that the test organisms used do not have a low ability to metabolize polycyclic aromatic hydrocarbons (PAHs), because this will bias the results. The exposure time for bioassay test depends on the test endpoint. All acute benthic tests are 10 days, while all bioaccumulation tests are 28 days.

While carrying out a sediment bioassay test, it is necessary to test the organisms with ‘control’ sediment and ‘reference’ sediment samples. Control sediment is defined as natural sediment that is free of contamination (USEPA/ACE 1991). The results of the control sediment are used to verify the health of the test organisms and the acceptability of the test conditions. It is important to use control samples that are compatible with the needs of the organisms used for a test.

Organisms are exposed to reference sediment samples for comparison with project sample exposures to evaluate the benthic effects of dredged material during a test. The reference sample has the same grain size as the dredged material and the sediment at the disposal site. “The reference sample should adequately represent the conditions that would exist in the vicinity of the disposal site had no dredge material been disposed at that site but had all the other influences on the sediment condition taken place” (USEPA/ACE 1991). Every Sampling Analysis Plan includes a description of sampling locations for both control and reference sediment samples.
The Dredged Material Management Office (DMMO) maintains a list of multiple reference sites that can be used for disposal site at the deep ocean site. For this project reference samples were not collected; instead, our results are compared to the reference SF-DODS database. The SF-DODS database comprises of 6 studies conducted with material collected from the SF-DODS site and tested on multiple organisms following Tier III procedures.

**3.2.2 Four-tier process**

The Army Corps of Engineers and the Environmental Protection Agency published the 1991 *Evaluation of dredged Material Proposed for Ocean Disposal- Testing Manual* that provides guidelines to evaluate the suitability of dredge material for ocean disposal through chemical, physical and biological evaluations by following a four-tier testing process. Tiers I and II use existing information and quick procedures to assess the environmental impact of the material to be dredged. If tiers I or II do not provide adequate information to make a decision, then tier III is carried out. Tier IV is carried out only if a decision cannot be made after tier III. The tier approach helps in using resources efficiently, since the intensity of testing is directly proportional to the amount of information required to make a sound decision.

Tier I identifies contaminants of concern using existing data. Tier II uses two models, a mixing model and a benthic model. The mixing model is evaluated against the marine water quality criteria to check compliance, while the benthic impact model calculates the theoretical bioaccumulation potential (TBP) of non-polar organic compounds, such as PCBs, in organisms. This TBP calculation is based on the partition of organic carbon in sediment and lipids in organisms. Even if TBP is not of concern, Tier II calculations indicate the amounts of TBP that can be expected in organisms, while carrying out tiers III or IV of the protocol. Tier III typically consists of two testing phases: water column and benthic. The water column testing evaluates the toxicities of suspended and dissolved contaminants associated with the proportion of dredged material in the water column after initial mixing. The benthic testing consists of an acute bioassay testing and, depending on the level of contamination, a bioaccumulation test. To assess whether the bioaccumulation has potential for being unacceptable, the contaminants
present in the tissue of test organisms are compared first with Food and Drug Administration (FDA) action levels for poisonous and deleterious substances in shellfish and fish for human food. They are also compared against the levels of contaminants found in organisms from the reference sample used during the test. Tier IV is used only under circumstances that warrant special designed case studies. It consists of water column and benthic bioassays that are interpreted on case-specific criteria. The endpoint in benthic acute toxicity testing is mortality (in the case of amphipods, mortality and reburial).

Results are compared to reference sediment results tested at the same time and using the same population of test organisms. Data should be analyzed as recommended in paragraph 11.2.4 of the Inland Testing Manual. Generally, acute toxicity is indicated when mortality in the test sediment is both statistically significant and at least 10% absolute (20% absolute for amphipods) greater than that in the reference sediment.
3.3 Methodology

As mentioned earlier my contribution in this project was working in the laboratory. To understand my work in the laboratory I reviewed the procedures used to carry out a dredging project, designate test area and collect the test sediment. The test area designation and test sediment

3.3.1 Test area designations

The Sampling and Analysis Plan (SAP): Oakland Harbor Channel Maintenance Dredging FY2003 Sampling and Analysis Plan (USACE 2003) assigned individual sample stations. These stations represented sampling areas previously designated by USACE-SF. These locations are shown in Figure 9. As described in the following sections, core samples were composited in the MEC laboratory to form one representative sample per area. A sufficient volume of sediment was collected to carry out all physical, chemical, and biological analyses, while providing an adequate amount of archived material from which aliquots could be taken, in case additional testing was necessary.

3.3.2 Test sediment collection and handling

Sediment core samples were collected from within the inner and outer channels of Oakland Harbor using either a pneumatic vibracore or a gravity coring system. The vibracore had a four-inch diameter aluminum core barrel, with a stainless steel cutter head and tined catcher. “The gravity coring system consisted of a five-foot steel barrel with a polycarbonate liner and stainless steel cutter head (Figure 11). between individual locations and sample areas core barrels and the core liner were washed with site water then washed with Alconox® and rinsed with site water” (MEC 2003).
Sample locations were pre-plotted at MEC on surveys provided by the USACE-SF (MEC 2003). A Garamond Differential Global Positioning System (dGPS) with an accuracy of ± 0.5 to 2 meters and visual aids helped locate the sample position in the field. The dGPS system uses U.S. Coast Guard differential correction data. Upon arrival at the sample station, water depth was measured with an onboard fathometer and verified with a lead-line meter tape. If the depth indicated an absence of dredge material above the project’s acceptable depth, the vessel was maneuvered to a nearby location with more shoaling without leaving the channel boundary (i.e., the dredge footprint). On deploying the coring device, final station location coordinates were recorded on coring logs. An anchor was dropped at each station to keep the vessel from drifting (MEC 2003).

The required depth of 43ft MLLW was attained at all stations except one. A total of the 39 individual sediment cores were taken. Five composites, representing the five sampling areas, were made from these samples. To ensure enough sediment was collected for the entire test, multiple cores were collected from stations within Areas 2 and 5 (Inner and Outer Harbor turning basins).

In addition to being characterized for physical attributes each sample core was measured and recorded for penetration depth and sediment retrieval depth. The cores were then placed in polyethylene containers, which were stored on ice in coolers. At the
end of each day, these coolers would be delivered to MEC’s Tiburon laboratory under chain-of-custody.

Once the samples reach the laboratory, I worked as a member on a team carrying out the required tests. The first step on receiving the sample at the laboratory was to check the seals and log the sample in the sample receipt book. The sample is then stored in the dark at 4°C until testing. To begin a test, the sample is thoroughly homogenized to a uniform color and texture in a clean stainless steel bowl. Subsamples of the homogenized sediment from each station site were then archived at 4°C. Five composites were created by thoroughly mixing together homogenized sediment that represent a sample area in proportions relative to those collected at each site (Figure 12).

Figure 12. Composting of samples.

Subsamples of the composites representing each area were shipped overnight, on ice, to the appropriate laboratories for chemistry testing, grain-size, and TOC testing analysis. Sampling Area 2 and 5 were also analyzed for benthic toxicity, water column toxicity, and potential for bioaccumulation mercury levels. These areas have historically exhibited elevated levels of contamination, especially mercury.

Control sediment for the sediment bioassay using *Nephtys caecoides* and *Rheoxynius abronius*, were collected from Tomales Bay, CA, by John Brezina and Associates, while the control sediment for bioaccumulation tests with *Macoma nasuta*
and *Nereis virens* were collected from Boothbay Harbor, MA by Aquatic Research Organisms, Inc. (MEC 2003).

### 3.3.3 Test Procedures

#### 3.3.3.1 Bioassay Testing

Three water column and two benthic toxicity bioassays were performed on the Area 2 and 5 composite samples from Oakland Harbor. The organisms used for the various tests are listed in Table 12. These bioassays were conducted at MEC’s bioassay laboratory in Tiburon, CA. The test procedures followed for these tests were in accordance to MEC’s standard operating procedures (SOP). These SOP’s are in compliance with the USEPA and ACE guideline manual “The Green Book.”

Table 12. Test organism name and age used for various tests.

<table>
<thead>
<tr>
<th>Test Organisms</th>
<th>Bioassays</th>
<th>Bioaccumulation For Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Name/Group, Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue Mussel, Bivalve, larvae</td>
<td><em>Mytilus edulis</em></td>
<td>X</td>
</tr>
<tr>
<td>Inland Silverside, Fish, 10 days</td>
<td><em>Menidia beryllina</em></td>
<td>X</td>
</tr>
<tr>
<td>Mysid, Shrimp, 5days</td>
<td><em>Mysidopsis bahia</em></td>
<td>X</td>
</tr>
<tr>
<td>Sand Flat head worm, Polychaete, juvenile</td>
<td><em>Nephtys caecoides</em></td>
<td>X</td>
</tr>
<tr>
<td>Amphipod, adult</td>
<td><em>Rheoxynius abronius</em></td>
<td>X</td>
</tr>
<tr>
<td>Bent-nose clam, Clam, adult</td>
<td><em>Macoma nasuta</em></td>
<td>X</td>
</tr>
<tr>
<td>Clam worm, Polychaete, adult</td>
<td><em>Nereis virens</em></td>
<td>X</td>
</tr>
</tbody>
</table>
To monitor and ensure the test conditions are being meet during a test, daily water quality and observations are recorded on laboratory bench sheets. The following are the instruments used for measuring water quality: a YSI Model 57 meter for dissolved oxygen (mg/L); an Orion Model 140 conductivity/salinity for temperature (°C) and conductivity (µS/s) or salinity (ppt); and an Orion Model 230 pH meter for pH. An Orion 95-12 electrode and the Orion 720 digital ion analyzer employing a two-point calibration curve (1 and 10 mg/L) were used to measure ammonia in terms of total ammonia nitrogen (mg/L). These instruments were calibrated each day before taking water quality measurements on the test.

To assess the impact of suspended dredged material on organisms living in the water column, three water column tests were conducted. The three test organisms used were the larvae from bivalve *Mytilus edulis*, the inland silverside *Menidia beryllina* and the mysid shrimp *Mysidopsis bahia*. Elutriate from the sediment composites was prepared using site water. This site water also acts as the diluent’s control. The elutriate diluent’s used as a control was San Francisco Bay seawater filtered to 0.2 µm.

The water column toxicity bioassays were performed in accordance with Green Book guidance for testing of sediment elutriates (USEPA/ACE, 1991). To prepare the elutriate project, sediment and project site water were combined in a 1:4 ratio by volume, vigorously agitated for 30 minutes, and allowed to settle for 1 hour. “Following settling, the supernatant was gently decanted. The supernatant represented the 100% test concentration and was used in serial dilutions with site water diluent to create 50%, 10%, and 1% test concentrations for the three water column toxicity tests” (MEC 2003).

### 3.3.3.2 Water column testing

The following test methods are tests from MEC’s SOP:

**Mytilus edulis Test**

Bivalve larvae bioassay methods are from ASTM E724-98 (ASTM 2001a). Four elutriate concentrations (100%, 50%, 10%, and 1%) and a site water control was tested. Adult *Mytilus edulis* were obtained from Carlsbad Aquafarms of Carlsbad, CA. Spawning was induced by temperature manipulation. Unfertilized eggs were separated
from debris by filtering the suspension through a 80-µm nitex mesh screen. Released gametes were then combined in individual containers of filtered seawater and allowed to fertilize for up to two hours under gentle aeration. Embryo stock density was estimated by counting an aliquot of dilute stock concentrate. Equal volumes of stock were then added to each test chamber to achieve an estimated density of 15-30 embryos/ml. The test was run using five replicates for each treatment and control at 15±2°C under a 16 hour light: 8-hour dark photoperiod. Temperature, pH, dissolved oxygen, and salinity were measured at test initiation and termination (48 hours). At 48 hours, each treatment replicate was preserved using 0.25 mL formaldehyde solution. All larvae in each treatment replicate were counted in a Sedgwick-Rafter cell and the total number of normally and abnormally developed larvae was determined. The test acceptability criterion is ≥70% control survival (normal embryos based on initial inoculation).

Reference toxicant tests were conducted using copper sulfate as a positive control with concentrations of 4.0, 8.0, 16, 32, and 64 µg Cu²⁺/L, and ammonia as a control for confounding bias with concentrations of 1, 2.5, 5, 10 and 20 mg N/L (MEC 2003).

**Menidia beryllina Test**

Bioassay methods for the *Menidia beryllina* water column toxicity bioassay are described in EPA/600/R-95/136 (USEPA 1993a) and the Green Book (USEPA/ACE 1991). Four elutriate concentrations (100%, 50%, 10% and 1%), a method control and a site water control were tested. Larval *Menidia beryllina* were obtained from Aquatic Biosystems of Fort Collins, CO. Ten organisms were exposed to 250 mLs in each replicate. The test was conducted using five replicates for each treatment, method control and site water control at 20±2 °C under a 16 hour light: 8 hour dark photoperiod. Organisms were fed 0.2 mL of a concentrated solution of *Artemia nauplii* after 48 hours. Temperature, pH, dissolved oxygen, and salinity were measured daily. Total ammonia was measured daily in the 100 percent concentration. Measurements in other concentrations were performed if the readings in the 100 percent elutriate were greater than 4 ppm total NH₃. Mortality and behavior observations were recorded and dead organisms were removed on a daily basis. Two reference toxicant tests were conducted; one employed copper as copper sulfate as a positive control with concentrations of 50,
100, 200, 400 and 800 ug Cu\textsuperscript{2+}/L; the other employed total ammonia with concentrations of 5, 10, 20, 40 and 80 mg N/L to account for ammonia as a confounding factor (MEC 2003).

The water column bioassay test using *M. beryllina* was reinitiated when the original test failed due to poor survival (<90%) among the control replicates. This test failure was attributed to inadequately healthy test organisms.

**Mysidopsis bahia Test**

The *Mysidopsis bahia* water column bioassay test methods are described in EPA/600/R-95/136 (USEPA 1993a) and the Green Book (USEPA/ACE 1991). Juvenile *M. bahia* (5 days old) were obtained from Aquatic Biosystems of Ft. Collins, Colorado and used upon receipt. Ten organisms were exposed to 250 mLs in each replicate. The test was conducted using five replicates for each treatment, method control and site water control at 20±2°C under a 16 hour light: 8-hour dark photoperiod. Organisms were fed 0.2 mL of a concentrated solution of *Artemia nauplii* once daily. Water quality measurements including salinity, dissolved oxygen, pH, and temperature were recorded daily for each replicate. Survival was recorded daily for each replicate. Test acceptability criteria is a minimum of 90 percent mean survival in the controls at test termination Two reference toxicant tests were conducted; one using copper as copper sulfate as a positive control with concentrations of 50, 100, 200, 400 and 800 ug Cu\textsuperscript{2+}/L, and one using ammonia to control for confounding bias with concentrations of 5, 10, 20, 40 and 80 mg NH\textsubscript{3}/L (MEC 2003).

3.3.3.3 Benthic Testing

Two acute benthic toxicity tests were conducted with the marine amphipod *Rhepoxynius abronius* and the polychaete *Nephtys caecoides*. *Rhepoxynius abronius* used because sediment had greater than 60% fines (USEPA/ACE 1991). Overlying water used for the benthic toxicity tests was 0.2-um filtered, U.V. sterilized San Francisco Bay seawater.
Rheoxyynius abronius 10-Day Static Test

Bioassay methods for the infaunal amphipod bioassay follow ASTM E1367-99 (ASTM 2001b). Sediments from the two Oakland Harbor composites and control sediment were placed in replicate 1L glass jars to a depth of 2-cm to which was added approximately 900 mL of seawater diluted to 28 ppt with commercial mineral water (Figure 13). Additional surrogate replicates (i.e., without test organisms) for each treatment were set up to obtain measurements of pore water ammonia at test initiation and termination. After 24 hours, overlying water was renewed (80% by volume), and an initial set of water quality parameter measurements was taken from each replicate of each sediment treatment and recorded. The water quality parameters measured were temperature, dissolved oxygen, pH, salinity, and overlying-water ammonia. In addition, a surrogate replicate from each treatment was broken down, and sediment pore water was extracted via centrifugation for subsequent analysis of pH, salinity, and ammonia. Test organisms were then randomly distributed to test chambers (20 animals per chamber). Animals remaining in the water column and exhibiting abnormal behavior after one hour were replaced. The chambers were covered with watch glasses to minimize evaporation.

The test was run under continuous light at a temperature of 15±2° C with gentle aeration applied to each test chamber. Daily water quality measurements were taken from one chamber per treatment, and the number of dead and surfaced animals was noted for each replicate. On day 10, the sediments from the chambers were sieved through a 0.5 mm screen and the number of survivors was recorded. The test acceptability criterion is 90% mean control survival. Two reference toxicant tests were conducted; one as a positive control using cadmium chloride with triplicate concentrations of 0.25, 0.5, 1, 2, and 4 mg Cd^{2+}/L, and the other with ammonia to account for confounding effects of porewater ammonia concentrations. Reference toxicant ammonia dilutions were prepared in triplicate with total ammonia concentrations of 6.25, 12.5, 25, 50, and 100 mg NH_3/L.
Figure 13. *Rheoxynius abronius* test setup in 1L jars with airlines.

**Nephtys caecoides 10-Day Static Test**

Bioassay methods for the marine polychaete bioassay are from ASTM E1611-99 (ASTM 2001c). Juvenile worms (i.e., approximately 5-10 cm in size) were supplied by Brezina & Associates of Dillon Beach, CA. Sediments from the two Oakland Harbor composites and control sediment were placed in replicate 2L polyethylene tubs to a thickness of 4 cm, to which was added approximately 1.5 L of seawater diluted to 28 ppt with commercial mineral water. Additional surrogate replicates (no animals) for each treatment were set up in order to obtain measurements of pore water ammonia at test initiation and termination. After 24 hours, overlying water was renewed (80% by volume) and an initial set of water quality parameters was measured: temperature, dissolved oxygen, pH, salinity, and overlying-water ammonia from each treatment were recorded. In addition, a surrogate replicate from each treatment was broken down and sediment pore water was extracted via centrifugation for subsequent analysis of pH, salinity, ammonia, and sulfides. Test organisms were then randomly distributed to test chambers (5 animals per chamber).

The test was run under a photoperiod of continuous light at a temperature of 15±2°C with gentle aeration. Daily water quality measurements were taken and the number of dead and surfaced animals was noted for each replicate. On day 10, the
sediments from the chambers were sieved through a 0.5 mm screen and the number of survivors was recorded. Test acceptability criterion is 90% mean control survival. Two reference toxicant tests were conducted; one as a positive control using cadmium chloride with triplicate concentrations of 2.5, 5.0, 10, 20, and 40 mg Cd\(^{2+}\)/L., and the other with ammonia to account for confounding effects of pore water ammonia concentrations. Reference toxicant ammonia dilutions were prepared in triplicate with total ammonia concentrations of 12.5, 25, 50, 100 and 200 NH\(_3\)mg/L (MEC 2003).

### 3.3.3.4 Bioaccumulation Testing

Exposures were conducted in accordance with procedures set forth in the USEPA’s *Guidance Manual – Bedded Sediment Bioaccumulation Tests* (USEPA 1993b), and the Green Book (USEPA/USACE 1991). Bioaccumulation tests were conducted using the polychaete worm *N. virens* and the bivalve mollusc *M. nasuta*. Adult test organisms were acquired from Aquatic Research Organisms of Hampton, NH (*N. virens*) and J&G Gunstone Clams, Inc. of Seattle, WA (*M. nasuta*) and used immediately upon receipt. Home (i.e., native control) sediment collected with the *N. virens* was used as control sediment for both species. For each composite sample, as well as the control sediment, 5 L of homogenized sediment was placed into each of ten 22 L fiberglass testing chambers (one set of five replicates for each species). Seawater was dispensed continuously into each tank at a rate of 1.7 – 3.3 ml/sec 24 hours prior to addition of test animals (Day 0). On Day 0, water quality readings (dissolved oxygen [DO], temperature, salinity and pH) were taken from each tank. Ammonia samples were taken from one tank from each site. Once water quality readings were completed, *M. nasuta* and *N. virens* were distributed to their respective tanks. Any *M. nasuta* with shells that were cracked or chipped were not used for this test. *N. virens* that did not immediately begin reburial were removed from the tanks and replaced.

Routine monitoring of the test (Days 1-28) consisted of measuring DO, temperature, salinity, and pH on one replicate from each site for both the *N. virens* and the *M. nasuta* test chambers. In addition to the daily readings, temperature was also monitored using a continuous recording computer. Water flow rate was checked and
calibrated in the same replicate from which water quality readings were taken. A visual check of all tanks was done each day to make sure all tanks were receiving seawater. Dead animals were noted and removed from the test chamber. Removal of all animals was logged on a separate data sheet.

On the final day of the test (Day 28), following routine water quality measurements, the animals were sieved out of the sediment and counted. Once the counts were recorded, the animals were placed back in the test chambers and water flow was resumed for a period of 24 hours. Purged sediment was removed by siphoning the bottom of the chambers with a length of Tygon tubing. This process was done twice, once on Day 28 and again on Day 29. The animals were then removed from the test chambers and placed into pre-cleaned and labeled chemistry jars. Individual replicates were kept separate. All test jars were then frozen pending delivery to the appropriate chemistry laboratory for tissue chemistry analysis. Table 12 summarizes bioassay procedures and organism data for the bioaccumulation study of Oakland Harbor sediments with *N. virens* and *M. nasuta*.

### 3.4 Data analysis and statistical methods

At the conclusion of all bioassays, test endpoint data were evaluated statistically. For the water column toxicity tests, EC50 values were estimated. An EC50 value is the estimated concentration that causes any effect, either lethal concentration (LC) or sublethal or inhibition concentration (IC) on 50% of the test population. For the benthic toxicity and bioaccumulation tests, exposure results were compared to the SF-DODS database.

#### 3.4.1 Analysis of Water Column Toxicity Test Results

**Effects Levels Point Estimates**

EC50 values for survival were estimated using the Probit or Linear Interpolation (Bootstrap) method. EC50 values were compared among the sample elutriates for response consistency. Percent survival data were compared to the site-water controls and analyzed via a Dunnett’s Test when variances were homogeneous, and a modified t-test
when the variances were heterogeneous. All statistical comparisons were made at an alpha level of 0.05 to determine a no observable effects concentration (NOEC).

3.4.2 Calculation of the Limiting Permissible Concentration (LPC)

The toxicity threshold for each area was calculated as a factor of 0.01 of the lowest EC50 calculated from the results of water column toxicity tests. The Limiting Permissible Concentration (LPC) is exceeded if the concentration of the material in the receiving water, after allowance for initial mixing (Projected Concentration), exceeds the toxicity threshold at the edge of mixing zone. The projected concentration was estimated using the mixing zone model, STFATE, as described in the ITM (USEPA/ACE 1998).

3.5 RESULTS

3.5.1 Chemical and Physical analysis

Conventional and Metals Constituents

Project material collected from the Oakland Harbor varied in grain size consistency among sample areas. Composition of the three Inner Harbor composites (Areas 3, 4, and 5) ranged from 63 to 81% fines (silt and clay), with the mid-reach area (Area 2) exhibiting the highest fine-grained concentration. The upper reach area of the Outer Harbor channel (Area 1) was primarily fine-grained (93.3% fines), while the down-reach area exhibited a primarily coarse grain composition (36.3% fines). This would be expected based on the exposed nature of the down reach portion of the Outer Harbor channel. TOC levels correlate with grain size at expected levels, with Areas 2 through 5 exhibiting concentrations ranging from 0.9 to 1.4, and Area 1 exhibiting a concentration of 0.45%. Total sulfides were detected in all composites, although dissolved sulfur was only detected in Areas 2 and 5. Total solids were consistent with previous results.

With the exception of nominal exceedences reported for mercury, silver, and zinc, method detection limits (MDLs) for all metals were below SAP reporting limits (MEC 2003). However, concentrations of mercury and zinc were detected at levels significantly higher than the achieved reporting limits and the silver reporting limits were consistent.
with the low end of the SF-DODS database range (MEC 2003). All metals concentrations measured in the five Oakland Harbor composites were either within the SF-DODS reference database range, or the range of levels previously approved for disposal at SF-DODS.

**Organic Constituents**

With the exception of nominal exceedences observed with some PCBs, PAHs and pesticides, the achieved reporting limits were lower than those required in the SAP, and in general, all method detection limits (MDLs) were below SAP reporting limits.

**Quality Control**

To ensure quality control of procedure method or reagent blanks, laboratory control sample (LCS) and laboratory control sample duplicate (LSCD) analyses, and matrix spike (MS) and matrix spike duplicate (MSD) were performed at a frequency of 5 percent of the samples. Percent recovery of surrogate standards added to each sample, as well as the percent recovery of analytes from LCS/LCSD and MS/MSD samples are used to assess laboratory accuracy. The relative percent difference (RPD) between duplicate analyses is used to assess laboratory precision. The samples were shipped and received in good condition within the acceptable temperature range of <4 or 4 ± 2°C.

**3.5.2 Bioaccumulation results**

**Summary of Organism Exposures**

Water quality parameters in the flow-through bioaccumulation exposures were within the recommended limits prescribed for the both test species. At the end of 28 days, the test organisms were removed by screening through a 1-mm screen, counted, and placed in a flow-through chamber without sediment for purging of gut contents for 24 hours. Mean survival observed with *M. nasuta* and *N. virens* was good for all treatments, ranging from 88 to 92% and 93 to 95%, respectively (MEC 2003).
3.5.3 Tissue Chemistry Results

The bulk sediment chemistry results show that all of the contaminants are either within the SF-DODS reference database range or the range of levels previously approved for disposal at SF-DODS. Therefore, it is reasonable to assume that the sediment to be dredged is not likely to exhibit significant bioaccumulation potential. However, the USACE-SF and EPA agreed to evaluate tissue uptake potential of at least one contaminant to assure consistency with Green Book Tier III testing requirements. The USACE-SF, in consultation with the EPA, decided to perform 28-day bioaccumulation testing and analyze test organism tissues for mercury, since this was the only contaminant that the bulk chemistry results show to be somewhat elevated in comparison to both the SF Bay ambient levels and SF-DODS reference database values (MEC 2003). Total mercury was measured in organism tissues exposed to Area 2, Area 5 and control (native) sediments. For purposes of calculating the mean mercury concentration for each sediment treatment, replicates measured below detection were assigned the MDL as a surrogate concentration.

Mercury concentrations detected in tissues excised from clams exposed to Oakland Harbor sediment ranged from 0.005 to 0.055 mg/kg wet weight. These levels are similar to the levels reported for the control replicates (0.005 to 0.074 mg/kg). Mean concentrations calculated for Area 2 and Area 5 clam tissues were 0.027 and 0.016 mg/kg, consistent with the SF-DODS range of 0.01 to 0.1 mg/kg (MEC 2003).

Mercury concentrations detected in Oakland Harbor sediment exposed polychaete tissues ranged from 0.074 to 0.169 mg/kg. These levels are all similar to the levels reported for the control replicates (0.087 to 0.113 mg/kg), and the baseline tissue (0.090 mg/kg). Mean concentrations calculated for Area 2 and Area 5 polychaete tissues were 0.086 and 0.106 mg/kg, consistent with the SF-DODS range of 0.01 to 0.1 mg/kg for *Nephtys caecoides* testing.
3.5.4 RESULTS OF BIOASSAY ANALYSIS

To determine disposal suitability of sediment collected from Areas 2 and 5, benthic toxicity test results are compared to the SFDODS database and water column results were statistically evaluated to determine whether the Limiting Permissible Concentration (LPC) was exceeded.

*Mytilus edulis* Water Column Toxicity Bioassay

Water quality parameters in *M. edulis* water column test were within the recommended limits prescribed for this test species. Mean percentage of normal surviving site-water control embryos relative to the initial embryo density was 100%, exceeding the passing criteria for this test (>70%). The calculated LC50 (median lethal concentration) values for Areas 2 and 5 were 32.9 and 92.5%, respectively. The EC50 (median sublethal effects concentration) values for the two 34.1 and >100% (MEC 2003).

The copper sulfate reference toxicant (positive control) was tested at nominal concentrations of 4.0, 8.0, 16, 32 and 64 µg Cu²⁺/L. The calculated Cu LC50 was 43.4 µg Cu²⁺/L, which was within two standard deviations of the laboratory mean (27.5±13.3 µg Cu²⁺/L), indicating normal sensitivity based on mortality. The Cu EC50 calculated for development was 2.4 µg Cu²⁺/L. This was also within two standard deviations of the lab mean (15.1 ± 8.8 µg Cu²⁺/L); however, this value falls at the low end of the sensitivity range, indicating that the test population may have potentially been compromised with respect to the normal development.

*Menidia beryllina* Water Column Toxicity Bioassay

Water quality parameters in *M. beryllina* water column test were within the recommended limits prescribed for this test species. Percent survival among *M. beryllina* exposed to laboratory control water was 92%, meeting the passing criterion of ≥90% survival. Percent survival among *M. beryllina* exposed to site water was 96%. There was no statistically significant difference between survival of the two control treatments.

*Menidia beryllina* survival in the 100% elutriates prepared from Areas 2 and 5 were 90% and 88%, respectively. Significant effects on survival relative to the site water
control results were not detected with any of the elutriate dilutions tested. The calculated LC50s were both greater than 100% for both elutriates.

The copper sulfate reference toxicant (positive control) LC50 was 225 µg Cu²⁺/L, which is within two standard deviations of the laboratory mean (301± 266 µg Cu²⁺/L), indicating that the sensitivity of the M. beryllina used in the water column assessment of Oakland Harbor sediments fell within the normal range. The total ammonia reference toxicant, calculated a LC50 of 27.7 mg NH₃/L.

**Mysidopsis bahia Water Column Toxicity Bioassay**

Water quality parameters in M. beryllina water column test were within the recommended limits prescribed for this test species. Percent survival among Mysidopsis bahia exposed to laboratory control water was 100%, meeting the passing criterion of ≥90% survival. Percent survival among Menidia beryllina exposed to site water was also 100%. Significant effects on survival relative to the site water control results were not detected with any of the elutriate dilutions tested. The calculated LC50s were greater than 100% for both elutriates (MEC 2003).

The copper sulfate reference toxicant, LC50 was 163 µg Cu²⁺/L, which was within two standard deviations of the laboratory mean (264±112 µg Cu²⁺/L), indicating that the sensitivity of the M. bahia used in the water column assessment of Oakland Harbor sediments fell within the normal range. The total ammonia reference toxicant also fell within the normal range (MEC 2003).

**Amphipod Benthic Toxicity Bioassay**

Water quality was monitored daily in each treatment, and with the exception of minor exceedances of the recommended range for salinity, water quality measurements were within appropriate limits. The test was conducted within a salinity range consistent with the test material pore water salinity. Salinity of the R. abronius native environment ranges from 0 to 35 ppt, and therefore the minor exceedance of the protocol specified salinity range is considered insignificant. Mean control survival achieved for the 10-day Rhepoxynius abronius test was 92%, meeting the Green Book test acceptability criterion of 90%. The mean R. abronius survival rate of 89.9% is reported in the SF-DODS
database. As such, the Oakland Harbor dredged material meets the amphipod benthic toxicity criteria for SF-DODS disposal suitability (MEC 2003).

The positive control reference toxicant used was cadmium chloride, had a Cd LC50 was 2.33 mg Cd\(^{2+}/L\). This was within two standard deviations of the laboratory mean (1.18 ± 0.77 mg Cd\(^{2+}/L\)), indicating \(R. abronius\) sensitivity fell within the normal range. The ammonia reference toxicant test performed had a calculated ammonia LC50 was 109 mg NH\(_3\)/L (MEC 2003).

**Benthic Toxicity Polychaete Bioassay**

Mean control survival for the 10-day \(Nephtys caecoides\) test was 100%, meeting the Green Book test acceptability criterion of 90%. As such, the Oakland Harbor dredged material meets the polychaete benthic toxicity criteria for aquatic disposal suitability. The positive control reference toxicant used was cadmium chloride, tested was within two standard deviations of the laboratory (16.1±10.2 mg Cd\(^{2+}/L\)), indicating that \(N. caecoides\) sensitivity fell within the normal range (MEC 2003).

**3.6 CONCLUSIONS**

Chemical contaminant concentrations in sediments collected from the Oakland Harbor navigation channels and in tissues from organisms exposed to sediment from the innermost portions of the inner and outer channels (Areas 2 and 5) indicate that disposal of this material is highly unlikely to result in significantly adverse effects to the aquatic environment at SF-DODS. The biological responses observed with all five bioassays performed for this study confirm that adverse biological effects caused by Oakland Harbor dredged material at SF-DODS, if any, would be negligible. Therefore, it is recommended that the material represented by samples collected from all dredge areas within the Oakland Harbor navigation channels be unconditionally classified as suitable for unconfined aquatic disposal at SF-DODS (MEC 2003).
4. SUMMARY OF THE INTERNSHIP EXPERIENCE

Both the internships I pursued as a part of the IES curriculum provided me with valuable real world experiences. My internship with the Bureau of Land Management reinforced some of the coursework with practical and first hand experience in hydrology. My summer work experience in Dr. Vanni’s and Dr. Gonzalez’s laboratory provided me with the skill of using a wide range of field and lab instruments. This internship also showed me how to work on a small budget and, at the same time, not compromise the science involved in the project.

During my second internship I learned a lot about toxicology and time management. My courses in statistics gave me a better understanding of the interpretation of results after each test. It was easy to manage my time between projects, since I had gone through a similar process during my public service project.

In all, I think I benefited from having two internships, a government agency and a private firm, since it showed me two disparate working environments. It was also nice to get experience in two fields within the water resources concentration, so that I could make a better decision on what I would like to do in future.
5. REFERENCE LIST


Breder, C.M., Jr. 1935. The reproductive habits of the common catfish, Ameiurus nebulosus (Lesueur), with a discussion of their significance in Ontogeny and phylogeny. Zoologica., 19(4).


Protection Agency/U.S. Army Corps of Engineers Technical Committee on criteria for dredged and fill material, U.S. Army Waterways Experimental Station. 471 pages.


Willow Creek URA, Step 2 Physical Profile, Obtained from Mr. Armentrout.