

TABLE OF CONTENTS

3.1	SEDIMENTS AND WATER QUALITY	3.1-1
3.1.1	INTRODUCTION AND METHODS	3.1-1
3.1.1.1	Introduction	3.1-1
3.1.1.2	Methods.....	3.1-8
3.1.2	AFFECTED ENVIRONMENT	3.1-11
3.1.2.1	Sediments	3.1-11
3.1.2.2	Water Quality.....	3.1-16
3.1.3	ENVIRONMENTAL CONSEQUENCES	3.1-22
3.1.3.1	Explosives and Explosion Byproducts	3.1-22
3.1.3.2	Metals	3.1-36
3.1.3.3	Chemicals Other than Explosives.....	3.1-46
3.1.3.4	Other Materials.....	3.1-56
3.1.3.5	Summary of Potential Impacts (Combined Impact of All Stressors) on Sediments and Water Quality	3.1-62

LIST OF TABLES

TABLE 3.1-1:	CONCENTRATIONS OF SELECTED ELEMENTS IN SEAWATER	3.1-6
TABLE 3.1-2:	SEDIMENT QUALITY CRITERIA AND INDEX, UNITED STATES WEST COAST AND HAWAIIAN ISLANDS	3.1-11
TABLE 3.1-3:	SEDIMENT SCREENING CRITERIA FOR PEARL HARBOR SEDIMENT REMEDIAL INVESTIGATION	3.1-13
TABLE 3.1-4:	CONTAMINANT CONCENTRATIONS IN BOTTOM SEDIMENTS OFFSHORE SAN CLEMENTE ISLAND	3.1-14
TABLE 3.1-5:	MILITARY MATERIALS AS COMPONENTS OF ALL MATERIALS RECOVERED ON THE WEST COAST, UNITED STATES, 2007-2008	3.1-15
TABLE 3.1-6:	WATER QUALITY CRITERIA AND INDEX, UNITED STATES WEST COAST.....	3.1-17
TABLE 3.1-7:	WATER QUALITY CRITERIA AND INDEX, HAWAIIAN ISLANDS	3.1-18
TABLE 3.1-8:	WATER POLLUTANT CONCENTRATIONS IN SURFACE WATERS AT SAN CLEMENTE ISLAND	3.1-21
TABLE 3.1-9:	BYPRODUCTS OF UNDERWATER DETONATION OF ROYAL DEMOLITION EXPLOSIVE	3.1-24
TABLE 3.1-10:	FAILURE AND LOW-ORDER DETERMINATION RATES OF MILITARY ORDNANCE	3.1-24
TABLE 3.1-11:	STATE WATER QUALITY CRITERIA FOR EXPLOSIVES AND EXPLOSION BYPRODUCTS	3.1-25
TABLE 3.1-12:	CRITERIA FOR EXPLOSIVES AND EXPLOSION BYPRODUCTS IN SALTWATER	3.1-25
TABLE 3.1-13:	WATER SOLUBILITY OF COMMON EXPLOSIVES AND EXPLOSIVE DEGRADATION PRODUCTS	3.1-26
TABLE 3.1-14:	VOLUME OF WATER NEEDED TO MEET MARINE SCREENING VALUE FOR ROYAL DEMOLITION EXPLOSIVE	3.1-29
TABLE 3.1-15:	HIGH-EXPLOSIVE MILITARY EXPENDED MATERIALS FROM TRAINING AND TESTING ACTIVITIES – ALL ALTERNATIVES	3.1-30
TABLE 3.1-16:	COMPARISON OF NUMBER OF HIGH-EXPLOSIVE ITEMS VERSUS WEIGHT OF EXPLOSIVES.....	3.1-31
TABLE 3.1-17:	COMPARISON OF NUMBER OF HIGH-EXPLOSIVE ITEMS VERSUS WEIGHT OF EXPLOSIVES.....	3.1-33
TABLE 3.1-18:	WATER QUALITY CRITERIA FOR METALS	3.1-37
TABLE 3.1-19:	FEDERAL THRESHOLD VALUES FOR EXPOSURE TO SELECTED METALS IN SALTWATER	3.1-38
TABLE 3.1-20:	CONCENTRATIONS OF AND SCREENING LEVELS FOR SELECTED METALS IN MARINE SEDIMENTS, VIEQUES, PUERTO RICO	3.1-39
TABLE 3.1-21:	COMPARISON OF TRAINING MATERIALS WITH METAL COMPONENTS – NO ACTION ALTERNATIVE.....	3.1-43
TABLE 3.1-22:	COMPARISON OF TRAINING MATERIALS WITH METAL COMPONENTS – ALTERNATIVE 1	3.1-44
TABLE 3.1-23:	ORDNANCE CONSTITUENTS IN RESIDUES OF LOW-ORDER DETONATIONS AND IN UNCONSUMED EXPLOSIVES	3.1-48
TABLE 3.1-24:	MILITARY EXPENDED MATERIALS WITH CHEMICAL COMPONENTS – ALL ALTERNATIVES	3.1-53
TABLE 3.1-25:	SUMMARY OF COMPONENTS OF MARINE MARKERS AND FLARES.....	3.1-57
TABLE 3.1-26:	MAJOR COMPONENTS OF CHAFF	3.1-58
TABLE 3.1-27:	SUMMARY OF ANNUAL MILITARY EXPENDED MATERIALS INVOLVING OTHER MATERIALS – ALL ALTERNATIVES	3.1-60

LIST OF FIGURES

FIGURE 3.1-1: SEDIMENT QUALITY INDEX FOR THE HAWAIIAN ISLANDS 3.1-12
FIGURE 3.1-2: WATER QUALITY INDEX FOR THE HAWAIIAN ISLANDS 3.1-19

3.1 SEDIMENTS AND WATER QUALITY

SEDIMENTS AND WATER QUALITY SYNOPSIS

The United States Department of the Navy considered all potential stressors and the following constituents have been analyzed for sediments and water quality:

- explosives and explosion byproducts,
- metals,
- chemicals other than explosives, and
- other materials.

Preferred Alternative

- Impacts of explosion byproducts could be short-term and local, while impacts of unconsumed explosives and metals could be long-term and local. Chemical, physical, or biological changes in sediment or water quality would be measurable but below applicable standards, regulations, and guidelines, and within existing conditions or designated uses.
- Impacts of metals could be long-term and local. Corrosion and biological processes would reduce exposure of military expended materials to seawater, decreasing the rate of leaching, and most leached metals would bind to sediments and other organic matter. Sediments near military expended materials would contain some metals, but concentrations would be below applicable standards, regulations, and guidelines.
- Impacts of chemicals other than explosives and impacts of other materials could be both short- and long-term and local. Chemical, physical, or biological changes in sediment or water quality would not be detectable, and would be within existing conditions or designated uses.
- Impacts of other materials could be short-term and local. Most other materials from military expended materials would not be harmful to marine organisms, and would be consumed during use. Chemical, physical, or biological changes in sediment or water quality would not be detectable.

3.1.1 INTRODUCTION AND METHODS

3.1.1.1 Introduction

The following sections provide an overview of the characteristics of sediment and water quality in the Hawaii-Southern California Training and Testing (HSTT) Study Area (Study Area), and describe in general terms the methods used to analyze potential impacts of the Proposed Action on these resources.

3.1.1.1.1 Sediments

The discussion of sediments begins with an overview of sediment sources and characteristics in the Study Area, and considers factors that affect sediment quality.

3.1.1.1.1.1 Characteristics of Sediments

Sediment consists of solid fragments of organic matter and inorganic matter from the weathering of rock that are transported by water, wind, and ice (glaciers), and deposited at the bottom of bodies of

water. Sediments range in size from cobble (2.5 to 10 inches [in.; 64 to 256 millimeters {mm}]), to pebble (0.15 to 2.5 in. [4 to 64 mm]), to granule (0.08 to 0.15 in. [2.03 to 3.81 mm]), to sand (0.002 to 0.08 in. [0.05 to 2.03 mm]), to silt (0.00008 to 0.0002 in. [0.002 to 0.05 mm]), and to clay (less than 0.00008 in. [less than 0.002 mm]). Sediment deposited on the continental shelf is mostly transported by rivers, but also by local and regional currents and wind. Most sediments in nearshore areas and on the continental shelf of the Pacific Ocean are aluminum silicates, derived from rocks on land, that are deposited at rates of more than 10 centimeters (cm) (3.9 in.) per 1,000 years. Sediments may also be produced locally by non-living particulate organic matter (“detritus”) that sinks to the bottom. Some areas of the deep ocean contain accumulations of the shells of marine microbes composed of silicones and calcium carbonates, termed biogenic ooze (Chester 2003). Through the downward movement of organic and inorganic particles in the water column, many substances that are otherwise scarce in the water column are concentrated in bottom sediments (Chapman et al. 2003; Kszos et al. 2003).

3.1.1.1.1.2 Factors Affecting Marine Sediment Quality

The quality of sediments is influenced by their physical, chemical, and biological components; by where they are deposited; by the properties of seawater; and by other inputs and sources of contamination. These factors interact to some degree, so sediments tend to be dynamic, and are not easily generalized. For this discussion, “contaminant” means biological, chemical, or physical materials normally absent in sediments, but which when present or present at high concentrations, can impact marine processes.

3.1.1.1.1.3 Sediment Physical Characteristics and Processes

At any given site, the texture and composition of sediments are important physical factors that influence the types of substances that are retained in the sediments, and subsequent biological and chemical processes. Clay-sized and smaller sediments and similarly sized organic particles tend to bind potential sediment contaminants such as metals, hydrocarbons, and persistent organic pollutants. Through this attraction, these particles efficiently scavenge contaminants from the water column and from the water between grains of sediment (“pore water”), and may bind them so strongly that their movement in the environment is limited (United States [U.S.] Environmental Protection Agency [EPA] 2008a). Conversely, fine-grained sediments are easily disturbed by currents and bottom-dwelling organisms (Hedges and Oades 1997), dredging (Eggleton and Thomas 2004), storms (Chang et al. 2001), and bottom trawling (Churchill 1989). Disturbance is also possible in deeper areas, where currents are minimal (Carmody et al. 1973), from mass wasting events such as underwater slides and debris flows (Coleman and Prior 1988). If re-suspended, fine-grained sediments (and any substances bound to them) can be transported long distances.

3.1.1.1.1.4 Sediment Chemical Characteristics and Processes

The concentration of oxygen in sediments strongly influences sediment quality through its effect on the binding of materials to sediment particles. At the sediment surface, the level of oxygen is usually the same as that of the overlying water. Deeper sediment layers, however, are often low in oxygen (“hypoxic”) or have no oxygen (“anoxic”), and have a low oxidation-reduction (“redox”) potential, which predicts the stability of various compounds that regulate nutrient and metal availability in sediments. Certain substances combine in oxygen-rich environments and become less available for other chemical or biological reactions. If these combined substances settle into the low or no-oxygen sediment zone, the change may release them into pore water, making them available for other chemical or biological reactions. Conversely, substances that remain in solution in oxygenated environments may combine with organic or inorganic substances under hypoxic or anoxic conditions, and are thus removed from further chemical or biological reactions (Spencer and MacLeod 2002; Wang et al. 2002).

3.1.1.1.1.5 Sediment Biological Characteristics and Processes

Organic matter in sediment provides food for resident microbes. Their metabolism can change the chemical environment in sediments and thereby increase or decrease the mobility of various substances and influence the ability of sediments to retain and transform those substances (Mitsch and Gosselink 2007; EPA 2008a). Bottom-dwelling animals often rework sediments in the process of feeding or burrowing (“bioturbation”). In this way, marine organisms influence the structure, texture, and composition of sediments as well as the horizontal and vertical distribution of substances in the sediment (Boudreau 1998). Moving substances out of or into low or no-oxygen zones in the sediment may alter the form and availability of various substances. The metabolic processes of bacteria also influence sediment components directly. For example, sediment microbes may convert mercury to methyl mercury, increasing its toxicity (Mitchell and Gilmour 2008).

3.1.1.1.1.6 Location

The quality of coastal and marine sediments is influenced substantially by inputs from adjacent watersheds (Turner and Rabalais 2003). Proximity to watersheds with large cities or intensively farmed lands often increases the amount of both inorganic and organic contaminants that find their way into coastal and marine sediments. Metals enter estuaries through the weathering of natural rocks and mineralized deposits carried by rivers and through man-made inputs that often contribute amounts substantially above natural levels. The metals of greatest concern are cadmium, chromium, mercury, lead, selenium, arsenic, and antimony because they bioaccumulate, are toxic to biota at low concentrations, and have few natural functions in biological systems (Summers et al. 1996). In addition to metals, a wide variety of organic substances, such as polycyclic aromatic hydrocarbons, polychlorinated biphenyls (PCBs), and pesticides—often referred to collectively as “persistent organic pollutants”—are discharged into coastal waters by urban, agricultural, and industrial point and non-point sources in the watershed (EPA 2008a).

The natural processes of estuaries retain a wide variety of substances (Li et al. 2008; Mitsch and Gosselink 2007). Examples of these processes include the binding of materials to small particles in the water column and the settling of those particles into sediments in calm areas. Thus, the concentrations of various substances generally decrease with increasing distance from the shore. Once in the ocean, the fates of various substances may also be influenced by longshore currents that travel parallel to the shore (Duursma and Gross 1971). Location on the ocean floor also influences the distribution and concentration of various elements through local geology and volcanic activity (Demina et al. 2009), as well as through mass wasting events (Coleman and Prior 1988).

3.1.1.1.1.7 Other Contributions to Sediments

While the greatest mass of sediments is carried into marine systems by rivers (EPA 2008a), wind and rain also deposit materials in coastal waters, and contribute to the mass and quality of sediments. For example, approximately 80 percent of the mercury released by human activities comes from coal combustion, mining and smelting, and solid waste incineration (Agency for Toxic Substances and Disease Registry 1999). These activities are generally considered to be the major sources of mercury in marine systems (Fitzgerald et al. 2007). Atmospheric deposition of lead is similar in that human activity is a major source of lead in sediments (Wu and Boyle 1997).

Hydrocarbons are common in marine sediments. In addition to washing in from land and shipping sources, they are generated by the combustion of fuels (both wood and petroleum), are produced directly by marine and terrestrial biological sources, and arise from processes in sediments, including microbial activity and natural hydrocarbon seeps (Boehm and Gequejo 1986; Geiselbrecht et al. 1998).

Means (1995) noted that, because of the large binding capacities of rich, organic, fine-grained sediments found at many coastal and estuarine sites, “hydrocarbons may concentrate to levels far exceeding those observed in the water column of the receiving water body.”

3.1.1.1.2 Water Quality

The discussion of water quality begins with an overview of the characteristics of marine waters, including pH, temperature, oxygen, nutrients, salinity, and dissolved elements. The discussion then considers how those characteristics of marine waters are influenced by physical, chemical, and biological processes.

3.1.1.1.2.1 Characteristics of Marine Waters

The composition of water in the marine environment is determined by complex interactions among physical, chemical, and biological processes. Physical processes include region-wide currents and tidal flows, seasonal weather patterns and temperature, sediment characteristics, and unique local conditions, such as the volume of fresh water delivered by large rivers. Chemical processes involve salinity, pH, dissolved minerals and gases, particulates, nutrients, and pollutants. Biological processes involve the influence of living things on the physical and chemical environment. The two dominant biological processes in the ocean are photosynthesis and respiration, particularly by microorganisms. These processes involve the uptake, conversion, and excretion of waste products during growth, reproduction, and decomposition (Mann and Lazier 1996).

3.1.1.1.2.2 pH

pH is a measure of the degree to which a solution is either acidic (pH less than 7.0) or basic (pH greater than 7.0). Seawater has a relatively stable pH between 7.5 and 8.5 because of the presence of dissolved elements, particularly carbon and hydrogen. Most of the carbon in the sea is present as dissolved inorganic carbon generated through the complex interactions of dissolved carbon dioxide in seawater. This carbon dioxide-carbonate equilibrium is the major pH buffering system in seawater. Changes in pH outside of the normal range of seawater can make maintaining their shells difficult for specialized marine animals (e.g., mollusks; Fabry et al. 2008).

3.1.1.1.2.3 Temperature

Temperature influences the speed at which chemical reactions take place in solution: higher temperatures increase reaction rates and vice versa. Seasonal changes in weather influence water temperatures that, in turn, influence the degree to which marine waters mix. The increases in surface water temperatures during summer create three distinct layers in deeper water, a process known as stratification. The warmer surface layer is separated from colder water toward the bottom by an intervening layer (“thermocline”) within which the temperature changes rapidly with depth. Stratification can limit the exchange of gases and nutrients, as well as the onset and decline of phytoplankton blooms (Howarth et al. 2002). In fall and winter, lower air temperatures and cool surface waters break down the vertical stratification and promote mixing within the water column.

Sea surface temperatures in Southern California range from 54 degrees Fahrenheit (°F) (12 degrees Celsius [°C]) to 70°F (21°C) during the year. In the Hawaiian Islands, temperatures are higher, ranging from 71°F (22°C) to 81°F (27°C) during the year (National Oceanographic Data Center 2011a, b).

3.1.1.1.2.4 Oxygen

Surface waters in the ocean are usually saturated or supersaturated with dissolved oxygen by photosynthetic activity and wave mixing (89 percent to 106 percent, 4.49 to 5.82 milliliters per liter

[ml/L]). As water depth below the surface increases, the oxygen concentration decreases from more than 60 percent (4.4 ml/L) to a minimum of 27 percent (1.7 ml/L) at intermediate depths between 1,000 and 3,000 feet (ft.) (300 and 900 m). Thereafter, the oxygen level increases with depth to about 6,500 ft. (2,000 m) (73 percent to 88 percent, 5.4 to 6.7 ml/L) and remains relatively constant at greater depths (Seiwell 1934).

A dissolved oxygen concentration of less than two milligrams per liter (mg/L) is considered to be poor, a condition referred to as hypoxia (Rabalais et al. 2002; EPA 2008a). Such low oxygen levels are natural in marine systems under certain conditions, such as oxygen minimum zones at intermediate depths, upwelling areas, deep ocean basins, and fjords (Helly and Levin 2004). Upwelling refers to the movement of colder, nutrient-rich waters from deeper areas of the ocean to the surface. However, the occurrence of hypoxia and anoxia in shallow coastal and estuarine areas can adversely affect fish, bottom-dwelling (“benthic”) creatures, and submerged aquatic vegetation. Hypoxia appears to be increasing (Diaz and Rosenberg 1995), and affects more than half of estuaries in the United States (Bricker et al. 1999).

3.1.1.1.2.5 Nutrients

Nutrients are elements and compounds necessary for the growth and metabolism of organisms. In marine systems, basic nutrients include dissolved nitrogen, phosphates, silicates, and metals such as iron and copper. Dissolved inorganic nitrogen occurs in ocean water as nitrates, and ammonia (Zehr and Ward 2002). Depending on local conditions, the productivity of marine ecosystems may be limited by the amount of phosphorus available or, more often, by the amount of nitrogen available (Cloern 2001; Anderson et al. 2002). Too much of either nutrient can lead to deleterious conditions referred to as eutrophication. Too many nutrients can stimulate algal blooms, the rapid expansion of microscopic algae (phytoplankton). Once the excess nutrients are consumed, the algae population dies off and the remains are consumed by bacteria. Bacterial consumption causes dissolved oxygen in the water to decline to the point where organisms can no longer survive (Boesch et al. 1997). Sources of excess nutrients include fertilizers, wastewater, and atmospheric deposition of the combustion products from burning fossil fuels (Turner and Rabalais 2003). Biogeochemical processes in estuaries and on the continental shelf influence the extent to which nitrogen and phosphorus reach the open ocean. Many of these nutrients eventually reside in coastal sediments (Nixon et al. 1996).

3.1.1.1.2.6 Salinity, Ions, and Other Dissolved Substances

The concentrations of major ions in seawater determine its salinity. These ions include sodium, chloride, potassium, calcium, magnesium, and sulfate. Salinity varies seasonally and geographically, especially in areas influenced by large rivers (Milliman et al. 1972). Table 3.1-1 provides estimated concentrations of elements in open ocean waters (Nozaki 1997). The presence of extremely small organic particles (less than 0.63 micrometer [μm]), carbonates, sulfides, phosphates, and other metals, will influence the dominant form of some substances, and determine whether they remain dissolved or form solids.

Salinity depends on the ratio of evaporation to precipitation. For example, regions closer to the equator are generally higher in salinity because of their higher evaporation rates. The salinity around the Hawaiian Islands is similar to other subtropical waters, where salinity ranges from 32 to 36 practical salinity units (psu), with a mean of 34.68 practical salinity units. Southern California salinity ranges from 30 to 36 psu, with a mean of 33.79 psu (Srokosz n.d.).

3.1.1.1.2.7 Influences of Marine Properties and Processes on Seawater Characteristics

Ocean currents and tides mix and redistribute seawater. In doing so, they alter surface water temperatures, transport and deposit sediment, and concentrate and dilute substances that are dissolved and suspended in the water. These processes operate to varying degrees from nearshore areas to the abyssal plain. Salinity also affects the density of seawater and, therefore, its movement relative to the sea surface (Libes 2009). Upwelling brings cold, nutrient-rich waters from deeper areas, increasing the productivity of local surface waters (Mann and Lazier 1996). Storms and hurricanes also cause strong mixing of marine waters (Li et al. 2006).

Table 3.1-1: Concentrations of Selected Elements in Seawater

Element	Estimated Mean Oceanic Concentration (ng/kg [ppt])
Magnesium	1,280,000,000
Silicon	2,800,000
Lithium	180,000
Phosphorus	62,000
Molybdenum	10,000
Uranium	3,200
Nickel	480
Zinc	350
Chromium (VI)	210
Copper	150
Cadmium	70
Aluminum	30
Iron	30
Manganese	20
Tungsten	10
Titanium	6.5
Lead	2.7
Chromium (III)	2
Silver	2
Cobalt	1.2
Tin	0.5
Mercury	0.14
Platinum	0.05
Gold	0.02

Notes: ng = nanogram; kg = kilogram; ppt = parts per trillion

Temperature and pH influence the behavior of trace metals in seawater, such as the extent to which they dissolve in water ("solubility") or their tendency to adsorb to organic and inorganic particles. However, the degree of influence differs widely among metals (Byrne et al. 1988). The concentration of a given element may change with position in the water column. For example, some metals (e.g., cadmium) are present at low concentrations in surface waters and at higher concentrations at depth (Bruland 1992), while others decline quickly with increasing depth below the surface (e.g., zinc and iron; Morel and Price 2003; Nozaki 1997). On the other hand, dissolved aluminum concentrations are highest

at the surface, lowest at mid-depths, and increase again at depths below about 3,300 ft. (1,006 m) (Li et al. 2008).

Substances like nitrogen, carbon, silicon, and trace metals are extracted from the water by biological processes. Others, like oxygen and CO₂, are produced. Metabolic waste products add organic compounds to the water, and may also absorb trace metals, removing those metals from the water column. Those organic compounds may then be consumed by biological organisms, or they may aggregate with other particles and sink (Wallace et al. 1977; Mann and Lazier 1996).

Runoff from coastal watersheds influences local and regional coastal water conditions, especially large rivers. Influences include increased sediments and pollutants, and decreased salinity (Wiseman and Garvine 1995; Turner and Rabalais 2003). Coastal bays and large estuaries serve to filter river outflows and reduce total discharge of runoff to the ocean (Edwards et al. 2006). Depending on their structure and components, estuaries can directly or indirectly affect coastal water quality by recycling various compounds (e.g., excess nutrients), sequestering elements in more inert forms (e.g., trace metals), or altering them, such as the conversion of mercury to methyl mercury (Mitsch and Gosselink 2007; Mitchell and Gilmour 2008).

3.1.1.1.2.8 Coastal Water Quality

A recent coastal condition report by the EPA (2008a) evaluated the condition of U. S. coastal water quality. According to the report, most water quality problems in coastal waters of the United States are from degraded water clarity or increased concentrations of phosphates or chlorophyll *a*. Water quality indicators measured included dissolved inorganic nitrogen, dissolved inorganic phosphorus, water clarity or turbidity, dissolved oxygen, and chlorophyll *a*. Chlorophyll *a* is an indicator of microscopic algae (phytoplankton) abundance used to judge nutrient availability (i.e., phosphates and nitrates). Excess phytoplankton blooms can decrease water clarity and, when phytoplankton die off following blooms, lower concentrations of dissolved oxygen. Most sources of these negative impacts arise from on-shore point and non-point sources of pollution. Point sources are direct water discharges from a single source, such as industrial or sewage treatment plants, while non-point sources are the result of many diffuse sources, such as runoff caused by rainfall.

3.1.1.1.2.9 Hydrocarbons, Trace Metals, and Persistent Organic Pollutants

In addition to the characteristics discussed above, other substances influence seawater quality, including hydrocarbons, metals, and persistent organic pollutants (e.g., pesticides, PCBs, organotins, polycyclic aromatic hydrocarbons, and similar synthetic organic compounds). The sources of these contaminants include commercial and recreational vessels; oil and gas exploration, processing, and spills; industrial and municipal discharges (point source pollution); runoff from urban and agricultural areas (non-point source pollution); legal and illegal ocean dumping; poorly or untreated sewage; and atmospheric deposition of combustion residues (EPA 2008a). Various physical, chemical, and biological processes work to remove many of these substances from seawater; thereafter, they become part of nearshore and continental shelf sediments.

Hydrocarbons

Hydrocarbons are common in marine ecosystems. They arise from man-made sources, from natural hydrocarbon seeps, and from microbial activity (Boehm and Requejo 1986; Geiselbrecht et al. 1998). According to Kvenvolden and Cooper (2003), during the 1980s, about 10 percent of crude oil entering the marine environment came from natural sources; 27 percent came from oil production, transportation, and refining; and the remaining 63 percent came from atmospheric emissions, municipal

and industrial sources, and urban and river runoff. These sources produce many thousands of chemically different hydrocarbon compounds. When hydrocarbons enter the ocean, the lighter-weight components evaporate, degrade by sunlight (“photolysis”), or undergo chemical and biological degradation. A wider range of constituents are consumed by microbes (“biodegradation”). Higher-weight molecular compounds such as asphaltene are more resistant to degradation, and tend to persist after these processes have occurred (Blumer et al. 1973; Mackay and McAuliffe 1988).

Trace Metals

Trace metals commonly present in seawater are listed in Table 3.1-1. Levels of dissolved metals in seawater are normally quite low because some are extracted by organisms (e.g., iron), many tend to precipitate with various ions already present in the water, and others bind to various metal oxides and small organic and inorganic particles in the water (Turekian 1977). These processes transform the metals from a dissolved state to a solid (particulate) state, and substantially decrease concentrations of dissolved metals in seawater (Wallace et al. 1977). Concentrations of heavy metals normally decrease with increasing distance from shore (Wurl and Obbard 2004) and vary with depth (Li et al. 2008). Certain amounts of trace metals are naturally present in marine waters because of the dissolution of geological formations on land by rain and runoff. However, the additional amounts of metals produced by human activity often have adverse consequences for marine ecosystems (Summers et al. 1996), such as the atmospheric deposition of lead into marine systems (Wu and Boyle 1997).

Persistent Organic Pollutants

Persistent organic pollutants, such as herbicides, pesticides, PCBs, organotins, polycyclic aromatic hydrocarbons, and similar synthetic organic compounds, are chemical substances that persist in the environment and bioaccumulate through the food web. Persistent organic pollutants have long half-lives in the environment. They are resistant to degradation, do not readily dissolve in water, and tend to adhere to organic solids and lipids (fats) (Jones and deVoogt 1999) and plastics. Although they are present in the open ocean and deep ocean waters (Tanabe and Tatsukawa 1983), they are more common and in higher concentrations in nearshore areas and estuaries (Means 1995; Wurl and Obbard 2004). The surface of the ocean is an important micro-habitat for a variety of microbes, larvae, and fish eggs. Because of the tendency of hydrocarbons and persistent organic pollutants to float in this surface micro-layer, they can be much more toxic to those organisms than the adjacent sub-surface water (Wurl and Obbard 2004). Also, persistent organic pollutants that adhere to particulates may sink to the seafloor. Levels of persistent organic pollutants in bottom-feeding fish were higher than fish that live higher up in the water column on the Palos Verde Shelf off the coast of the Palos Verdes peninsula near Los Angeles (EPA 2011). Sauer et al. (1989) noted that concentrations of PCBs and dichlorodiphenyltrichloroethane (DDT) have been declining in the open ocean for several decades.

3.1.1.2 Methods

The following four stressors may impact sediment or water quality: (1) explosives and explosive byproducts, (2) metals, (3) chemicals other than explosives, and (4) a miscellaneous category of other materials. The term “stressor” is used because the military expended materials in these four categories may negatively affect sediment or water quality by altering their physical or chemical characteristics. The potential impacts of these stressors are evaluated based on the extent to which the release of these materials would directly or indirectly impact sediments or water quality such that existing laws or standards would be violated or recommended guidelines would be exceeded. The differences between standards and guidelines are described below.

- **Standards** are established by law or through government regulations that have the force of law. Standards may be numerical or narrative. Numerical standards set allowable concentrations of specific pollutants (e.g., micrograms per liter [$\mu\text{g/L}$]) or levels of other parameters (e.g., pH) to protect the water's designated uses. Narrative standards describe water conditions that are not acceptable.
- **Guidelines** are nonregulatory, and generally do not have the force of law. They reflect an agency's preference or suggest conditions that should prevail. Guidelines are often used to assess the condition of a resource to guide subsequent steps, such as the disposal of dredged materials. Terms such as screening criteria, effect levels, and recommendations are also used.

3.1.1.2.1 State Standards and Guidelines

State jurisdiction over sediment and water quality extends from the low tide line out 3 nautical miles (nm; Submerged Lands Act of 1953 [43 United States Code {U.S.C.} § 1301, et seq.]). Creating state-level sediment and water quality standards and guidelines begins with each state establishing a use for the water, which is referred to as its "beneficial" or "designated" use. Examples of such uses of marine waters include fishing, shellfish harvest, and swimming. For this section, a water body is considered "impaired" if any one of its designated uses is not met. Once this use is designated, standards or guidelines are established to protect the water at the desired level of quality. Applicable state standards and guidelines specific to each stressor are detailed in Section 3.1.3, Environmental Consequences.

3.1.1.2.2 Federal Standards and Guidelines

Chief of Naval Operations Instruction 5090.1 is the Navy's controlling authority for all at-sea compliance with federal regulations. Federal jurisdiction over ocean waters extends from 3 to 12 nm (Outer Continental Shelf Lands Act of 1953 [43 U.S.C. § 1331 et seq.]). Sediments and water quality standards and guidelines are mainly the responsibility of the EPA, specifically ocean discharge provisions of the Clean Water Act (33 U.S.C. § 1251, et seq.). Ocean discharge may not result in "unreasonable degradation of the marine environment." Specifically, the disposal may not result in (1) unacceptable negative effects on human health, (2) unacceptable negative effects on the marine ecosystem, (3) unacceptable negative persistent or permanent effects because of the particular volumes or concentrations of the dumped materials, or (4) unacceptable negative effects on the ocean for other uses as a result of direct environmental impact (40 Code of Federal Regulations [C.F.R.] § 125.122). Federal standards and guidelines applicable to each stressor are described in Section 3.1.3, Environmental Consequences. Where U.S. legal and regulatory authority do not apply (e.g., beyond 200 nm from shore), federal standards and guidelines may be used as reference points for evaluating effects of proposed training and testing activities on sediment and water quality.

The International Convention for the Prevention of Pollution from Ships (Convention) addresses pollution generated by normal vessel operations. The Convention is incorporated into U.S. law as 33 U.S.C. §§ 1901-1915. The Convention includes six annexes: Annex I, oil discharge; Annex II, hazardous liquid control; Annex III, hazardous material transport; Annex IV, sewage discharge; Annex V, plastic and garbage disposal; and Annex VI, air pollution. The U.S. Department of the Navy (Navy) is required to comply with the Convention; however, the United States is not a party to Annex IV. The Convention contains handling requirements and specifies where materials can be discharged at sea, but it does not contain standards related to sediment and water quality.

3.1.1.2.3 Intensity and Duration of Impact

The intensity or severity of impact is defined as follows (increasing order of negative impacts):

- Chemical, physical, or biological changes in sediment or water quality would not be detectable and total concentrations would be below or within existing conditions or designated uses.
- Chemical, physical, or biological changes in sediment or water quality would be measurable but total concentrations would be below applicable standards, regulations, and guidelines, and would be within existing conditions or designated uses.
- Chemical, physical, or biological changes in sediment or water quality would be measurable and readily apparent but total concentrations would be within applicable standards, regulations, and guidelines. Sediment or water quality would be altered compared to historical baseline, desired conditions, or designated uses. Mitigation would be necessary and would likely be successful.
- Chemical, physical, or biological changes in sediment or water quality would be readily measurable, and some standards, regulations, and guidelines would be periodically approached, equaled, or exceeded by total concentrations. Sediment or water quality would be frequently altered from the historical baseline, desired conditions, or designated uses. Mitigation would be necessary, but success would not be assured.

Duration is characterized as either short-term or long-term. Short-term is defined as days or months. Long-term is defined as months or years, depending on the type of activity or the materials involved.

3.1.1.2.4 Measurement and Prediction

Many of the conditions discussed above often influence each other, so measuring and characterizing various substances in the marine environment is often difficult (Byrne 1996; Ho et al. 2007). For instance, sediment contaminants may also change over time. Valette-Silver (1993) reviewed several studies that demonstrated the gradual increase in a variety of contaminants in coastal sediments that began as early as the 1800s, continued into the 1900s, peaked between the 1940s and 1970s, and declined thereafter (e.g., lead, dioxin, PCBs). After their initial deposition, normal physical, chemical, and biological processes can re-suspend, transport, and redeposit sediments and associated substances in areas far removed from the source (Hameedi et al. 2002; EPA 2008a). The conditions noted above further complicate predictions of the impact of various substances on the marine environment.

3.1.1.2.5 Sources of Information

Relevant literature was systematically reviewed to complete this analysis of sediment and water quality. The review included journals, technical reports published by government agencies, work conducted by private businesses and consulting firms, U.S. Department of Defense reports, operational manuals, natural resource management plans, and current and prior environmental documents for facilities and activities in the Study Area.

Because of its importance and proximity to humans, information is readily available on the condition of inshore and nearshore sediment and water quality. However, much less is known about deep ocean sediments and open ocean water quality. Because inshore and nearshore sediment and water quality are negatively affected mostly by various human social and economic activities, two general assumptions are used in this discussion: (1) the greater the distance from shore, the higher the quality of sediments and waters; and (2) deeper waters are generally of higher quality than surface waters.

3.1.1.2.6 Areas of Analysis

The locations where specific military expended materials would be used are discussed under each stressor in Section 3.1.3, Environmental Consequences.

3.1.2 AFFECTED ENVIRONMENT

The affected environment includes sediment and water quality within the Study Area, from nearshore areas to the open ocean and deep sea bottom. Existing sediment conditions are discussed first and water quality thereafter.

3.1.2.1 Sediments

The following subsections discuss sediments for each region in the Study Area. Table 3.1-2 provides the sediment quality criteria and index for the U.S. west coast and Hawaiian Islands.

Table 3.1-2: Sediment Quality Criteria and Index, United States West Coast and Hawaiian Islands

Criterion	Site Criteria			Regional Criteria		
	Good	Fair	Poor	Good	Fair	Poor
Sediment Toxicity	Amphipod survival rate \geq 80%	N/A	Amphipod survival rate $<$ 80%	$<$ 5% of coastal area in poor condition	N/A	\geq 5% of coastal area in poor condition
Sediment Contaminants	No ERM concentration exceeded, and $<$ 5 ERL concentrations exceeded	No ERM concentration exceeded and \geq 5 ERL concentrations exceeded	An ERM concentration exceeded for one or more contaminants	$<$ 5% of coastal area in poor condition	5-15% of coastal area in poor condition	$>$ 15% of coastal area in poor condition
Excess Sediment TOC	TOC concentration $<$ 2%	TOC concentration 2% to 5%	TOC concentration $>$ 5%	$<$ 20% of coastal area in poor condition	20-30% of coastal area in poor condition	$>$ 30% of coastal area in poor condition
Sediment Quality Index	No individual criteria rated poor, and sediment contaminants criteria is rated good	No individual criteria rated poor, and sediment contaminants criteria is rated fair	One or more individual criteria rated poor	$<$ 5% of coastal area in poor condition, and $>$ 50% in good condition	5-15% of coastal area in poor condition, and $>$ 50% in combined fair and poor condition	$>$ 15% of coastal area in poor condition

Note: ERM = effects range–median; is the level measured in the sediment below which adverse biological effects were measured 50 percent of the time; ERL = effects range–low; is the level measured in the sediment below which adverse biological effects were measured 10 percent of the time (Long et al. 1995); N/A = Not Applicable; TOC = total organic carbon, refers to the amount of carbon contained in organic compounds; $<$ = less than; $>$ = greater than.

Source: EPA 2008a

3.1.2.1.1 Sediments in the Insular Pacific-Hawaiian Large Marine Ecosystem

The composition and distribution of bottom substrate in the Insular Pacific-Hawaiian Large Marine Ecosystem are discussed in Section 3.3, Marine Habitats. The sediment quality index for Hawaii's coastal waters is rated good to fair, with seven percent of the coastal sediment rated fair and five percent rated poor (Figure 3.1-1; EPA 2008a). Sediment quality was based on three components: sediment toxicity, sediment contaminants, and sediment total organic carbon. Poor sediment quality ratings were primarily influenced by metal and organic contaminants near the heavily urbanized southern shore of Oahu. In terms of sediment toxicity, 97 percent of the coastal area was rated good, with three percent rated poor because of elevated levels of arsenic and DDT (EPA 2008a). Most sediments in Hawaii's coastal waters are rated good for sediment contaminants, with approximately nine percent of the

coastal area rated fair or poor. Those sites generally exhibited elevated levels of metals, such as chromium, lead, copper, mercury, silver, and zinc, and polycyclic aromatic hydrocarbons (EPA 2008a).

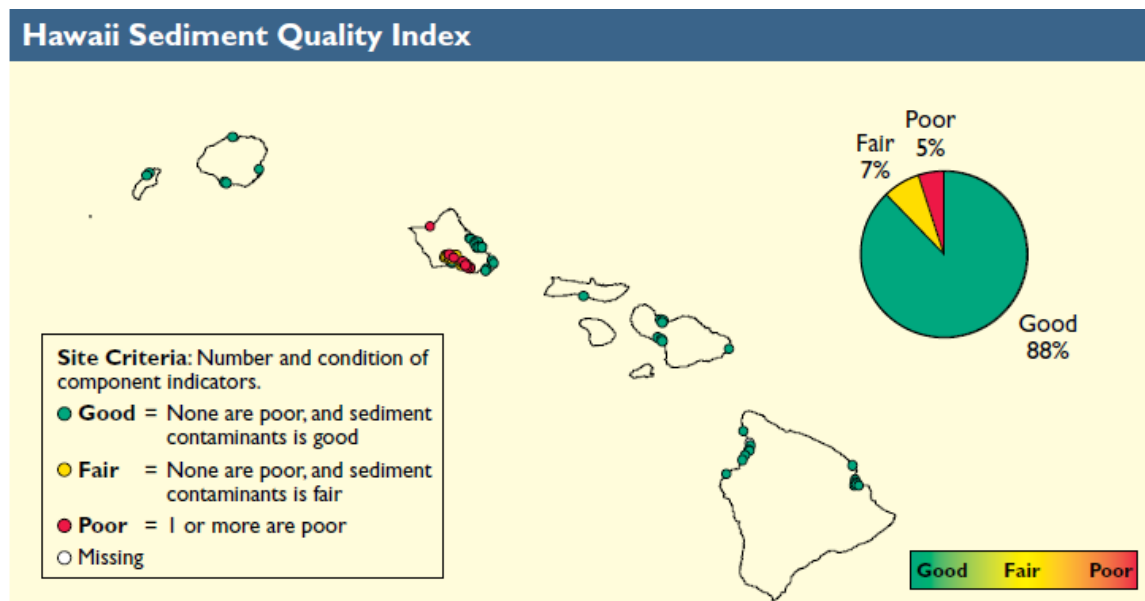


Figure 3.1-1: Sediment Quality Index for the Hawaiian Islands

Some metals naturally occur at elevated concentrations in the volcanic soils of Hawaii. Natural concentrations of copper, zinc, nickel, and chromium are high compared to soils in the mainland United States. Pearl Harbor receives a substantial amount of metal contamination because it serves as a natural trap for sediment particles (Agency for Toxic Substance and Disease Registry 2005).

Anthropogenic activities within and around Pearl Harbor, including Navy activities and private industrial, commercial, and agricultural activities, contribute pollutants through point and non-point sources. These activities release numerous pollutants into Pearl Harbor, where sediments can act as a sink or repository for chemicals (U.S. Department of the Navy 1999). The Department of the Navy conducted a Remedial Investigation/Feasibility Study of the sediments in Pearl Harbor from March to June 2009. The results of the Remedial Investigation indicate that eight metals (antimony, cadmium, copper, lead, mercury, selenium, silver, and zinc), total high molecular weight polycyclic aromatic hydrocarbons, total PCBs, and two chlorinated pesticides (dieldrin and total endosulfan) exceed the project screening criteria (Table 3.1-3). Surface weighted-average concentrations in sediment were below project screening criteria in Middle Loch and West Loch and above project screening criteria in Southeast Loch, Bishop Point, northwest shoreline of Ford Island, Aiea Bay, shoreline of Oscar 1 and 2, and off the Waiau Power Plant (U.S. Department of the Navy 2010a). In 1998, the Hawaii Department of Health and EPA issued an advisory stating that marine life from Pearl Harbor should not be eaten (Agency for Toxic Substance and Disease Registry 2005).

3.1.2.1.2 Sediments in the California Current Large Marine Ecosystem

The composition and distribution of bottom substrates in the California Current Large Marine Ecosystem is discussed in Section 3.3, Marine Habitats. In a report on the *Southern California Bight 1998 Regional Monitoring Program*, the Southern California Coastal Water Research Project stated that sediment toxicity was most severe in port and marina areas within bays, harbors, and river mouths (Southern California Coastal Water Research Project 2003). A study conducted between 1984 and 1990 along the

California coast showed that the highest concentrations of sediment contaminants were present in the most highly urbanized areas, including chlordanes, dieldrin, DDT, polycyclic aromatic hydrocarbons, and PCBs. The highest concentrations were found in highly populated areas of Los Angeles, San Diego Bay, and San Francisco Bay (Center for Ocean Solutions 2009).

Table 3.1-3: Sediment Screening Criteria for Pearl Harbor Sediment Remedial Investigation

Parameter		Sediment Screening Criterion (mg/kg [ppm], dry weight)
Metals	Antimony	8.4
	Arsenic	27.5
	Cadmium	3.2
	Chromium	277
	Copper	214
	Lead	119
	Mercury	0.71
	Nickel	660
	Selenium	3.8
	Silver	1.8
	Zinc	330
	HMW-PAHs	35,253
	Total PCBs	92 (>2m water depth) 29 (<2m water depth)
Pesticides	Total DDT	106.6
	Dieldrin	14.4
	Total BHC	1,215
	Total Chlordane	174
	Heptachlor Epoxide	174
	Total Endosulfan	1.09
Dioxins	2,3,7,8-TCDD	0.36

Notes: mg = milligram; kg = kilogram; ppm = parts per million; HMW-PAH = high molecular weight-polycyclic aromatic hydrocarbons; PCBs = polychlorinated biphenyls; DDT = dichlorodiphenyltrichloroethane; BHC = benzene hexachloride; TCDD = tetrachlorodibenzo-p-dioxin; < = less than; > = greater than

Source: U.S. Department of the Navy 2010a

Sediment quality in the waters surrounding San Clemente Island was tested in 2006 (U.S. Department of the Navy 2006); the results for contaminants found in sediments surrounding San Clemente Island are shown in Table 3.1-4. The 10-day solid-phase amphipod bioassay tests of the sediments also indicated high survival and no substantial toxicity. The results indicate that ocean bottom sediment quality is good in that portion of the Southern California (SOCAL) Range Complex Operating Areas (OPAREAs) off San Clemente Island where training and testing activities are most concentrated.

Pacific Ocean sediments offshore of Silver Strand have above-average levels of organic loading and concentrations of some metals (aluminum, arsenic, chromium, copper, iron, manganese, and zinc), but these substances are not present at concentrations that pose a risk to public health or the environment. Traces of synthetic organic contaminants (e.g., polycyclic aromatic hydrocarbons) are occasionally

detected in sediments, but have been well below a threshold of concern (U.S. Army Corps of Engineers 2002).

Table 3.1-4: Contaminant Concentrations in Bottom Sediments Offshore San Clemente Island

Constituent	Sediment Concentration at SCI Reference Sampling Site, ppm	EPA Sediment Quality Guidelines (ERM Values), ppm
Arsenic	2.87	70
Cadmium	0.11	9.6
Chromium	8.56	370
Copper	7.48	270
Lead	2.19	218
Mercury	0.275	0.71
Nickel	4.6	51.6
Selenium	0.56	NA
Silver	0.09	3.7
Zinc	19.2	410
Polychlorinated biphenyls	ND (<0.005)	180
Phenols	ND (<0.1)	NA
Dioxins (TEQ)	0.0 - 0.028	NA

Notes: ppm = parts per million; ERM = Effects Range Median; ND = nondetectable concentration; NA = not available; TEQ = toxicity equivalency factor; SCI = San Clemente Island; EPA = United States Environmental Protection Agency; < = less than.

Sources: U.S. Department of the Navy 2006, National Oceanic and Atmospheric Administration 1999.

Past sources of sediment contamination in San Diego Bay include sewage, industrial wastes, ship discharges, urban runoff, and accidental spills, while current sources include underground dewatering, industries in the Bay, Navy installations, underwater hull cleaning, vessel antifouling paints, and urban runoff. Known contaminants in San Diego Bay include arsenic, copper, chromium, lead, cadmium, selenium, mercury, tin, manganese, silver, zinc, polycyclic aromatic hydrocarbons, petroleum hydrocarbons, PCBs, chlordane, dieldrin, and DDT (U.S. Department of the Navy 2000).

Sediments from sampling events from 1984-1990 at two sites in San Diego Bay, the 28th Street Pier site and a northern San Diego Bay site, showed concentrations of polycyclic aromatic hydrocarbons and PCBs that tended to be higher than most of the other sites sampled along the west coast (McCain et al. 2000). Recent sediment sampling in San Diego Bay near Silver Strand Training Complex (SSTC)-North indicates that—while concentrations of some contaminants are elevated above background levels—no contaminants were present at concentrations which would adversely affect marine organisms (Port of San Diego 2002). The *Ecological Assessment of San Diego Bay* (City of San Diego 2003) stated that “in comparison to other bays and harbors in the Southern California Bight...San Diego Bay has relatively low levels of widespread contamination and has considerably less contamination than in decades past.”

Sediment studies performed in 1998 and 2002 for dredging projects in San Diego Bay indicate that its sediments are substantially free of chemical contamination, compared to a reference site (Naval Oceans Systems Center 2002). Additional sediment samples were collected in December 2002 for a dredging project in San Diego Bay. Samples were collected to a depth of 44 ft. (13 m) below mean low water.

Concentrations of heavy metals in test sediments were comparable to the heavy-metal concentrations in the reference sample collected from the ocean. In general, man-made organic chemicals were either not detected in the sediment samples or were found in trace concentrations.

3.1.2.1.3 Marine Debris, Military Expended Materials, and Marine Sediments

Keller et al. (2010) surveyed marine debris collected from the seafloor at 1,347 randomly selected stations off the coasts of Washington, Oregon, and California during annual groundfish surveys in 2007 and 2008. Depth of trawling ranged from 180 to 4,200 ft. (55 to 1,280 m) and marine debris was recovered in 469 tows. Categories of marine debris collected included plastic, metal, glass, fabric and fiber, rubber, fishing, and other. Plastic and metallic debris occurred in the greatest number of hauls, followed by fabric and glass. The survey area included portions of the SOCAL Range Complex. Data about military materials as a component of the recovered materials are provided in Table 3.1-5.

Table 3.1-5: Military Materials as Components of All Materials Recovered on the West Coast, United States, 2007-2008

Category	Number of Items	Percent of Total Items Recovered	Weight	Percent of Total Weight
Plastic	29	7.4	62.3 lb. (28.3 kg)	5.8
Metal	37	6.2	926.6 lb. (420.3 kg)	42.7
Fabric, Fiber	34	13.2	51.4 lb. (23.3 kg)	6.7
Rubber	3	4.7	32.8 lb. (14.9 kg)	6.8

Notes: lb. = pound; kg = kilogram
Source: Keller et al. 2010

Military materials containing metals recovered during surveys included ammunition boxes, helmets, rocket boosters and launchers, and cannon shells (Keller et al. 2010). The authors noted that “virtually all” materials identified as military were collected off the coast of Southern California in an area where naval maneuvers are conducted.

Because of their buoyancy, many types of plastic float, and may travel thousands of miles in the ocean (U.S. Commission on Ocean Policy 2004). Many plastics remain in the water column, so additional discussion of marine debris is provided in Section 3.1.2.2.3, Marine Debris and Marine Water Quality. Although plastics are resistant to degradation, they do gradually break down into smaller particles because of exposure to sunlight (“photolysis”) and mechanical wear (Law et al. 2010). A study in 1998 collected debris from 43 coastal sites Orange County, California. Approximately 106 million items (weighing 12 metric tons) were collected, with 99 percent of items consisting of pre-production pellets, foamed plastics, and hard plastic fragments (Stevenson 2011). Thompson et al. (2004) found that microscopic particles were common in marine sediments at 18 beaches around the United Kingdom. They noted that such particles were ingested by small filter and deposit feeders, with unknown effects. The fate of plastics that sink beyond the continental shelf is largely unknown. However, analysis of debris in the center of an area near Bermuda with a high concentration of plastic debris on the surface showed no evidence of plastic as a substantial contributor to debris sinking at depths of 1,650 to 10,500 ft. (500 to 3,200 m) (Law et al. 2010). Marine microbes and fungi are known to degrade biologically produced polyesters such as polyhydroxyalkanoates, a bacterial carbon and energy source (Doi et al.

1992). Marine microbes also degrade other synthetic polymers, although at slower rates (Shah et al. 2008).

3.1.2.1.4 Climate Change and Sediments

Aspects of climate change that influence sediments include increasing ocean acidity (pH), increasing sea surface water temperatures, and increasing storm activity. Breitbarth et al. (2010) referred to seawater temperature and pH as “master variables for chemical and biological processes,” and noted that effects of changes on trace metal biogeochemistry “may be multifaceted and complex.” Under more acidic conditions, metals tend to dissociate from particles to which they are bound in sediments, become more soluble, and potentially more available.

As noted in the beginning of this section, tropical storms can substantially affect re-suspension and distribution of bottom sediments (Wren and Leonard 2005). If storm frequency and intensity increase from climate change, the additional disturbance of marine sediment may adversely impact water quality in nearshore and coastal areas. However, no consensus seems to exist as to whether there will be more tropical storms or whether those storms will be more intense. This issue is addressed in more detail in Section 3.1.2.2.3, Marine Debris and Marine Water Quality.

3.1.2.2 Water Quality

The current state of water quality in the Study Area is discussed below, from nearshore areas to the open ocean and deep sea bottom. Table 3.1-6 and Table 3.1-7 provide the water quality criteria and index for the U.S. west coast and Hawaiian Islands, respectively.

3.1.2.2.1 Water Quality in the Insular Pacific-Hawaiian Large Marine Ecosystem

Population growth is the primary cause of impacts on the coastal water quality of the Hawaiian Islands. The coastal waters of the Hawaiian Islands are affected by different kinds of marine debris, garbage, and solid wastes that deposit toxic chemicals and nutrients in the ocean. In addition to large quantities of marine debris, PCBs have been deposited in the marine environment because of urbanization (Center for Ocean Solutions 2009). Urban land use typically results in water quality contaminants such as nitrogen, phosphorous, suspended solids, sediments, pesticides, and herbicides, as well as fecal contamination. Agricultural runoff contains the same water quality contaminants as urban runoff, but has higher concentrations of pesticides, herbicides, and sediments.

A survey for the *National Coastal Condition Report III* of 50 stations across the main islands and 29 stations along the southern shore of Oahu, mostly near heavily urbanized areas, resulted in a water quality index of “good” (Figure 3.1-2; EPA 2008a). This rating was based on five indicators: concentrations of dissolved inorganic nitrogen, dissolved inorganic phosphorus, chlorophyll *a* and dissolved oxygen, and water clarity. Most of the coastal area surveyed (78 percent) was rated “good,” while 18 percent of the surveyed area was “fair” and four percent was considered “poor.” The finding of 22 percent considered either fair or poor is preliminary because some stations did not measure all five component indicators (EPA 2008a).

Table 3.1-6: Water Quality Criteria and Index, United States West Coast

Criterion	Site Criteria			Regional Criteria		
	Good	Fair	Poor	Good	Fair	Poor
Dissolved Inorganic Nitrogen	< 0.5 mg/L	0.5-1.0 mg/L	> 1.0 mg/L	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 25% of the coastal area is in poor condition.
Dissolved Inorganic Phosphorus	< 0.01 mg/L	0.01-0.1 mg/L	> 0.1 mg/L			
Water Clarity	Sites with naturally high turbidity: > 10% light at 1 meter Sites with normal turbidity: > 20% light at 1 meter Sites that support submerged aquatic vegetation: > 40% light at 1 meter	Sites with naturally high turbidity: 5- 10% light at 1 meter Sites with normal turbidity: 10-20% light at 1 meter Sites that support submerged aquatic vegetation: 20-40% light at 1 meter	Sites with naturally high turbidity: < 5% light at 1 meter Sites with normal turbidity: < 10% light at 1 meter Sites that support submerged aquatic vegetation: < 20% light at 1 meter			
Dissolved Oxygen	> 5.0 mg/L	2.0-5.0 mg/L	< 2.0 mg/L	Less than 5% of the coastal area is in poor condition and more than 50% of the coastal area is in good condition.	5% to 15% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 15% of the coastal area is in poor condition.
Chlorophyll <i>a</i>	< 5 µg/L	5-20 µg/L	> 20 µg/L	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 20% of the coastal area is in poor condition.
Water Quality Index	A maximum of one indicator is rated fair, and no indicators are rated poor.	One of the indicators is rated poor, or two or more indicators are rated fair.	Two or more of the five indicators are rated poor.			

Notes: < = less than; > = greater than; mg/L = milligram per liter; µg/L = microgram per liter

Source: EPA 2008a

Table 3.1-7: Water Quality Criteria and Index, Hawaiian Islands

Criterion	Site Criteria			Regional Criteria		
	Good	Fair	Poor	Good	Fair	Poor
Dissolved Inorganic Nitrogen	< 0.05 mg/L	0.05-0.1 mg/L	> 0.1 mg/L	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 25% of the coastal area is in poor condition.
Dissolved Inorganic Phosphorus	< 0.005 mg/L	0.005-0.01 mg/L	> 0.01 mg/L			
Water Clarity	Sites with naturally high turbidity: > 10% light at 1 meter Sites with normal turbidity: > 20% light at 1 meter Sites that support submerged aquatic vegetation: > 40% light at 1 meter	Sites with naturally high turbidity: 5- 10% light at 1 meter Sites with normal turbidity: 10-20% light at 1 meter Sites that support submerged aquatic vegetation: 20-40% light at 1 meter	Sites with naturally high turbidity: < 5% light at 1 meter Sites with normal turbidity: < 10% light at 1 meter Sites that support submerged aquatic vegetation: < 20% light at 1 meter			
Dissolved Oxygen	> 5.0 mg/L	2.0-5.0 mg/L	< 2.0 mg/L	Less than 5% of the coastal area is in poor condition and more than 50% of the coastal area is in good condition.	5% to 15% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 15% of the coastal area is in poor condition.
Chlorophyll a	< 0.5 µg/L	0.5-1.0 µg/L	> 1.0 µg/L	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 20% of the coastal area is in poor condition.
Water Quality Index	A maximum of one indicator is rated fair, and no indicators are rated poor.	One of the indicators is rated poor, or two or more indicators are rated fair.	Two or more of the five indicators are rated poor.			

Notes: <=less than; >=greater than; mg/L=milligram per liter; µg/L=microgram per liter

Source: EPA 2008a

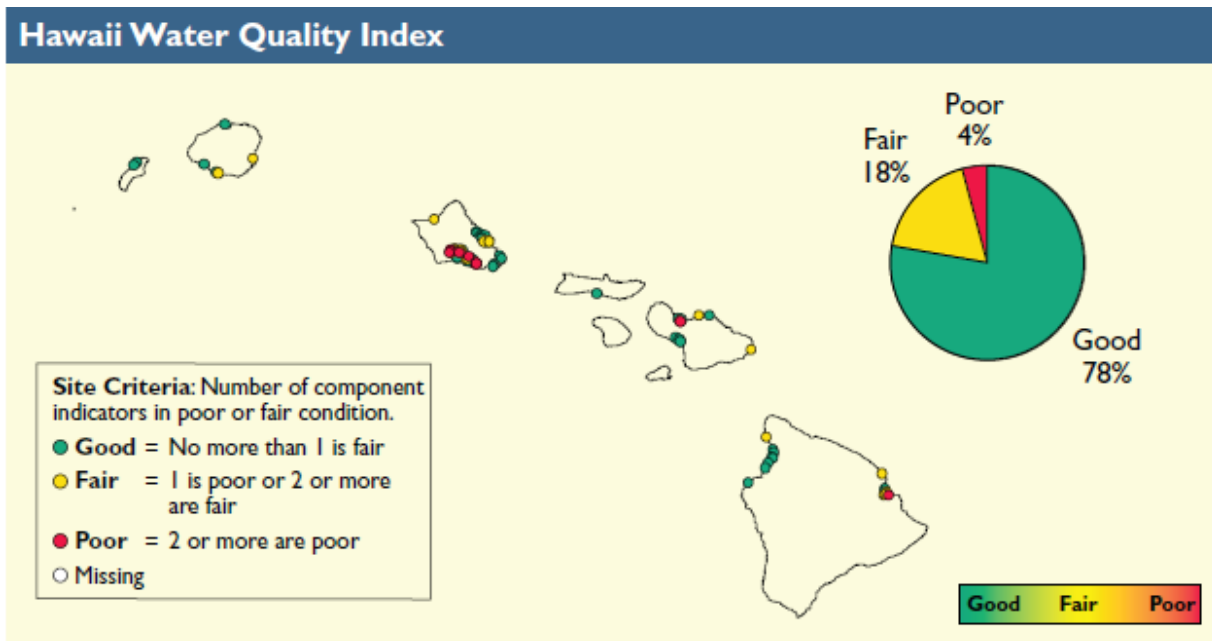


Figure 3.1-2: Water Quality Index for the Hawaiian Islands

In 2006, the Hawaii Department of Health listed 209 marine segments in the Hawaiian Islands as impaired¹ under the Clean Water Act, Section 303(d) (Hawaii Department of Health 2008). The most common pollutants of 303(d)-listed marine waters were bacteria and turbidity. Potential bacterial sources included animal wastes, soils, and human sewage. Other contaminant indicators for 303(d) listings included total nitrogen, nitrites or nitrates, phosphorous, total suspended solids, chlorophyll *a*, and ammonium (Hawaii Department of Health 2008).

Pearl Harbor is on Hawaii's Clean Water Act Section 303(d) List of Water Quality Limited Segments. The Pearl Harbor Water Quality Limited Segment includes the entire harbor and the mouths of perennial streams discharging into the harbor. Beneficial uses of Pearl Harbor include bait fish and shellfish propagation in West and East Lochs, shipping navigation and industrial water in East Loch, and water fowl habitat in Middle and West Lochs (Hawaii Department of Health 2000).

Contaminants are introduced into Pearl Harbor via point source and non-point source discharges. Surface runoff from urban, industrial, and agricultural activities carries variable levels of herbicides, pesticides, and other contaminants, in addition to natural loads of sediment, dissolved metals, and other soluble constituents (Agency for Toxic Substance and Disease Registry 2005). Water quality criteria that are frequently violated in Pearl Harbor include maximum nitrogen, phosphorous, fecal coliform, and chlorophyll *a* concentrations, and turbidity and temperature limits (Hawaii Department of Health 2000).

3.1.2.2.2 Water Quality in the California Current Large Marine Ecosystem

The offshore waters of the SOCAL Range Complex are vast. Their expanse, distance from the shore, and the mixing and transport effects of ocean currents and upwelling, combine to maintain a generally high quality of water that meets or exceeds criteria set forth by the *California Ocean Plan* (State of California 2009) and by the *National Ambient Water Quality Criteria* (EPA 2009).

¹ Impaired water bodies are those waters that do not meet water quality standards for one or more pollutants; thus, they are impaired for their designated use.

Water quality in the SOCAL Range Complex is strongly affected by human activities in heavily developed Southern California. In a report on the *Southern California Bight 1998 Regional Monitoring Program*, the Southern California Coastal Water Research Project identified urban runoff as one of the largest sources of contamination along the Southern California coast, containing bacteria, inorganic nutrients, various organic compounds, and metals (Southern California Coastal Water Research Project 2003).

Nonpoint source runoff is substantial in Southern California because most rivers are highly modified stormwater conveyance systems that are not connected to sewage treatment systems. When storm events occur, runoff plumes can become large oceanographic features that extend for many kilometers (Center for Ocean Solutions 2009). Along the Southern California coast, land-based chemical pollution, in particular PCBs and DDT, affect water quality.

Most of the marine water pollution in the SOCAL Range Complex results from municipal discharges. The oil and gas industry, however, is a source of water pollution in the northern part of the Southern California Bight. Several active oil platforms are located near the northern boundary of the SOCAL Range Complex. As offshore oil and gas activities continue in Southern California, potential pollutants may be introduced into the marine environment through oil leaks, accidental spills, discharges of formation water, drill mud, sediment, debris, and sludge, all of which degrade water quality.

Commercial, recreational, and institutional vessels also discharge water pollutants in the SOCAL Range Complex. Shipboard waste-handling procedures governing the discharge of nonhazardous waste streams have been established for commercial and Navy vessels. These categories of wastes include (a) liquids: "black water" (sewage); "grey water" (water from deck drains, showers, dishwashers, laundries, etc.); and oily wastes (oil-water mixtures) and (b) solids (garbage).

Water quality in the nearshore waters of San Clemente Island, which are affected by baseline at-sea and ashore training and testing activities, has been tested (U.S. Department of the Navy 2006). Based on *California Ocean Plan* criteria for protection of aquatic life (Table 3.1-8), concentrations of potential water pollutants are low, and have no substantial effects on marine water quality in that portion of the SOCAL Range Complex OPAREAs where training and testing activities are most concentrated.

Major contaminants found in San Diego Bay include chlorinated hydrocarbons, PCBs, toxic components of petroleum hydrocarbons, polycyclic aromatic hydrocarbons, heavy metals, and organotins such as tributyltin (U.S. Department of the Navy 1998). The sources of these compounds include effluents from non-point-source storm drain runoff (municipal and industrial); contaminants from vessel maintenance; antifouling paints (military, commercial, and private vessels); marina discharges; and residues of prior industrial discharges. These contaminants have generally been incorporated into bottom sediments in the Bay, and are periodically re-suspended in the water column when bottom sediments are disturbed by natural or human activities.

Water quality in north-central San Diego Bay is affected primarily by tidal flushing and currents. Water quality also is influenced locally by freshwater inflows. The Shelter Island Yacht Basin portion of San Diego Bay is listed as an impaired water body by the Regional Water Quality Control Board for dissolved copper pursuant to Clean Water Act Section 303(d); a Total Maximum Daily Load has been adopted to address excessive dissolved copper (Regional Water Quality Control Board 2007). Gross water quality characteristics (e.g., salinity, temperature, and dissolved oxygen) form a gradient within San Diego Bay. Waters in northern San Diego Bay are similar to ocean conditions; waters in southern San Diego Bay are

strongly affected by shallow depths, fresh water inflows, and solar insolation; waters in central San Diego Bay are intermediate in character.

Table 3.1-8: Water Pollutant Concentrations in Surface Waters at San Clemente Island

Constituent	Concentration (micrograms/liter [ppb])	
	SCI Reference Sampling Site	California Ocean Plan Objective
Antimony	0.18	1,200
Arsenic	1.19	8 ^a
Beryllium	ND (<0.005)	0.033 ^b
Cadmium	ND (<0.005)	1 ^a
Copper	0.142	3 ^a
Lead	0.228	2 ^a
Mercury	ND (<0.01)	0.04 ^a
Nickel	0.25	5 ^a
Selenium	ND (<0.01)	15 ^a
Silver	ND (<0.005)	0.7
Thallium	ND (<0.005)	2 ^b
Zinc	2.65	20 ^a
Polychlorinated biphenyls	ND (<0.005)	0.000019 ^b
Phenols	ND (<0.1)	30 ^a
Chromium, hexavalent	ND (<5.0)	2 ^a
Cyanide	ND (<1.0)	1 ^a

Notes: (a) 6-month median value; (b) 30-day arithmetic average; ppb = parts per billion; ND = nondetectable concentration; SCI = San Clemente Island; < = less than

Sources: U.S. Department of the Navy 2006; State of California 2009.

3.1.2.2.3 Marine Debris and Marine Water Quality

The National Marine Debris Monitoring Program developed three categories of marine debris for its study of the extent of man-made materials in the oceans. The three categories were land-based, ocean-based, and general (i.e., origin unspecified; Sheavly 2007). Land-based debris may be blown in on the wind, washed in with stormwater, arise from recreational use of coastal areas, or generated by extreme weather such as hurricanes. Ocean sources of marine debris include commercial shipping and fishing, private boating, offshore mining and extraction, and legal and illegal dumping at sea. Ocean current patterns, weather and tides, and proximity to urban centers, industrial and recreational areas, shipping lanes, and fishing grounds influence the types and amounts of debris that are found (Sheavly 2010).

Teuten et al. (2007) found that water-borne phenanthrene (a type of polycyclic aromatic hydrocarbon) adhered preferentially to small pieces of plastic that were ingested by a bottom-dwelling marine lugworm and incorporated into its tissue. Plastics also may transport various pollutants, whether through adsorption from seawater or from the constituents of the plastics themselves. Mato et al. (2001) noted that polypropylene resin pellets – precursors to certain manufactured plastics – collected from sites in Japan contained PCBs, dichlorodiphenyldichloroethylene (a breakdown product of DDT), and nonylphenol, a persistent organic pollutant that is a precursor to certain detergents. PCBs and DDT were adsorbed from seawater. The original source of nonylphenol is less clear; it may have come from the pellets themselves or may have been adsorbed from the seawater.

3.1.2.2.4 Climate Change and Marine Water Quality

Aspects of climate change that influence water quality include decreasing ocean pH (i.e., more acidic), increasing water temperatures, and increasing storm activity. Changes in pH outside of the normal range can make it difficult for marine organisms to maintain their shells (Fabry et al. 2008). Many of those creatures are at the base of the marine food chain, such as phytoplankton, so changes may reverberate through the ecosystem. Rising water temperatures can be detrimental to coastal ecosystems. For example, in waters that are warmer than normal, coral colonies appear to turn white (“bleaching”) because they expel symbiotic microbes (“zooxanthellae”) that give them some of their colors. These microbes are important for coral survival because they provide the coral with food and oxygen, while the coral provides shelter, nutrients, and CO₂. Rising seawater temperatures combined with decreasing ocean pH can be especially detrimental to corals (Anthony et al. 2008). Water pollution and natural disturbances (e.g., hurricanes) can inflict additional stress on coral (Hughes and Connell 1999).

3.1.3 ENVIRONMENTAL CONSEQUENCES

This section evaluates how and to what degree the training and testing activities described in Chapter 2 may impact sediment and water quality in the Study Area. Tables 2.8-1 through 2.8-5 present the baseline and proposed training and testing activity locations for each alternative (including number of events and ordnance expended). Each water quality stressor is introduced, analyzed by alternative, and analyzed for training activities and testing activities. Potential impacts could be from:

- releasing materials into the water that subsequently disperse, react with seawater, or may dissolve over time;
- depositing materials on the ocean bottom and any subsequent interactions with sediments or the accumulation of such materials over time;
- depositing materials or substances on the ocean bottom and any subsequent interaction with the water column; and
- depositing materials on the ocean bottom and any subsequent disturbance of those sediments or their resuspension in the water column.

These potential impacts may result from four stressors: (1) explosives and explosive byproducts, (2) metals, (3) chemicals other than explosives, and (4) a miscellaneous category of other materials. The term “stressor” is used because materials in these four categories may directly impact sediment and water quality by altering their physical and chemical characteristics.

The area of analysis for sediment and water quality includes estuaries, nearshore areas, and the open ocean (including the sea bottom) in the Study Area. Sediments and marine waters within territorial and nonterritorial waters along the coasts of California and the Hawaiian Islands would react similarly to military expended materials. For instance, sediment size is a major determinant of how metals behave in sediments, and sediment size would be similar at a given distance from shore. Thus, for this analysis, potential impacts on sediment and water quality from military expended materials that are deposited in sediments at any given distance from shore are assumed to be similar.

3.1.3.1 Explosives and Explosion Byproducts

3.1.3.1.1 Introduction

Explosives are complex chemical mixtures that may affect sediment and water quality through the byproducts of their detonation in water and the distribution of unconsumed explosives in water and sediments. Detonating explosives may also disturb sediments and increase turbidity. Underwater

explosions re-suspend sediments in the water column. However, these impacts are minimal because, depending on site-specific conditions of wind and tidal currents, the sediment plume eventually dissipates as particles settle to the bottom or disperse. Therefore, this issue is not considered further.

The Proposed Action involves three categories of high-explosives:

- Nitroaromatics, such as trinitrotoluene (TNT), ammonium picrate, and tetryl (methyl-2,4,6-trinitrophenyl-nitramine),
- Nitramines, such as royal demolition explosive (hexahydro-1,3,5-trinitro-1,3,5-triazine) and high melting explosive (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), and
- Nitrate esters, such as pentaerythritol-tetranitrate.

The explosives TNT, royal demolition explosive, and high melting explosive are components of bombs, missile and rocket fuels and warheads, torpedoes, sonobuoys, medium- and large-caliber munitions, and charges used in a variety of training and testing activities, such as mine countermeasure and mine neutralization (Clausen et al. 2007). Pentaerythritol-tetranitrate is most commonly used in blasting caps, detonation cord, and other initiators of explosions. Chemical stressors other than explosives are discussed in Section 3.1.3.3.

When they are used, explosives may undergo a high-order detonation, a low-order detonation, or may fail to detonate. High-order (“complete”) detonations consume 98 to 99 percent of the explosive material; the remainder is released into the environment as discrete particles. Low-order (“incomplete”) detonations consume a lower percentage of the explosive and release larger amounts of explosives into the environment. If ordnance fails to detonate, the energetic materials it contains may be released into the environment over time as its casing corrodes. In this discussion, the term “explosives” means unconsumed explosives remaining after low-order detonations and detonation failures. The term “explosion byproducts” is used to refer to the liquids and gases that remain after detonation of explosives.

Explosions that occur above or at the surface are assumed to distribute nearly all of the explosion byproducts into the air, rather than into the water, and are discussed in Section 3.2, Air Quality. This analysis concerns only those explosions that occur underwater. However, military expended materials that explode in the air or at the water surface may deposit particles of unconsumed explosives in the marine environment. These materials are addressed in the next section on unconsumed explosives.

3.1.3.1.2 Background

Under the Proposed Action, explosions would occur (1) above, at, or just beneath the water surface during training and testing activities that use bombs, medium- and large-caliber projectiles, missiles, and rockets; and (2) underwater during mine countermeasure and mine neutralization training and testing activities and from training and testing activities that use explosive sonobuoys. Mine countermeasure and neutralization activities occur beneath the surface and on or near the bottom typically in fairly shallow areas. Explosives charges for training and testing activities range in size up to 600 pounds (lb.) (270 kilograms [kg]).

Mine countermeasure and mine neutralization activities most often involve the explosive Composition 4 (C-4), which is composed of about 95 percent royal demolition explosive mixed with polyisobutylene, a plastic binding material. When it functions properly (i.e., complete detonation), 99.997 percent of the explosive is converted to inorganic compounds (U.S. Army Corps of Engineers 2003). Table 3.1-9 below lists the byproducts of underwater detonation of royal demolition explosive. Of the byproducts

identified in Table 3.1-9, nitrogen, carbon dioxide, water, carbon monoxide, ammonia, and hydrogen are natural components of seawater, and represent 98 percent of all byproducts produced by the detonation of royal demolition explosive.

Table 3.1-9: Byproducts of Underwater Detonation of Royal Demolition Explosive

Byproduct	Percent of Total, by Weight	Byproduct	Percent of Total, by Weight
Nitrogen	37.0	Propane	0.2
Carbon dioxide	24.9	Methane	0.2
Water	16.4	Hydrogen cyanide	< 0.01
Carbon monoxide	18.4	Methyl alcohol	< 0.01
Ethane	1.6	Formaldehyde	< 0.01
Ammonia	0.9	Other compounds	< 0.01
Hydrogen	0.3		

Notes: < = less than

3.1.3.1.3 Ordnance Failure and Low-Order Detonations

Table 3.1-10 provides information about the rates of failure and low-order detonations for high-explosives and other munitions (Rand Corporation 2005; U.S. Army Corps of Engineers 2007).

Table 3.1-10: Failure and Low-Order Determination Rates of Military Ordnance

Ordnance	Failure Rate (Percent)	Low-Order Detonation Rate (Percent)
Guns / artillery	4.68	0.16
Hand grenades	1.78	n/a
High-explosive ordnance	3.37	0.09
Rockets	3.84	n/a
Submunitions	8.23	n/a

3.1.3.1.4 Approach to Analysis

Most activities involving explosives and explosion byproducts would be conducted more than 3 nautical miles offshore. Out to 12 nm, these activities would be subject to federal sediment and water quality standards and guidelines. Explosives are also used in nearshore areas during shallow water and very shallow water mine countermeasure and mine neutralization activities. These activities would occur within three nautical miles of shore, and would be subject to state sediment and water quality standards and guidelines.

For explosion byproducts, "local" means the water column that is disturbed by an underwater detonation. For unconsumed explosives, "local" means the area of potential impact from explosives in a zone of sediment about 66 in. (170 centimeter [cm]) in diameter around the ordnance or unconsumed explosive where it settles on the sea floor.

3.1.3.1.4.1 State Standards and Guidelines

Table 3.1-11 below summarizes existing state standards and guidelines for sediment and water quality related to explosives and explosion byproducts

Table 3.1-11: State Water Quality Criteria for Explosives and Explosion Byproducts

State	Explosive, Explosion Byproduct	Criteria (µg/L)	Source
California	Cyanide	6-month median = 1, Daily Max = 4, Instant Max = 10	State of California 2009
	2,4-dinitrotoluene	30-day average = 2.6	
Hawaii	Cyanide	1.0 (chronic/acute)	Hawaii Department of Health 2009
	2,4-dinitrotoluene	200 (acute)	

Note: "Acute" criteria apply to a one-hour average concentration not to be exceeded more than once every three years on average. "Chronic" criteria apply to a four-day average concentration not to be exceeded more than once every three years on average.

3.1.3.1.4.2 Federal Standards and Guidelines

Table 3.1-12 summarizes the EPA criteria for explosives and explosion byproducts in saltwater (EPA 2009).

Table 3.1-12: Criteria for Explosives and Explosion Byproducts in Saltwater

Explosives, Explosion Byproducts	Criteria Maximum Concentration	Criterion Continuous Concentration
Cyanide	1 µg/L	1 µg/L

Note: µg/L = microgram per liter

"Criteria maximum concentration" is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. "Criterion continuous concentration" is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

3.1.3.1.5 Fate of Military Munitions in the Marine Environment

3.1.3.1.5.1 Explosives and Explosion Byproducts

Little data are available on the fate and degradation of unconsumed explosives in marine sediments (Zhao et al. 2004). Cruz-Urbe et al. (2007) noted that "contamination of the marine environment by munitions constituents is not well documented," and Montgomery et al. (2008) noted that there is "little published information on TNT degradation in seawater or marine sediments aside from the work of Carr and Nipper (2003)." Still, Zhao et al. (2004) noted that leaching of unconsumed explosives is considered a major source of sediment contamination in seas and waterways, and that contaminants can subsequently move from sediments and accumulate in aquatic organisms. According to Nipper et al. (2002), their studies of Puget Sound sediments demonstrate that the studied ordnance compounds were not a cause for environmental concern in the levels previously measured in marine sediments. The studied compounds included 2, 6-dinitrotoluene, tetryl, and picric acid. They remarked that the "levels of ordnance compounds that would be of concern in marine sediments have not yet been identified."

The behavior of explosives and explosion byproducts in marine environments and the extent to which those constituents have adverse impacts are influenced by a number of processes, including the ease with which the explosive dissolves in a liquid such as water (solubility), the degree to which explosives are attracted to other materials in the water (e.g., clay-sized particles and organic matter, "sorption"), and the tendency of the explosives to evaporate (volatilization). These characteristics, in turn, influence

the extent to which the material is subject to biotic (biological) and abiotic (physical and chemical) transformation and degradation (Pennington and Brannon 2002). The solubility of various explosives is provided in Table 3.1-13. In the table, higher values indicate greater solubility. For example, high melting explosive is virtually insoluble in water. Table salt, which dissolves easily in water, is included in the table for comparison.

Solubility rates are not affected by pH, but increase as temperature increases (Lynch et al. 2002). As Table 3.1-13 indicates, explosives associated with the Proposed Action dissolve slowly over time, and thus are not very mobile in marine environments (Juhasz and Naidu 2007). Nitroaromatics such as TNT do not bind to metal hydroxides, but may bind to clays, depending on the type (more so with potassium or ammonium ions but negligible for clays with sodium, calcium, magnesium, or aluminum ions). Sorption by nitroamines such as royal demolition explosive is very low (Haderlein et al. 1996).

According to Walker et al. (2006), TNT, royal demolition explosive, and high melting explosive experience rapid biological and photochemical degradation in marine systems. The authors noted that productivity in marine and estuarine systems is largely controlled by the limited availability of nitrogen. Because nitrogen is a key component of explosives, they are attractive as substrates for marine bacteria

Table 3.1-13: Water Solubility of Common Explosives and Explosive Degradation Products

Compound	Water Solubility ¹
Table salt (sodium chloride)	357,000
Ammonium perchlorate (D)	249,000
Picric acid (E)	12,820
Nitrobenzene (D)	1,900
Dinitrobenzene (E)	500
Trinitrobenzene (E)	335
dinitrotoluene (D)	160-161
TNT (E)	130
Tetryl (E)	51
Pentaerythritoltetranitrate (E)	43
Royal Demolition Explosive (E)	38
High Melting Explosive (E)	7

Notes: ¹Units are milligrams per liter (mg/L) at 20°C; E = explosive;
D = explosive degradation product.

Source: U.S. Department of the Navy 2008a

that metabolize other naturally-occurring organic matter, such as polycyclic aromatic hydrocarbons. Juhasz and Naidu (2007) also noted that microbes use explosives as sources of carbon and energy.

Carr and Nipper (2003) indicated that conversion of TNT to CO₂, methane, and nitrates in coastal sediments (a process referred to as “mineralization”) occurred at rates that were typical for naturally-occurring compounds such as phenanthrene, fluoranthene, toluene, and naphthalene. They noted that transformation of 2, 6-dinitrotoluene and picric acid by organisms in sediments is dependent on temperature and type of sediment (i.e., finer-grained). Pavlostathis and Jackson (2002) reported the uptake and metabolism of TNT by the marine microalgae *Anabaena* spp. Nipper et al. (2002) noted that enhanced degradation of 2, 6-dinitrotoluene, tetryl, and picric acid occurred in fine-grained sediments high in organic carbon. Cruz-Urbe et al (2007) noted that three species of marine macroalgae

metabolize TNT to 2-amino-4,6-dinitrotoluene and 4-amino-2, 6-dinitrotoluene, and speculate that “the ability of marine macroalgae to metabolize TNT is widespread, if not generic.”

Singh et al. (2009) indicated that biodegradation of royal demolition explosive and high melting explosive occurs with oxygen (aerobic) and without oxygen (anoxic or anaerobic), but that they were more easily degraded under anaerobic conditions. Crocker et al. (2006) indicated that the mechanisms of high melting explosive and royal demolition explosive biodegradation are similar, but that high melting explosive degrades more slowly. Singh et al. (2009) noted that royal demolition explosive and high melting explosive are biodegraded under a variety of anaerobic conditions by specific microbial species and by mixtures (“consortia”) of such species. Zhao et al. (2004) found that biodegradation of royal demolition explosive and high melting explosive occurs in cold marine sediments.

According to Singh et al. (2009), typical end products of royal demolition explosive degradation include nitrite, nitrous oxide, nitrogen, ammonia, formaldehyde, formic acid, and carbon dioxide. Crocker et al. (2006) stated that many of the primary and secondary intermediate compounds from biodegradation of royal demolition explosive and high melting explosive are unstable in water and spontaneously decompose. Thus, these explosives are degraded by a combination of biotic and abiotic reactions. Formaldehyde is subsequently metabolized to formic acid, methanol, CO₂, or methane by various microorganisms (Crocker et al. 2006).

According to Juhasz and Naidu (2007), TNT, royal demolition explosive, and high melting explosive also degrade from photolysis (exposure to light) and hydrolysis (exposure to water). The byproducts of TNT photolysis include nitrobenzenes, benzaldehydes, azoxydicarboxylic acids, and nitrophenols. The byproducts of royal demolition explosive and high melting explosive photolysis include azoxy compounds, ammonia, formaldehyde, nitrate, nitrite, nitrous oxide, and *N*-nitroso-methylenediamine (Juhasz and Naidu 2007). Walker et al. (2006) speculated that degradation of TNT “below the photic [light] zone in coastal waters and sediments may be largely controlled by metabolism by heterotrophic bacteria.” According to Monteil-Rivera et al. (2008), at the pH common in marine environments (i.e., pH of 8), there should be a “slow but significant removal” of royal demolition explosive and high melting explosive through alkaline hydrolysis. Under such conditions, and absent biodegradation, royal demolition explosive would take over 100 years to hydrolyze, while high melting explosive would require more than 2,100 years (Monteil-Rivera et al. 2008).

3.1.3.1.5.2 Unexploded Ordnance

Most studies of unexploded ordnance in marine environments have not detected explosives or have detected them in the range of parts per billion. Studies examining the impact of ordnance on marine organisms have produced mixed results. The amounts and concentrations of ordnance deposited in the areas studied, however, were far in excess of those that would occur under the Proposed Action.

Several authors have studied the impacts of unexploded ordnance in Halifax Harbor, Nova Scotia, Canada. Rodacy et al. (2000) noted that munitions explosions in 1917 and 1946 scattered ordnance across an area known as the Bedford Basin. Ordnance was both fully exposed on and partially buried in the sea floor. They reported that 34 of 59 water samples (58 percent) “produced detectable signatures” of ordnance, as did 26 of 27 sediment samples (96 percent). They also noted that marine growth was observed on most of the exposed ordnance, and that TNT metabolites were present and suspected as the result of biological decomposition. In a prior study (Durrach et al. 1998), sediments collected near unexploded, but broken, ordnance did not indicate the presence of TNT, but samples near ordnance targets that appeared intact showed trace explosives in the range of low parts per billion or high parts

per trillion. The sampling distance was 6 to 12 in. (15 to 30 cm) from the munitions. The authors expressed the opinion that, after 50 years, the contents of broken munitions had dissolved, reacted, biodegraded, or photodegraded, and that intact munitions appear to be slowly releasing their contents through corrosion pinholes or screw threads. Studies by Zhao et al. (2004) in Halifax Harbor documented the biodegradation of royal demolition explosive and high melting explosive in cold marine sediments.

Chemical and conventional munitions disposed on the ocean floor approximately 5 miles (mi.) (8.05 km) south of Pearl Harbor, Hawaii were recently studied (Hawaii Undersea Military Munitions Assessment 2010). Documents indicate that sixteen thousand 100 lb. (45 kg) mustard-filled bombs may have been disposed in this area in October-November 1944. The condition of the munitions ranged from “nearly intact to almost completely disintegrated.” The authors collected 94 sediment samples and 30 water samples from 27 stations at five locations. These samples were analyzed for chemical agents, explosives, metals (arsenic, copper, lead, and zinc), polycyclic aromatic hydrocarbons, pesticides, PCBs, phenols, and organic tin. No chemical agents or explosives were detected, and comparisons between the disposal site and reference sites showed no statistically significant differences in levels of munitions constituents, chemical agents, or metals. However, the sampling distance for this project was 3 to 6 ft. (1 to 2 m). The authors compared their sampling distance to that used by Durrach et al. (1998), that is, 6 to 12 in. (15 to 30 cm). They indicated that the project sampling distance may have been too far to detect chemical agents or explosives, and that sampling distance may be a significant factor determining whether or not munitions constituents can be detected near discarded munitions. Samples with elevated concentrations of metals relative to typical deep-sea sediments were “most likely” the result of dumping of sediments dredged from Oahu harbors.

Hoffsommer et al. (1972) analyzed seawater and ocean floor sediments and fauna for military ordnance constituents at known ocean dumping sites. The sites were located 85 mi. (136 km) west of Cape Flattery, Washington, and 172 mi. (280 km) south-southeast of Charleston, South Carolina. Samples were tested for TNT, royal demolition explosive, tetryl, and ammonium perchlorate, none of which were detected in the samples. Detection limits were in the parts-per-trillion. Walker et al. (2006) sampled seawater and sediment at two offshore underwater demolition sites where 10 lb. (4.5 kg) charges of TNT and royal demolition explosive were used. Seawater concentrations of both explosives were below their detection limits, including samples collected in the detonation plume within five minutes of the detonation.

According to Fisheries Research Services Report (1996), over one million tons of chemical and conventional munitions were disposed of at Beaufort’s Dyke, a trench in the North Channel between Scotland and Ireland. The trench is more than 30 mi. (48 km) long and 2 mi. (3 km) wide. The average density of munitions is about 2,225 tons per square mile (mi.²) (5,760 tons per square kilometer [km²]). Seabed sediment samples were obtained from 105 sites. Sampling distance from the munitions was not noted. Sediment sampling results did not find detectable concentrations of the explosives nitroglycerine, TNT, royal demolition explosive, or tetryl, and analysis of metals indicated that levels within the survey area were within the ranges reported for other Scottish coastal areas.

Nipper et al. (2002) studied the impacts of the explosives 2, 6-dinitrotoluene, tetryl, and picric acid on marine sediments in Puget Sound. They noted that the levels measured did not account for the sediment’s toxicity. Test subjects and processes included small marine crustaceans (amphipods), marine segmented worms (polychaetes), macro-algae germination and growth, and sea urchin embryo development. The authors suggested that the degradation products of the explosives rather than the

explosives themselves may be responsible. They acknowledged that the “persistence of such degradation compounds in marine environments is not known.”

An underwater explosion deposits a fraction of the chemical products of the reaction in the water in a roughly circular surface pool that moves with the current (Young and Willey 1977). In a land-based study, Pennington et al. (2006) noted that data demonstrate that explosives in the main charge of howitzer rounds, mortar rounds, and hand grenades are efficiently consumed (on average 99.997 percent or more) during live-fire operations that result in high-order detonations. The explosives not consumed during these detonations are spread over an area that would, on average, contribute 10 µg/kg (parts per billion) per detonation or less to the ground surface. However, the applicability of the study by Pennington et al. (2006) to underwater marine systems remains uncertain.

Table 3.1-14 provides (1) the amount of explosive remaining after underwater detonation of 5 and 20 lb. (9.0 kg) charges of C-4, and (2) the volume of water required to meet the marine screening value for the remaining amount of C-4. A 5-lb. (2.3 kg) block of C-4 contains 2.27 lb. (1.03 kg) of royal demolition explosive; a 20 lb. (9.1 kg) block contains 18.2 lb. (8.25 kg) of royal demolition explosive (U.S. Department of the Navy 2010b). Pennington et al. (2006) assumed that 0.02 percent of royal demolition explosive residue remained after detonation (Pennington et al. 2006). The failure rate is zero for C-4 because, during mine countermeasure and mine neutralization activities, personnel do not leave any undetonated C-4 on range at the end of training.

Table 3.1-14: Volume of Water Needed to Meet Marine Screening Value for Royal Demolition Explosive

Screening Value for Ecological Marine Surface Water	Explosive Charge, lb. (kg)			
	5 lb. (2.27 kg)		20 lb. (9.1 kg)	
	Amount of RDX Remaining after Detonation	Attenuation Needed to Meet Screening Value	Amount of RDX Remaining after Detonation	Attenuation Needed to Meet Screening Value
5,000 µg/L	0.01 ounce (oz.) (0.41 gram [g])	22 gallons (gal.) (82.6 Liters [L])	0.06 oz. (1.65 g)	87 gal. (330 L)

Notes: lb. = pound; kg = kilogram; RDX = Royal Demolition Explosive; µg/L = microgram/liter; oz. = ounce; g = gram; gal. = gallon; L = liter

The amount of pentaerythritol-tetranitrate in detonation cord associated with any underwater detonation event is low (approximately 13.4 ounces [oz.]) (380 grams [g]). Assuming five percent is not consumed in the detonation, 0.7 oz. (20 g) of pentaerythritol-tetranitrate would be present. This amount would attenuate to a level below the benchmark risk screening value for marine surface water in 8 cubic feet (ft.³) (0.22 cubic meters [m³]) of water (U.S. Department of the Navy 2010b).

3.1.3.1.6 Evaluation of Alternatives

Table 3.1-15 summarizes the types and amounts of high-explosive military expended materials proposed to be used annually under the alternatives. The types and amounts of expended materials in the table are based on the tables in Chapter 2. In most instances, explosive bombs, projectiles, missiles, and rockets detonate above the surface of the water, at the water surface, or just beneath the surface. Underwater detonations always occur during sinking exercises, mine countermeasure and mine neutralization training and testing, explosives testing, and during the use of explosive torpedoes, percussion grenades, and explosive sonobuoys.

Table 3.1-15: High-Explosive Military Expended Materials from Training and Testing Activities – All Alternatives

Type of Military Expended Material	Hawaii Range Complex			Southern California Range Complex		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
High-Explosive Bombs						
Training	110	74	74	652	166	166
Testing	0	0	0	0	0	0
Total	110	74	74	652	166	166
Medium Caliber High-Explosive Projectiles						
Training	3,100	6,640	6,640	15,000	13,920	13,920
Testing	0	0	0	2,500	15,000	16,500
Total	3,100	6,640	6,640	17,500	28,920	30,420
Large Caliber High-Explosive Projectiles						
Training	11,200	1,894	1,894	16,400	4,244	4,244
Testing	0	678	678	0	791	791
Total	11,200	2,572	2,572	16,400	5,035	5,035
High-Explosive Missiles						
Training	160	146	146	142	330	330
Testing	4	50	52	29	56	62
Total	164	196	198	171	386	392
High-Explosive Rockets						
Training	0	760	760	0	3,800	3,800
Testing	0	0	0	0	284	297
Total	0	760	760	15	4,084	4,097
Underwater Detonations						
Training	68	82	82	575	758	758
Testing	0	12	16	20	81	88
Total	68	94	98	595	839	846
High-Explosive Torpedoes						
Training	6	6	6	2	2	2
Testing	8	26	29	8	8	8
Total	14	32	35	10	10	10
Explosive Sonobuoys						
Training	0	480	480	0	120	120
Testing	314	408	500	2,652	2,760	2,892
Total	314	888	980	2,652	2,880	3,012

3.1.3.1.6.1 No Action Alternative

Under the No Action Alternative, up to 52,327 high-explosive ordnance items would be expended during training (46,772 items) and testing (5,555 items) activities in the Study Area. Within the Study Area, approximately 71 percent of high-explosive ordnance (37,425 items) would be expended in the SOCAL Range Complex, while approximately 29 percent (14,902 items) would be expended in the Hawaii Range

Complex (HRC). Numerically, medium- and large-caliber high-explosive projectiles would represent over 87 percent of high-explosive ordnance used during training and testing activities within the Study Area. Charge sizes for medium- and large-caliber projectiles range from 0.5 to 10 lb. (0.2 to 4.5 kg), in comparison to charges in missiles (2.5 to 20 lb. [1.1 to 9.1 kg]) and charges in bombs range from 250 to 1,000 lb. (113.4 to 453.6 kg).

Training Activities

Under the No Action Alternative, 46,772 high-explosive ordnance items would be expended during training activities in the Study Area. Approximately 69 percent of high-explosive ordnance (32,196 items) would be expended in the SOCAL Range Complex, with the remaining 31 percent (14,576 items) expended in HRC. No ordnance would be expended in the HSTT Transit Corridor under the No Action Alternative.

Comparison of Training Materials by Weight of Explosives

A review of training materials based on the weight of explosives provides a different perspective on the relative contribution of various items under the No Action Alternative. Table 3.1-16 depicts those categories of training materials that contribute nearly all (99 percent) of the total weight under the No Action Alternative. The total weight of explosives used during training under the No Action Alternative would be an estimated 473,200 lb. (212,900 kg).

Table 3.1-16: Comparison of Number of High-Explosive Items versus Weight of Explosives

Type of Military Expended Material	Percent of Total HE by Number	Percent of Total HE by Weight
Medium-and Large-Caliber Projectiles	97.7	58.2
Bombs	1.6	30.9
Missiles	<1.0	6.4
Underwater Detonations	<1.0	2.7
Torpedoes	<1.0	1.3

Notes: HE = high-explosive; < = less than

Under the No Action Alternative, the distribution of training materials based on the weight of explosives would be approximately 65 percent in SOCAL and 35 percent in HRC. Note: Because the contribution of testing materials to the total amount of high-explosive material is relatively small, by number and by weight, only training materials were used for the comparisons in Table 3.1-16.

Subsurface High-Order Explosions and Explosion Byproducts

Under the No Action Alternative, most training-related underwater explosions would be during mine countermeasure and neutralization training, with charges up to 60 lb. (27 kg). The impacts of explosion byproducts on sediment and water quality would be short-term, local, and negative. Chemical, physical, or biological changes in sediment or water quality would not be detectable.

Unconsumed Explosives

Under the No Action Alternative, approximately 18,200 lb. (8,190 kg) per year of residual explosives would remain from high-explosive ordnance used during training activities because of ordnance failure and low-order detonations. Approximately 69 percent (12,600 lb. [5,670 kg]) of the residual explosives would be expended in SOCAL Range Complex, with the remaining 31 percent (5,600 lb. [2,520 kg])

expended in HRC. Over 98 percent of residual explosive materials would result from ordnance failures. Ordnance failure rates are listed in Table 3.1-10. The amount of residual explosive materials is based on the rate of failure multiplied by the number of explosive ordnance and weight of explosives of each ordnance item expended during training activities.

In the event of an ordnance failure, the energetic materials it contains would remain intact. These materials would leach from the item slowly because they would have little or no direct exposure to marine waters. Small amounts of explosives may be released into sediment and into the surrounding water column as the ordnance item degrades and decomposes. Ocean currents would quickly disperse leached explosive constituents, and these constituents would not result in water toxicity.

Sinking exercises require the highest concentrations of high-explosive ordnance. During each sinking exercise, an estimated 720 high-explosive ordnance items would be expended, 97 percent of which would consist of large-caliber projectiles. Approximately 530 lb. (240 kg) of explosive materials would be released per sinking exercise from low-order detonations and ordnance failures. The sinking exercise training area is approximately 2 square nautical miles (nm²) in size. Thus, during each exercise, approximately 360 items per nm² (104 items per km²) and 265 lb. (120 kg) of explosive material per nm² (77 lb. [35 kg] of explosive material per km²) would sink to the ocean floor.

Testing Activities

An estimated 5,555 high-explosive ordnance items would be expended during testing activities in the Study Area. Over 99 percent (5,229 items) of high-explosive ordnance would be expended in the SOCAL Range Complex, with the remainder expended in HRC.

Subsurface High-Order Explosions and Explosion Byproducts

Under the No Action Alternative, most training-related underwater explosions would be during mine countermeasure and neutralization testing, with charges up to 60 lb. (27 kg). The impacts of explosion byproducts on sediment and water quality would be short-term, local, and negative. Chemical, physical, or biological changes in sediment or water quality would not be detectable.

Unconsumed Explosives

Under the No Action Alternative, approximately 690 lb. (310 kg) per year residual explosives would remain from high-explosive ordnance used during testing activities because of ordnance failure and low-order detonations. Approximately 59 percent (400 lb. [180 kg]) of the residual explosives would be expended in SOCAL Range Complex, with the remaining 41 percent (280 lb. [130 kg]) expended in HRC. Over 98 percent of explosive residues would result from ordnance failures. In the event of an ordnance failure, the energetic materials it contains would remain mostly intact. These materials would leach from the item slowly because they would have little or no direct exposure to marine waters. Small amounts of explosives may be released into sediments and into the surrounding water column as the ordnance item degrades and decomposes. Ocean currents would quickly disperse leached explosive constituents, and these constituents would not result in water toxicity.

3.1.3.1.6.2 Alternative 1

Under Alternative 1, the number of high-explosive ordnance items expended during training and testing activities would increase from 52,327 to 52,643 items, less than a one percent increase compared to the No Action Alternative. This increase would include additional high-explosive ordnance expended in the Transit Corridor (320 medium-caliber and 20 large-caliber projectiles) as part of training activities. In the Study Area, the majority of high-explosive ordnance (approximately 79 percent [41,521 items]) would be

expended in the SOCAL Range Complex, while approximately 21 percent (11,162 items) would be expended in HRC and less than one percent (340 items) would be expended in the Transit Corridor. Training activities account for about 62 percent of the high-explosive ordnance under Alternative 1.

The amount of training materials expended under Alternative 1 would be similar to the No Action Alternative and impacts would be similar to those under the No Action Alternative. Short-term impacts would arise from explosion byproducts, while long-term impacts would arise from unconsumed explosives. The majority of high-order explosions would occur at or above the surface of the ocean, and would have no impacts on sediments and minimal impacts on water quality.

Training Activities

Under Alternative 1, the amount of high-explosive ordnance used for training activities would decrease from 46,772 to 32,582 items. Approximately 69 percent (22,582 items) of high-explosive ordnance would be expended in the SOCAL Range Complex, with about 30 percent (10,000 items) expended in HRC and one percent (340 items) in the HSTT Transit Corridor. Numerically, medium- and large-caliber high-explosive projectiles would represent over 81 percent of high-explosive ordnance used during training and testing activities within the Study Area.

Comparison of Training Materials by Weight of Explosives

A review of training materials based on the weight of explosives provides a different perspective on the relative contribution of various items under the No Action Alternative. Table 3.1-17 depicts those categories of training materials that contribute nearly all (99 percent) of the total weight under the No Action Alternative. Under Alternative 1, the total weight of explosives used during training would decrease from an estimated 473,200 lb. (212,900 kg) to an estimated 229,200 lb. (103,100 kg).

Table 3.1-17: Comparison of Number of High-Explosive Items versus Weight of Explosives

Type of Military Expended Material	Percent of Total HE by Number	Percent of Total HE by Weight
Medium-and Large-Caliber Projectiles	81.9	38.4
Missiles	1.5	20.8
Bombs	<1.0	20.1
Rockets	14.0	9.5
Underwater Detonations	<1.0	7.3
Torpedoes	<1.0	3.5

Notes: HE = high-explosive; < = less than

Under Alternative 1, the distribution of training materials based on weight of explosives would be approximately 62 percent in SOCAL, 38 percent in HRC, and less than one percent in the HSTT Transit Corridor. Note: Because the contribution of testing materials to the total amount of high-explosive material is relatively small, by number and by weight, only training materials were used for the comparisons in Table 3.1-17.

Subsurface High-Order Explosions and Explosion Byproducts

Under Alternative 1, nearly all training-related underwater explosions would be from mine countermeasures and neutralization training and explosive sonobuoys. Explosive sonobuoys use small charges approximately 4.2 lb. (1.9 kg). The impacts of explosion byproducts on sediment and water

quality would be short-term, local, and negative. Chemical, physical, or biological changes in sediment or water quality would not be detectable.

Unconsumed Explosives

Although Alternative 1 would increase the number of training activities, the amount of explosives released during training would decrease compared to the No Action Alternative. The estimated amounts of residual explosives from ordnance failures and low-order detonations during training activities would decrease to 8,360 lb. (3,760 kg) per year because of a decrease in the use of high-explosive bombs and large-caliber projectiles for training. The majority of residual explosives (65 percent) (5,390 lb. [2,430 kg]) would be expended in SOCAL Range Complex and 35 percent (2,930 lb. [1,320 kg]) would be expended in HRC. In addition, a minimal amount of residual explosive material about 40 lb. (18 kg) would be expended in the HSTT Transit Corridor during training activities. The deposition of explosive materials from sinking exercises would be the same as under the No Action Alternative. Therefore, because the amount of explosives released during training would decrease under Alternative 1, impacts would be less than under the No Action Alternative.

Testing Activities

Under Alternative 1, the number of high-explosive ordnance used for testing activities would increase from 5,555 to 20,061 items, a substantial increase compared to the No Action Alternative. Within the Study Area, approximately 94 percent (18,939 items) of high-explosive ordnance would be expended in the SOCAL Range Complex, with the remaining 6 percent (1,162 items) expended in HRC.

Subsurface High-Order Explosions and Explosion Byproducts

Under Alternative 1, underwater explosions associated with testing activities would be from underwater detonations, explosive sonobuoys, and torpedo testing. Despite the increase in underwater explosions, the impacts of explosion byproducts on sediment and water quality would be short-term, local, and negative. Chemical, physical, or biological changes in sediment or water quality would not be detectable.

Unconsumed Explosives

Under Alternative 1, approximately 2,640 lb. (1,190 kg) per year of residual explosives would remain from high-explosive ordnance used during testing activities because of ordnance failure and low-order detonations. Approximately 51 percent (1,350 lb. [610 kg]) and 49 percent (1,290 lb. [580 kg]) of residual explosives would be expended in HRC and SOCAL Range Complex, respectively. Over 98 percent of explosive residues would result from ordnance failures. In the event of an ordnance failure, the energetic materials it contains would remain mostly intact.

3.1.3.1.6.3 Alternative 2

Under Alternative 2, the number of high-explosive ordnance items expended during training and testing activities would increase from 52,327 to 54,391 items, a 4-percent increase compared to the No Action Alternative. Within the Study Area, the majority of high-explosive ordnance (approximately 79 percent [43,176 items]) would be expended in the SOCAL Range Complex, while approximately 21 percent (11,259 items) would be expended in HRC and less than one percent (340 items) would be expended in the HSTT Transit Corridor. Numerically, medium- and large-caliber high-explosive projectiles would represent over 82 percent of high-explosive ordnance used during training and testing activities within the Study Area.

Training Activities

Under Alternative 2, the number of training activities and amounts of high-explosive ordnance would be the same as under Alternative 1. Therefore, the impacts of underwater explosions and explosives residues would be the same as under Alternative 1.

Testing Activities

Under Alternative 2, high-explosive ordnance used for testing activities would increase from 5,555 to 21,809 items, a substantial increase compared to the No Action Alternative. Within the Study Area, approximately 94 percent (20,594 items) of high-explosive ordnance would be expended in the SOCAL Range Complex, with the remaining 6 percent (1,259 items) expended in HRC.

Subsurface High-Order Explosions and Explosion Byproducts

Under Alternative 2, the number of underwater explosions during testing activities would increase slightly over the number under the No Action Alternative. Underwater explosions would be from underwater detonations, explosive sonobuoys, and torpedo testing. Despite the increase in underwater explosions during testing activities, the impacts of explosion byproducts on sediment and water quality would be short-term, local, and negative.

Unconsumed Explosives

Under Alternative 2, approximately 2,790 lb. (1,260 kg) per year of residual explosives would remain from high-explosive ordnance used during testing activities because of ordnance failure and low-order detonations. Approximately 52 percent (1,460 lb. [660 kg]) of residual explosives would be expended in HRC, while 48 percent (1,330 lb. [600 kg]) would be expended in SOCAL Range Complex. Over 98 percent of explosives residues would result from ordnance failures. In the event of an ordnance failure, the energetic materials it contains would remain mostly intact.

3.1.3.1.6.4 Summary and Conclusions for Explosives and Explosion Byproducts

Over 98 percent of residual explosive materials would result from ordnance failures. In the event of an ordnance failure, the energetic materials it contained would remain mostly intact. The explosive materials in failed ordnance items would leach slowly because they would have little or no direct exposure to marine waters. Residual explosive materials deposited in sediments would be limited to small areas surrounding the ordnance item. Ocean currents would quickly disperse leached explosive materials in the water column, and residual explosive materials would not result in water toxicity.

Short-term impacts arise from explosion byproducts; long-term impacts arise from unconsumed explosives. The majority of high-order explosions occur at or above the surface of the ocean, and would have no impacts on sediments and minimal impacts on water quality. Chemical, physical, or biological changes in sediment or water quality would not be detectable. Neither state nor federal standards or guidelines would be violated

The impacts of unconsumed explosives on water and sediment quality would be long-term, local, and negative. Chemical, physical, or biological changes in sediment or water quality would be measurable, but neither state nor federal standards or guidelines would be violated. This conclusion about the level of impact is based on (1) most of the explosives would be consumed during detonation; (2) the frequency of low-order detonations would be low, and therefore the frequency of releases of explosives would be low; (3) the amounts of explosives used would be small relative to the area within which they would be distributed; and (4) the constituents of explosives would be subject to physical, chemical, and

biological processes that would render the materials harmless or otherwise disperse them to undetectable levels.

3.1.3.2 Metals

3.1.3.2.1 Introduction

Many metals occur naturally in seawater, and several are necessary for marine organisms and ecosystems to function properly, such as iron, zinc, copper, and manganese. Other metals have adverse impacts on sediment and water quality (e.g., cadmium, chromium, lead, and mercury), but zinc, copper, and manganese may also be harmful to plants and animals at high concentrations.

Metals are introduced into seawater and sediments by the Proposed Action. These materials represent parts or the whole of vessels, manned and unmanned aircraft, ordnance (bombs, projectiles, missiles, and torpedoes), sonobuoys, batteries, electronic components, and anti-corrosion compounds coating the exterior surfaces of some munitions. Because of the physical and chemical reactions that occur with metals in marine systems (e.g., precipitation), metals often concentrate in sediments. Thus, metal contaminants in sediments are a greater issue than metals in the water column.

Military expended materials such as steel bomb bodies or fins, missile casings, small arms projectiles, and naval gun projectiles may contain small percentages (less than one percent by weight) of lead, manganese, phosphorus, sulfur, copper, nickel, tungsten, chromium, molybdenum, vanadium, boron, selenium, columbium, or titanium. Small-caliber projectiles are composed of steel with small amounts of aluminum and copper and brass casings that are 70 percent copper and 30 percent zinc. Medium- and large-caliber projectiles are composed of steel, brass, copper, tungsten, and other metals. The 20-mm cannon shells used in close-in weapons systems are composed mostly of tungsten alloy. Some projectiles have lead cores (U.S. Department of the Navy 2008b). Torpedo guidance wire is composed of copper and cadmium coated with plastic (U.S. Department of the Navy 2008a). Sonobuoy components include metal housing, batteries and battery electrodes, lead solder, copper wire, and lead used for ballast. Thermal batteries in sonobuoys are contained in a hermetically-sealed and welded stainless steel case that is 0.03 to 0.1 in. (0.07 to 0.25 cm) thick and resistant to the battery electrolytes (Naval Facilities Engineering Command 1993). Rockets are usually composed of steel and steel alloys, although composite cases made of glass, carbon, or Kevlar fiber are also used (Missile Technology Control Regime 1996).

Non-explosive practice munitions consist of ammunition and components that contain no explosive material, and may include (1) ammunition and components that have had all explosive material removed and replaced with non-explosive material, (2) empty ammunition or components, and (3) ammunition or components that were manufactured with non-explosive material in place of all explosive material. These practice munitions vary in size from 25 to 500 lb. (11 kg to 230 kg), and can be built to simulate different explosive capabilities. Some non-explosive practice munitions may also contain unburned propellant (e.g., rockets), and some may contain spotting charges or signal cartridges for locating the point of impact (e.g., smoke charges for daylight spotting or flash charges for night spotting) (U.S. Department of the Navy 2010b). Non-explosive bombs – also called “practice” or “bomb dummy units” – are composed mainly of iron and steel casings filled with sand, concrete, or vermiculite. These materials are similar to those used to construct artificial reefs. Non-explosive bombs are configured to have the same weight, size, center of gravity, and ballistics as live bombs (U.S. Department of the Navy 2006). Practice bombs do not contain the energetic materials found in live bombs.

Decommissioned vessels used as targets for sinking exercises are selected from a list of U.S. Navy-approved vessels that have been cleaned or remediated in accordance with EPA guidelines. By rule, vessel-sinking exercises must be conducted at least 50 nm offshore and in water at least 6,000 ft. (1,828.8 m) deep (40 C.F.R. 229.2). The EPA considers the contaminant levels released during the sinking of a target to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 U.S.C. 1341, et seq.).

3.1.3.2.2 Approach to Analysis

Most activities involving military expended materials with metal components would be conducted more than 3 nm offshore in each range complex or test range. Activities in these areas would be subject to federal sediment and water quality standards and guidelines. For metals, “local” means the zone of sediment about 0.4 in. (1.02 cm) surrounding the metal where it comes to rest.

3.1.3.2.2.1 State Standards and Guidelines

Table 3.1-18 summarizes the state water quality standards and guidelines for metals in California and Hawaii waters.

Table 3.1-18: Water Quality Criteria for Metals

State	Metal	Acute (µg/L [ppb])	Chronic (µg/L [ppb])
California	Cadmium	Daily Max = 32, Instant Max = 80	6-month median = 8
	Chromium	Daily Max = 8, Instant Max = 20	6-month median = 2
	Copper	Daily Max = 12, Instant Max = 30	6-month median = 3
	Lead	Daily Max = 8, Instant Max = 20	6-month median = 2
	Mercury	Daily Max = 0.16, Instant Max = 0.4	6-month median = 0.04
	Nickel	Daily Max = 2.8, Instant Max = 7	6-month median = 0.7
	Silver	Daily Max = 0.16, Instant Max = 0.4	6-month median = 0.04
	Zinc	Daily Max = 80, Instant Max = 200	6-month median = 20
Hawaii	Cadmium	43	9.3
	Chromium	1,100	50
	Copper	2.9	2.9
	Lead	140	5.6
	Mercury	2.1	0.025
	Nickel	75	8.3
	Silver	2.3	NA
	Zinc	95	86

Notes: N/A = no value is available; µg/L = microgram per liter; ppb = parts per billion
Sources: State of California 2009; Hawaii Department of Health 2009

3.1.3.2.2.2 Federal Standards and Guidelines

Table 3.1-19 summarizes the EPA “threshold values” for metals in marine waters (EPA 2009). “Acute toxicity” means an adverse response to a substance observed in 96 hours or less (e.g., mortality, disorientation, or immobilization). “Chronic toxicity” means the lowest concentration of a substance that causes an observable effect (e.g., reduced growth, lower reproduction, or mortality). This effect occurs over a relatively long period, such as one-tenth of the life span of the species. A 28-day test period is used for small fish test species (EPA 1991).

3.1.3.2.3 Impacts of Metals

The discussion below summarizes studies that investigated the impacts of metals in military expended materials on the marine environment.

Table 3.1-19: Federal Threshold Values for Exposure to Selected Metals in Saltwater

Metal	Criteria (µg/L [ppb])	
	Acute (1-hour exposure)	Chronic (4-day mean exposure)
Cadmium	40	8.8
Chromium	1,000	50
Copper	4.8	3.1
Lead	210	8.1
Lithium ¹	6,000	N/A
Mercury	1.8	0.94
Nickel	74	8.2
Silver	1.9	N/A
Zinc	90	81

Notes: N/A = no value is available; µg/L = microgram per liter; ppb = parts per billion. (1) No threshold value established by U.S. Environmental Protection Agency. Value shown is from Kszos et al. (2003).

Source: EPA 1991

In general, three things happen to materials that come to rest on the ocean floor: (1) they lodge in sediments where there is little or no oxygen below 4 in. (10.2 cm), (2) they remain on the ocean floor and begin to react with seawater, or (3) they remain on the ocean floor and become encrusted by marine organisms. As a result, rates of deterioration depend on the metal or metal alloy and the conditions in the immediate marine and benthic environment. If buried deep in ocean sediments, materials tend to decompose at much lower rates than when exposed to seawater (Ankley 1996). With the exception of torpedo guidance wires and sonobuoy parts, sediment burial appears to be the fate of most ordnance used in marine warfare (Canadian Forces Maritime Experimental and Test Ranges 2005).

When metals are exposed to seawater, they begin to slowly corrode, a process that creates a layer of corroded material between the seawater and uncorroded metal. This layer of corrosion removes the metal from direct exposure to the corrosiveness of seawater, a process that further slows movement of the metals into the adjacent sediments and water column. This is particularly true of aluminum. Elevated levels of metals in sediments would be restricted to a small zone around the metal, and any release to the overlying water column would be diluted. In a similar fashion, as materials become covered by marine life, the direct exposure of the material to seawater decreases and the rate of corrosion decreases. Dispersal of these materials in the water column is controlled by physical mixing and diffusion, both of which tend to vary with time and location. The analysis of metals in marine systems begins with a review of studies involving metals used in military training and testing activities that may be introduced into the marine environment.

In one study, the water was sampled for lead, manganese, nickel, vanadium, and zinc at a shallow bombing range in Pamlico Sound (state waters of North Carolina) immediately following a training event with non-explosive practice bombs. All water quality parameters tested, except nickel, were within the state limits. The nickel concentration was significantly higher than the state criterion, although the

concentration did not differ significantly from the control site located outside the bombing range. The results suggest that bombing activities were not responsible for the elevated nickel concentrations (U.S. Department of the Navy 2010b). A recent study conducted by the U.S. Marine Corps sampled sediment and water quality for 26 different constituents related to munitions at several U.S. Marine Corps water-based training ranges. Metals included lead and magnesium. These areas also were used for bombing practice. No munitions constituents were detected above screening values used at the U.S. Marine Corps water ranges (U.S. Department of the Navy 2010b).

A study by Pait et al. (2010) of previous Navy training areas at Vieques, Puerto Rico, found generally low concentrations of metals in marine sediments. Areas in which live ammunition and loaded weapons were used (“live-fire areas”) were included in the analysis. Table 3.1-20 compares the sediment concentrations of several metals from those naval training areas with sediment screening levels established by the National Oceanic and Atmospheric Administration (Buchman 2008).

As shown in Table 3.1-20, average sediment concentrations of the metals evaluated, except for copper, were below both the threshold and probable effects levels. The average copper concentration was above the threshold effect level, but below the probable effect level. For other elements: (1) the mean sediment concentration of arsenic at Vieques was 4.37 micrograms per gram ($\mu\text{g/g}$), and the highest concentration was 15.4 $\mu\text{g/g}$. Both values were below the sediment quality guidelines examined, and (2) the mean sediment concentration of manganese in sediment was 301 $\mu\text{g/g}$, and the highest concentration was 967 $\mu\text{g/g}$ (Pait et al. 2010). The National Oceanic and Atmospheric Administration did not report threshold or probable effects levels for manganese.

Table 3.1-20: Concentrations of and Screening Levels for Selected Metals in Marine Sediments, Vieques, Puerto Rico

Metal	Sediment Concentration ($\mu\text{g/g}$)			Sediment Guidelines – National Oceanic and Atmospheric Administration ($\mu\text{g/g}$)	
	Minimum	Maximum	Average	Threshold Effect Level	Probable Effect Level
Cadmium	0	1.92	0.15	0.68	4.21
Chromium	0	178	22.5	52.3	160
Copper	0	103	25.9	18.7	390
Lead	0	17.6	5.42	30.24	112
Mercury	N/R	0.112	0.019	130	700
Nickel	N/R	38.3	7.80	15.9	42.8
Zinc	N/R	130	34.4	124	271

Notes: N/R = not reported; $\mu\text{g/g}$ = micrograms per gram

The impacts of lead and lithium were studied at the Canadian Forces Maritime Experimental and Test Ranges near Nanoose Bay, British Columbia, Canada (Canadian Forces Maritime Experimental and Test Ranges 2005). These materials are common to Expendable Mobile Anti-Submarine Warfare Training Targets, acoustic device countermeasures, sonobuoys, and torpedoes. The study noted that lead is a naturally-occurring metal in the environment, and that typical concentrations of lead in seawater in the test range were between 0.01 and 0.06 parts per million (ppm), and from 4 to 16 ppm in sediments. Cores of marine sediments in the test range show a steady increase in lead concentration from the bottom of the core to a depth of approximately 8 in. (20.3 cm). This depth corresponds to the late 1970s

and early 1980s, and the lead contamination was attributed to atmospheric deposition of lead from gasoline additives. The sediment cores showed a general reduction in lead concentration to the present time, coincident with the phasing out of lead in gasoline by the mid-1980s. The study also noted that other training ranges have shown minimal impacts of lead ballasts because they are usually buried deep in marine sediments where they are not biologically available. The study concluded that the lead ballasts would not adversely impact marine organisms because of the low probability of mobilization of lead.

A study by the Navy examined the impacts of materials from activated seawater batteries in sonobuoys that freely dissolve in the water column (e.g., lead, silver, and copper ions), as well as nickel-plated steel housing, lead solder, copper wire, and lead shot used for sonobuoy ballast (Naval Facilities Engineering Command 1993). The study concluded that constituents released by saltwater batteries as well as the decomposition of other sonobuoy components did not exceed state or federal standards, and that the reaction products are short-lived in seawater.

3.1.3.2.3.1 Lead

Lead is used as ballast in torpedoes, in batteries in torpedoes and sonobuoys, and in various munitions. Lead is nearly insoluble in water, particularly at the near-neutral pH levels of seawater. While some dissolution of lead could occur, such releases into the water column would be small and would be diluted (U.S. Department of the Navy 2006).

Several studies have evaluated the potential impacts of batteries expended in seawater (Naval Facilities Engineering Command 1993; Borener and Maugham 1998; Canadian Forces Maritime Experimental and Test Ranges 2005; U.S. Coast Guard 1994). Sediment was sampled adjacent to and near fixed navigation sites where batteries are used, and analyzed for all metal constituents in the batteries. Results indicated that metals were either below or consistent with background levels or were below National Oceanic and Atmospheric Administration sediment screening levels (Buchman 2008), “reportable quantities” under the Comprehensive Environmental Response, Compensation, and Liability Act §103(a), or EPA toxicity criteria (EPA 2008b).

A sonobuoy battery experiment employed lead (II) chloride batteries in a 17 gal. (64 L) seawater bath for eight hours (Naval Facilities Engineering Command 1993). Under these conditions, the dilution assumptions are conservative relative to normal ocean bottom conditions. The concentration released from the battery was diluted to 200 µg/L (200 parts per billion [ppb]) in two seconds, which is less than the acute criteria of 210 µg/L (210 ppb), a criteria applied as a 24-hour mean. Considering each milliliter as a discrete parcel, dilution by a current traveling at 2 in. per second (5.1 cm per second) would dilute the lead released from the battery to 200 µg/L (200 ppb) in two seconds, which is less than the acute criteria of 210 µg/L (210 ppb), a criteria applied as a one-hour mean. Assuming the exponential factor of two dilutions, the concentration is less than the chronic limit (8.1 µg/L [8.1 ppb]) in seven seconds. The calculated rate of leaching will decrease as the concentration of lead in the battery decreases.

Lead (II) chloride tends to dissolve more readily than either silver chloride or copper thiocyanate, this assures that the potential impacts of batteries employing silver chloride or copper thiocyanate are substantially lower than those of the lead (II) chloride battery. The copper thiocyanate battery also could release cyanide, a material often toxic to the marine environment. However, thiocyanate is tightly bound and can form a salt or bind to bottom sediments. Therefore, the risk from thiocyanate is low (U.S. Department of the Navy 2008a). The peak concentration of copper released by a copper thiocyanate seawater battery was calculated to be 0.015 µg/L (0.015 ppb) (Naval Facilities Engineering Command 1993), which is substantially lower than EPA acute and chronic toxicity criteria.

3.1.3.2.3.2 Tungsten and Tungsten Alloys

Because of environmental concerns about lead, tungsten has been used to replace lead in munitions (Defense Science Board 2003). Tungsten was chosen because it was considered to be non-reactive in the environment under normal circumstances. However, concerns have arisen lately about that assessment. Adverse health consequences arise with inhalation, and movement of tungsten into groundwater is an issue. However, no drinking water standard exists for tungsten and it is not listed as a carcinogen (EPA 2008b). Neither inhalation nor groundwater are issues relative to sediment and water quality.

The natural concentration of tungsten reported in seawater is about 0.1 µg/L (Agency for Toxic Substances and Disease Registry 2005). It arises naturally from weathering of tungsten-rich deposits and from underwater hydrothermal vents; elevated levels in marine sediments from natural sources have been reported. Industrial processes also release tungsten into the environment (Koutsospyros et al. 2006). In water, tungsten can exist in several different forms depending on pH, and it has a strong tendency to form complexes with various oxides and with organic matter. The rate at which tungsten dissolves or dissociates increases as the pH decreases below 7.0 (pH of seawater is normally between 7.5 and 8.4). The speed of the process also depends on the metal with which tungsten is alloyed. For instance, iron tends to enhance the dissolution of tungsten, while cobalt slows the process (Agency for Toxic Substances and Disease Registry 2005). Tungsten is a component of metabolic enzymes in various microbes (Kletzin and Adams 1996). Much is known about the physical and chemical properties of tungsten. Less is known about the behavior of the various complexes that tungsten forms, making predictions about its behavior in the environment difficult. For instance, it is not known whether the organic complexes that tungsten forms affect its bioavailability (Koutsospyros et al. 2006).

3.1.3.2.3.3 Lithium

Silver chloride, lithium, or lithium iron disulfide thermal batteries are used to power subsurface units of sonobuoys. Lithium iron disulfide thermal batteries are used in the some types of sonobuoys. Lithium-sulfur batteries typically contain lithium sulfur dioxide and lithium bromide, but may also contain lithium carbon monofluoroxide, lithium manganese dioxide, sulfur dioxide, and acenitrile (a cyanide compound). During battery operation, the lithium reacts with the sulfur dioxide to form lithium dithionite. Thermal batteries are contained in a hermetically-sealed and welded stainless steel case that is 0.03 to 0.1 in. (0.07 to 0.3 cm) thick and resistant to the battery electrolytes.

Lithium always occurs as a stable mineral or salt, such as lithium chloride or lithium bromide (Kszos et al. 2003). Lithium is naturally present in seawater at 180 µg/L, and its incorporation into clay minerals is a major process in its removal from solution (Stoffyn-Egli and Machenzie 1984). Kszos et al. (2003) demonstrated that sodium ions in saltwater mitigate the toxicity of lithium to sensitive aquatic species. Fathead minnows (*Pimephales promelas*) and the water flea (*Ceriodaphnia dubia*) were unaffected by lithium concentrations as high as 6 mg/L (6 ppm) in the presence of tolerated concentrations of sodium. Therefore, in the marine environment, where sodium concentrations are at least an order of magnitude higher than tolerance limits for the tested freshwater species, lithium would be essentially nontoxic.

Canadian Forces Maritime Experimental and Test Ranges (2005) reported that 99 percent of the lithium in a sonobuoy battery would be released into the environment over 55 years. The release will result in a dissolved lithium concentration of 83 mg/L (83 ppm) near the breach in the sonobuoy housing. At a distance of 0.2 in. (0.5 cm) from the breach, the concentration of lithium will be about 15 mg/L (15 ppm), or 10 percent of typical seawater lithium values (150 ppm); thus it would be difficult to measure the change in the seawater concentration of lithium resulting from lithium leaking out of the battery (Canadian Forces Maritime Experimental and Test Ranges 2005). Cores of marine sediments collected in

the Canadian Forces Maritime Experimental and Test Ranges near Nanoose Bay, British Columbia, Canada, showed fairly consistent lithium concentrations with depth, indicating little change in lithium deposition with time. Compared with lithium concentrations measured outside of the range, the report concluded that “it is difficult to demonstrate an environmental impact of lithium caused by (test range activities)” (Canadian Forces Maritime Experimental and Test Ranges 2005).

3.1.3.2.3.4 Metals in Non-Explosive Practice Munitions

On the ocean bottom, non-explosive practice munitions and fragments are exposed to seawater or lodge in sediments. Once settled, metal components slowly corrode in seawater. Over time, natural encrustation of exposed surfaces occurs and reduces the rate of corrosion. Elemental aluminum in seawater tends to be converted by hydrolysis to aluminum hydroxide, which is relatively insoluble, and scavenged by particulates and transported to the bottom sediments (Monterey Bay Research Institute 2010). Practice bombs are made of materials similar to those used to construct artificial reefs. The steel and iron, though durable, corrode over time, with no noticeable environmental impacts (U.S. Department of the Navy 2006).

3.1.3.2.3.5 Metals in Vessels Used as Targets

Target vessels are only used during sinking exercises. The metal structure of a target vessel can be a suitable substrate for the development of hardbottom marine habitat. Hard reef materials such as rock, concrete, and steel become encrusted with a variety of marine life. Certain bait fish school around sunken ships, and open water (“pelagic”) species use these structures as sources of prey (Carberry 2008). Properly prepared and strategically sited artificial reefs can enhance fish habitat and provide more access to quality fishing grounds (EPA 2006).

3.1.3.2.4 Evaluation of Alternatives

Tables 3.0-63, 3.0-64, and 3.0-64 (Section 3.0, Introduction) summarize the types and amounts of military expended materials with metal components for all alternatives.

3.1.3.2.4.1 No Action Alternative

Under the No Action Alternative, 1,495,428 military items with metal components would be expended throughout the Study Area during training and testing activities. Approximately 86 percent (1,279,024 items) of military expended materials would be expended in the SOCAL Range Complex, with the remaining 14 percent (216,404 items) expended in HRC. Small-caliber and medium-caliber projectiles would account for the highest percentages of military expended material by number (66 percent and 27 percent, respectively). Metal components on the sea floor could be exposed to seawater or, more likely, be buried in sea floor sediments. These metals would slowly corrode over years or decades and release small amounts of metals and metal compounds to adjacent sediments and waters.

Training Activities

Approximately 1,496,802 military items with metals components would be expended during training activities under the No Action Alternative. The majority of these materials (approximately 86 percent [1,262,298 items]) would be expended in SOCAL Range Complex, with the remaining 14 percent (214,755 items) expended in HRC.

Comparison of Training Materials by Weight. A review of training materials based on weight provides a different perspective on the relative contribution of various items under the No Action Alternative. For instance, although small-caliber projectiles comprise 65.6 percent of the total number of items, small-caliber projectiles represent less than one percent of the total weight. Table 3.1-21 depicts those

categories of materials that contribute nearly all of the total weight of training items with metal components under the No Action Alternative. Under the No Action Alternative, training activities would expend approximately 221,000 lb. (99,450 kg) of potentially toxic metals. Approximately 54 percent (118,760 lb. [53,440 kg]) and 46 percent (102,230 lb. [46,000 kg]) of potentially toxic metals (i.e., cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc) would be expended in HRC and SOCAL Range Complex, respectively.

Table 3.1-21: Comparison of Training Materials with Metal Components – No Action Alternative

Type of Military Expended Material	Percent of Total by Number	Percent of Total by Weight
Sonobuoys	2.8	56.4
Torpedo Accessories	<1.0	22.4
Large- and Medium-Caliber Projectiles	30.0	15.9
Bombs	<1.0	3.7
Missiles	<1.0	1.1
Small-Caliber Projectiles	65.6	<1.0

Notes: < = less than

Because the contribution of testing materials to the total amount of materials with metal components is relatively small, by number and by weight, only training materials were used for comparisons in Table 3.1-21. Surface vessels used as targets would also contribute a large amount of metal weight. Under the No Action Alternative, eight target vessels would be proposed for sinking exercises during training activities. However, the number and types of vessels used as targets would depend on their availability and, therefore, cannot be specified. A Navy vessel used as a target would weigh between 5,000 and 10,000 tons (4,536,000 and 9,072,000 kg).

Testing Activities

Approximately 19,749 military expended materials containing potentially toxic metals would be expended in the Study Area during testing activities. Numerically, the majority of expended materials would be deposited in the SOCAL Range Complex (88 percent [17,384 items]), with the remaining 12 percent (2,365 items) deposited in HRC. Under the No Action Alternative, testing activities would expend approximately 55,200 lb. (24,900 kg) of potentially toxic metals. Within the Study Area, approximately 70 percent (38,600 lb. [17,400 kg]) would be expended in SOCAL Range Complex and 30 percent (16,600 lb [7,500 kg]) would be expended in HRC.

Summary of Impacts from Metals

Metals with potential toxicity would be incorporated with benign metals (i.e., steel) in military expended materials. Metal components settling on the sea floor would be exposed to seawater or, more likely, would be gradually buried in sea floor sediments. These metals would slowly corrode over years or decades, and would release small amounts of metal compounds to adjacent sediments and waters.

The potential impacts of metal components from training and testing activities on sediment and water quality would be long-term, local, and negative. However, because of slow corrosion rates and prevailing ocean currents, chemical, physical, and biological changes in sediment or water quality would not be detectable beyond the vicinity of the corroding metals. This conclusion is based on: (1) most of the metals are benign, and those of potential concern are a small percentage of those munitions; (2) metals

released through corrosion would be diluted by currents or bound up and sequestered in adjacent sediments; (3) impacts would be limited to a small area around the expended material; (4) the areas within which metal components would be distributed would be large; and (5) most of the metals would be small-caliber projectiles. Neither state nor federal standards or guidelines would be violated.

3.1.3.2.4.2 Alternative 1

Under Alternative 1, the number of military items with metal components expended during training and testing activities would increase from 1,496,802 to 3,945,911, a 160-percent increase compared to the No Action Alternative. Approximately 80 percent (3,154,891 items) of military expended materials would be expended in the SOCAL Range Complex, with 18 percent (700,010 items) expended in HRC and two percent (91,010 items) expended in the Transit Corridor. Numerically, projectiles would represent 95 percent of these materials, with small-caliber projectiles making up 77 percent of all military expended materials with metal components.

Training Activities

Approximately 3,798,582 military items with metals components would be expended during training activities under Alternative 1. The majority of these materials (approximately 80 percent [3,052,365 items]) would be expended in SOCAL Range Complex, with 18 percent (655,207 items) expended in HRC and 2 percent (91,010 items) expended in the Transit Corridor.

Comparison of Training Materials by Weight. A review of training materials based on weight provides a different perspective on the relative contribution of various items under Alternative 1. For instance, although small-caliber projectiles comprise 80.7 percent of the total number of items, small-caliber projectiles represent less than 1 percent of the total weight. Table 3.1-22 depicts those categories of materials that contribute nearly all of the total weight of training items with metal components under Alternative 1. Under Alternative 1, the amount of potentially toxic metals expended during training activities would be approximately 242,200 lb. (109,000 kg). Approximately 52 percent (126,400 lb. [56,900 kg]) of potentially toxic metals would be expended in the SOCAL Range Complex and 47 percent (114,400 lb. [51,500 kg]) would be expended in HRC. In addition, about 1 percent of metals (about 1,400 lb. [630 kg]) would be expended in the Transit Corridor during training activities.

Table 3.1-22: Comparison of Training Materials with Metal Components – Alternative 1

Type of Military Expended Material	Percent of Total by Number	Percent of Total by Weight
Sonobuoys	1.4	63.5
Torpedo Accessories	<1.0	25.0
Large- and Medium-Caliber Projectiles	17.7	4.9
Bombs	<1.0	3.7
Missiles	<1.0	1.7
Rockets	<1.0	<1.0
Small-Caliber Projectiles	80.7	<1.0

Notes: < = less than.

Surface vessels used as targets would also contribute a large amount of metal weight. Under Alternative 1, eight surface vessels would be proposed for sinking exercises during training activities. However, the

number and types of vessels used as targets would depend on their availability and, therefore, cannot be specified. A Navy vessel used as a target would weigh between 5,000 and 10,000 tons (4,536,000 and 9,072,000 kg).

Testing Activities

During testing activities, approximately 147,329 military items with potentially toxic metals would be expended in the Study Area under Alternative 1. Numerically, the majority of expended materials would be deposited in the SOCAL Range Complex (70 percent [102,526 items]), with the remaining 30 percent (44,803 items) deposited in HRC. Under Alternative 1, the amount of potentially toxic metals expended during testing activities would be more than under the No Action Alternative. Approximately 102,300 lb. (46,000 kg) of potentially toxic metals would be expended, compared to 55,200 lb. (24,900 kg) under the No Action Alternative. Within the Study Area, approximately 56 percent (60,300 lb. [27,100 kg]) would be expended in SOCAL Range Complex and 44 percent (42,000 lb. [18,900 kg]) would be expended in HRC.

Summary of Impacts from Metals

Although the amount of expended materials associated with training and testing under Alternative 1 would represent a notable increase over the No Action Alternative, impacts are judged to be similar to the No Action Alternative for the reasons enumerated under the No Action Alternative. Metal components would come to rest on the sea floor exposed to seawater when resting on the bottom or, more likely, buried in sea floor sediments. These metals would slowly corrode over years or decades and release small amounts of metals and metal compounds to adjacent sediments and waters. Potential impacts on sediments and water quality would be long-term, local, and negative. Chemical, physical, or biological changes to sediments or water quality would be measurable, but neither state nor federal standards or guidelines would be violated.

3.1.3.2.4.3 Alternative 2

Under Alternative 1, the number of military items with metal components expended during training and testing activities would increase from 1,496,802 to 3,957,635, a 160-percent increase compared to the No Action Alternative. Approximately 80 percent (3,164,134 items) of military expended materials would be expended in the SOCAL Range Complex, with 18 percent (702,491 items) expended in HRC and two percent (91,010 items) expended in the Transit Corridor.

Training Activities

Under Alternative 2, the number of training activities and amounts of ordnance used would be the same as under Alternative 1. Therefore, metals in the military expended materials would have the same environmental impacts as under Alternative 1.

Testing Activities

During testing activities, approximately 159,053 military items with potentially toxic metals would be expended in the Study Area under Alternative 2. Numerically, the majority of expended materials would be deposited in the SOCAL Range Complex (70 percent [111,769 items]), with the remaining 30 percent (47,284 items) deposited in HRC. Under Alternative 2, the amount of potentially toxic metals, by weight, would be approximately 127,500 lb. (57,400 kg). Within the Study Area, approximately 57 percent (72,800 lb. [32,800 kg]) would be expended in SOCAL Range Complex and 43 percent (54,600 lb. [24,600 kg]) would be expended in HRC.

Summary of Impacts from Metals

Although the amount of materials with metal components associated with training and testing activities under Alternative 2 would represent a notable increase, the increase is similar to Alternative 1 and the impacts are judged to be similar to the No Action Alternative. Metal components would come to rest on the sea floor exposed to seawater when resting on the bottom or, more likely, buried in sea floor sediments. These metals would slowly corrode over years or decades and release small amounts of metals and metal compounds to adjacent sediments and waters. Potential impacts on sediments and water quality would be long-term, local, and negative. Chemical, physical, or biological changes in sediment or water quality would be measurable but neither state nor federal standards or guidelines would be violated.

3.1.3.2.4.4 Summary and Conclusions for Metals

Corrosion and biological processes (e.g., colonization by marine organisms) would reduce exposure of military expended materials to seawater, decreasing the rate of leaching. Most leached metals would bind to sediments and other organic matter. Sediments near military expended materials would contain some metals, but their concentrations would not be at harmful levels because of the bottom substrate composition. Metals in batteries are readily soluble, which would result in faster releases of metals if batteries are exposed to seawater once they are expended. Batteries are sealed, however, and the exterior metal casing can become encrusted by marine organisms or coated by corrosion. Batteries continue to operate until most of their metals are consumed. Any leached metals would be present in seawater and sediments at low concentrations, and would behave similarly to leached metals from other military expended materials.

3.1.3.3 Chemicals Other than Explosives

3.1.3.3.1 Introduction

Under the Proposed Action, chemicals other than explosives are associated with the following military expended materials: (1) solid-fuel propellants in missiles and rockets, (2) Otto Fuel II torpedo propellant and combustion byproducts, (3) PCBs in target vessels used during sinking exercises, (4) other chemicals associated with ordnance, and (5) chemicals that simulate chemical warfare agents, referred to as “chemical simulants.”

Hazardous air pollutants from explosives and explosion byproducts are discussed in Section 3.2, Air Quality. Explosives and explosion byproducts are discussed in Section 3.1.3.1. Fuels onboard manned aircraft and vessels are not reviewed, nor are fuel-loading activities, onboard operations, or maintenance activities reviewed.

3.1.3.3.2 Missile and Rocket Propellant – Solid Fuel

The largest chemical constituent of missiles is solid propellant. Solid propellant contains both the fuel and the oxidizer, a source of oxygen needed for combustion. A Standard Missile-1 typically contains 150 lb. (68.04 kg) of solid propellant (U.S. Department of the Navy 2008b). Ammonium perchlorate is an oxidizing agent used in most modern solid-propellant formulas. It normally accounts for 50 to 85 percent of the propellant by weight. Ammonium dinitramide may also be used as an oxidizing agent. Aluminum powder as a fuel additive makes up five to 21 percent by weight of solid propellant; it is added to increase missile range and payload capacity. The high-explosives high melting explosive (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) and royal demolition explosive (hexahydro-1,3,5-trinitro-1,3,5-triazine) may be added, although they usually comprise less than 30 percent of the propellant weight (Missile Technology Control Regime 1996).

The most common substance used as binding material for solid propellants is hydroxyl-terminated polybutadiene. Other binding materials include carboxyl-terminated polybutadiene and polybutadiene-acrylic acid-acrylonitrile. These materials also burn as fuels and contribute to missile thrust. Other materials found in solid-fuel propellants include curing agents and catalysts such as triphenyl bismuth, nitrate esters and nitrated plasticizers - liquid explosives added to increase the engine burn rate, and n-hexyl carborane and carboranyl methyl propionate to increase propellant performance.

Double-base propellant is a solid fuel that is a mixture of fuels and small particulate oxidizers. Like other solid propellants, the most commonly used fuel component of these propellants is ammonium perchlorate. High melting explosive and royal demolition explosive may be added to improve performance, and the most common binder is hydroxyl-terminated polybutadiene. In addition to the binders listed in the preceding paragraph, polybutadiene-acrylic acid polymer, elastomeric polyesters, polyethers, and nitrocellulose plasticized with nitroglycerine or other nitrate esters may be used. To reduce decomposition of propellant, 2-nitrodiphenylamine and N-methyl-4-nitroaniline may be added (Missile Technology Control Regime 1996).

3.1.3.3.3 Torpedo Propellant – Otto Fuel II and Combustion Byproducts

The MK 48 torpedo weighs roughly 3,700 lb. (1,680 kg) and uses Otto Fuel II as a liquid propellant. Otto Fuel II is composed of propylene glycol dinitrate and nitro-diphenylamine (76 percent), dibutyl sebacate (23 percent) and 2-nitrodiphenylamine as a stabilizer (2 percent). Combustion byproducts of Otto Fuel II include nitrous oxides, carbon monoxide, CO₂, hydrogen, nitrogen, methane, ammonia, and hydrogen cyanide. During normal venting of excess pressure or upon failure of the torpedo's buoyancy bag, the following constituents are discharged – carbon dioxide, water, hydrogen, nitrogen, carbon monoxide, methane, ammonia, hydrochloric acid, hydrogen cyanide, formaldehyde, potassium chloride, ferrous oxide, potassium hydroxide, and potassium carbonate (U.S. Department of the Navy 1996a,b).

3.1.3.3.4 Polychlorinated Biphenyls in Target Vessels

Target vessels are only used during sinking exercises. PCBs are mixtures of up to 209 individual chlorinated compounds that are related chemicals of the same elemental group, also known as congeners. They were used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment. Manufacture of PCBs stopped in the United States in 1977 (Agency for Toxic Substances and Disease Registry 2000). Marine sources include runoff from agricultural and urban areas and atmospheric deposition from industrial areas (Kalmaz and Kalmaz 1979). PCBs do not readily degrade in the environment, and tend to persist for many years. They can easily move between air, water, and soil, although in aquatic systems, they tend to adhere to fine-grained sediments, organic matter, and marine debris. PCBs have a variety of effects on aquatic organisms, including disrupting endocrine systems. PCBs persist in the tissues of animals at the bottom of the food chain. Consumers of those species accumulate PCBs to levels that may be many times higher than their concentrations in water. Microbial breakdown of PCBs (dechlorination) has been documented in estuarine and marine sediments (Agency for Toxic Substances and Disease Registry 2000).

PCBs are a concern because they are present in certain solid materials (e.g., insulation, wires, felts, and rubber gaskets) on vessels used as targets for sinking exercises. These vessels are selected from a list of Navy-approved vessels that have been cleaned in accordance with EPA guidelines (EPA 1999). By rule, a sinking exercise must be conducted at least 50 nm offshore and in water at least 6,000 ft. (1,828.8 m) deep (40 C.F.R. 229.2).

The EPA estimates that as much as 100 lb. (45.4 kg) of PCBs remain onboard sunken target vessels. The EPA considers the contaminant levels released during the sinking of a target to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 U.S.C. 1341, et seq.) (EPA 1999). Based on these considerations, PCBs will not be considered further.

3.1.3.3.5 Other Chemicals Associated with Ordnance

Table 3.1-23 lists ordnance constituents remaining after low-order detonations and in unconsumed explosives. These constituents are in addition to the explosives contained in the ordnance.

Lead azide, titanium compounds, perchlorates, barium chromate, and fulminate of mercury are not natural constituents of seawater. Lead oxide is a rare, naturally occurring mineral. It is one of several lead compounds that form films on lead objects in the marine environment (Agency for Toxic Substances and Disease Registry 2007). Metals are discussed in more detail in Section 3.1.3.2.

3.1.3.3.6 Chemical Simulants

Chemical simulants are used as substitutes for chemical warfare agents during the testing of equipment intended to detect chemical warfare agents. Two common simulants are glacial acetic acid, used to simulate blistering agents, and triethyl phosphate, used to simulate nerve agents.

Table 3.1-23: Ordnance Constituents in Residues of Low-Order Detonations and in Unconsumed Explosives

Ordnance Component	Constituent
Pyrotechnics Tracers Spotting Charges	Barium chromate Potassium perchlorate Chlorides Phosphorus Titanium compounds
Oxidizers	Lead (II) oxide
Delay Elements	Barium chromate Potassium perchlorate Lead chromate
Fuses	Potassium perchlorate
Detonators	Fulminate of mercury Potassium perchlorate
Primers	Lead azide

Glacial acetic acid is a strong concentration of acetic acid, a clear, colorless liquid with a strong vinegar-like odor (U.S. Department of the Navy 2004). Vinegar is five percent acetic acid. Acetic acid occurs throughout nature as a normal metabolite of both plants and animals. It is also used for manufacturing aspirin, vitamins, antibiotics, plastics, dyes, insecticides, photographic chemicals, and rubber. Direct exposure to high concentrations of glacial acetic acid can cause severe irritation and damage to the mouth, throat, and stomach if ingested or inhaled, and can burn skin and eyes on contact.

Biodegradation in water is rapid, and a large number of biological screening studies have demonstrated that acetic acid biodegrades readily under both aerobic and anaerobic conditions and, therefore, does not bioaccumulate. If released into water, acetic acid is not expected, based on aquatic adsorption studies, to adsorb to suspended solids and sediment. Glacial acetic acid is listed on the chemical substance inventory of the Toxic Substances Control Act (15 U.S.C. 2601, et seq.), but is not further regulated under the Act. It is not listed as a hazardous waste under the Resource Conservation and

Recovery Act (42 U.S.C. 6901, et seq.), and does not have a toxic chemical release reporting requirement under the Emergency Planning and Community Right-to-Know Act (42 U.S.C. 11001, et seq.). The federal Occupational Safety and Health Administration does not list glacial acetic acid as a hazardous chemical (U.S. Department of the Navy 2004).

Triethyl phosphate is regulated by the federal Food and Drug Administration as an adhesive for packaging, holding, or transporting food (U.S. Department of the Navy 2004). It is also used in the manufacture of plastics, flame retardant, and other chemicals (Organization for Economic Cooperation and Development no date). Its half-life under environmental conditions is between five and ten years (Organization for Economic Cooperation and Development no date). Triethyl phosphate is also a common component of insecticides, and is known to adversely affect marine organisms. Most triethyl phosphate is conveyed into marine waters in runoff from agricultural areas during the spring and summer growing seasons (Böttger et al. 2001). Triethyl phosphate is not listed on the Toxic Substance Control Act's Health and Safety Reporting List, nor is it listed as a hazardous waste under the Resource Conservation and Recovery Act or as a hazardous substance under the Comprehensive Environmental Response, Compensation, and Liability Act (42 U.S.C. 9601, et seq.) (U.S. Department of the Navy 2004).

During prior tests, between one percent and seven percent of these simulants did not vaporize, and the airborne and water column concentrations were one to two orders of magnitude lower than human health and ecological toxicity standards. Releases during those tests involved 10 gal. (37.9 kg) of each simulant; each stimulant was released 20 times. The standards used were established by the National Institute for Occupational Safety and Health. The eight-hour exposure standard for glacial acetic acid is $8.8 \times 10^{-5} \text{ kg/m}^3$, and the corresponding standard for triethyl phosphate is $2.5 \times 10^{-5} \text{ kg/m}^3$. Surface deposition modeling indicates that, four minutes after release, the concentration of glacial acetic acid would be 10^{-6} kg/m^2 over an area of 0.4 km^2 (0.2 mi.^2). For triethyl phosphate, the corresponding concentration would be 10^{-5} kg/m^2 over an area of 0.003 km^2 (0.0012 mi.^2) (U.S. Department of the Navy 2004).

Prior environmental evaluations of simulant testing concluded that there would be no significant environmental impacts (U.S. Department of the Navy 2004). Therefore, glacial acetic acid and triethyl phosphate would not have adverse impacts and will not be considered further.

3.1.3.3.7 Approach to Analysis

Activities involving the chemicals discussed above would be subject to state and federal sediment and water quality standards and guidelines; however, no state or federal sediment or water quality standards or guidelines exist that apply specifically to the chemicals discussed above. The areas within each range complex represent the region within which the chemicals discussed would be distributed. For properly functioning expended materials, the term "local" means the volume of water that a self-propelled subsurface training or testing device passes through. In these situations, water quality would be impacted by combustion byproducts. For lost or malfunctioning expended training items, the term "local" means a small zone around non-combusted propellant in sediments, perhaps a centimeter or two, and a smaller area if directly exposed to seawater.

3.1.3.3.8 Impacts of Chemicals

The following sections discuss the potential impacts on sediment and water quality of solid-fuel propellants from missiles and rockets, Otto Fuel II torpedo propellant, and combustion byproducts.

3.1.3.3.8.1 Solid-Fuel Propellants

Missiles and rockets typically consume 99 to 100 percent of their propellant when they function properly (U.S. Department of the Navy 2008b). The failure rate of rockets is 3.8 percent (Rand Corporation 2005; U.S. Army Corps of Engineers 2007). The remaining solid propellant fragments (i.e., one percent or less of the initial propellant weight) sink to the ocean floor and undergo physical and chemical changes in contact with sediments and seawater. Tests show that water penetrates about 0.06 in. (0.15 cm) into the propellant during the first 24 hours of immersion, and that fragments slowly release ammonium and perchlorate ions (Fournier and Brady 2005). These ions would disperse into the surrounding seawater, so local concentrations would be low. For example, a standard missile with 150 lb. (68.04 kg) of solid propellant would generate less than 1.5 lb. (0.6 kg) of propellant residue after completing its flight. If all the propellant deposited on the ocean floor were in the form of 4 in. (10.2 cm) cubes, about 0.42 percent of the propellant would be wetted during the first 24 hours of immersion. If all of the ammonium perchlorate leached out of the wetted propellant, then approximately 0.01 lb. (0.005 kg) of perchlorate would enter the surrounding seawater (U.S. Department of the Navy 2008b). This leach rate would decrease over time as the concentration of perchlorate in the propellant declined. The aluminum in the binder would be converted to aluminum oxide by seawater.

Perchlorate

Ammonium perchlorate accounts for 50 to 85 percent of solid propellant by weight (Missile Technology Control Regime 1996). Perchlorates are highly soluble and stable in water. According to the Agency for Toxic Substances and Disease Registry (2008), perchlorate “does not readily bind to soil particles or to organic matter, and does not readily form ionic complexes with other materials in solution.” Because of these characteristics, perchlorate is highly mobile in soils and does not readily leave solution through chemical precipitation. Thus, perchlorate could affect sediment and water quality because of its persistence in the environment.

Natural sources of perchlorate include Chilean caliche ore (EPA 2008c) and ozone oxidation of atmospheric chlorine (Petrisor and Wells 2008). Martinelango (2006) stated that perchlorate was present in seawater at levels ranging from less than 0.07 µg/L to 0.34 µg/L (0.07 to 0.34 ppb). Studies indicate that it may accumulate in living organisms, such as fish and plants (Agency for Toxic Substances and Disease Registry 2008). Toxicity in plants and microbes is thought to be because of adverse impacts on metabolic enzymes (van Wijk and Hutchinson 1995). Research by Martinelango (2006) found that perchlorate can concentrate in marine algae from 200 to 5,000 times, depending on the species. Chaudhuri et al. (2002) noted that several species of microbes can metabolize chlorate and perchlorate. The end product is chloride. Logan et al. (2001) used sediment samples from a variety of marine and saline environments to demonstrate that microbial perchlorate reduction can occur in saline solutions greater than three percent. Seawater salinity is about 3.5 percent. The organism responsible for the perchlorate reduction was not identified in the study. However, Okeke et al. (2002) identified three species of halophilic (“salt-loving”) bacteria that biodegrade perchlorate. The EPA has established a drinking water standard for perchlorate, but no standards or guidelines have been established for perchlorate in marine systems.

Polyesters

Regarding other solid-fuel components, marine microbes and fungi are known to degrade biologically produced polyesters, such as polyhydroxyalkanoates, a bacterial carbon and energy source (Doi et al. 1992). These organisms also can degrade other synthetic polymers, although at lower rates (Shah et al. 2008). The chemical structure of natural rubber is similar to that of polybutadiene (Tsuchii and Tokiwa 2006). Thus, although no specific studies were located that documented biodegradation of

polybutadiene in marine ecosystems, the prospects seem likely based on the findings of researchers such as Tsuchii and Tokiwa (2006).

Nitriles

Nitriles are cyanide-containing organic compounds that are both natural and man-made. Several species of marine bacteria can metabolize acrylonitrile (Brandao and Bull 2003). The productivity of marine ecosystems is often limited by available nitrogen (Vitousek and Howarth 1991), so biodegradation of nitrate esters and nitrated plasticizers in the marine environment seems likely.

3.1.3.3.8.2 Otto Fuel II and Combustion Byproducts

Microbial degradation of the main components of Otto Fuel II (propylene glycol dinitrate and nitro-diphenylamine) has been demonstrated (Sun et al. 1996; Walker and Kaplan 1992). Although these studies did not involve marine microbes, other studies have demonstrated that marine bacteria in anaerobic sediments were able to degrade 2-nitrodiphenylamine (Drzyzga and Blotevogel 1997; Powell et al. 1998). According to the Agency for Toxic Substances and Disease Registry (1995), 2-nitrodiphenylamine tends to bind to sediments. The agency indicated that dibutyl sebacate “is readily degraded by environmental bacteria and fungi” (Agency for Toxic Substances and Disease Registry 1995).

Combustion byproducts of Otto Fuel II would be released into the ocean where they would dissolve, dissociate, or be dispersed and diluted in the water column. Except for hydrogen cyanide, combustion byproducts are not a concern (U.S. Department of the Navy 1996a,b) for the reasons listed below.

- Most Otto Fuel II combustion products, such as carbon dioxide, nitrogen, methane, and ammonia, occur naturally in seawater.
- Several of the combustion products are bioactive. Nitrogen is converted into nitrogen compounds through nitrogen fixation by certain cyanobacteria, providing nitrogen sources and essential micronutrients for marine phytoplankton. Carbon dioxide and methane are integral parts of the carbon cycle in the oceans, and are taken up by many marine organisms.
- Carbon monoxide and hydrogen have low solubility in seawater and excess gases bubble to the surface.
- Trace amounts of nitrogen oxides may be present, but they are usually below detectable limits. Nitrogen oxides in low concentrations are not harmful to marine organisms, and are a micronutrient source of nitrogen for aquatic plant life.
- Ammonia can be toxic to marine organisms in high concentrations, but releases from the combustion of Otto Fuel II are quickly diluted to negligible concentrations. Ammonia is present in exhaust from Otto Fuel II at estimated concentrations of 10 parts per billion (U.S. Department of the Navy 2007).

Hydrogen cyanide does not normally occur in seawater. Major releases of cyanide to water are from metal-finishing industries, iron and steel mills, and organic chemical industries (EPA 1981). At high concentrations, cyanide can pose a risk to both humans and marine biota. Compared to recommendations of the EPA of 1.0 µg/L (1.0 ppb) (EPA 2010), hydrogen cyanide released from MK 48 torpedoes would result in ambient concentrations ranging from 140 to 150 parts per billion (U.S. Department of the Navy 1996b), well above the level recommended levels. However, because hydrogen cyanide is soluble in seawater, it would be diluted to less than 1 µg/L (1.0 ppb) at a distance of 18 ft. (5.5 m) from the center of the torpedo’s path when first discharged. Additional dilution would occur thereafter.

Approximately 30,000 exercise tests of the MK 48 torpedo have been conducted over the last 25 years. Most of these launches have been on U.S. Navy test ranges where there have been no reports of harmful impacts on water quality from Otto Fuel II or its combustion products. Furthermore, Navy studies conducted at torpedo test ranges that have lower flushing rates than the open ocean did not detect residual Otto Fuel II in the marine environment (U.S. Department of the Navy 1996a,b).

3.1.3.3.8.3 Operational Failure – Torpedoes, Missiles, and Rockets

Some materials are recovered after use, such as torpedoes. However, sometimes these recoverable items are lost or they fail to perform correctly. For instance, the failure rate of rockets is 3.8 percent (Rand Corporation 2005; U.S. Army Corps of Engineers 2007). Corrosion of munitions in the marine environment is discussed in more detail in Section 3.1.3.2.

3.1.3.3.9 Evaluation of Alternatives

Table 3.1-24 summarizes the types and amounts of military expended materials that contain chemicals other than explosives for all alternatives. The numbers represent amounts expended annually for each type of material under each alternative. The types and amounts of expended materials in the table were drawn from the tables in Chapter 2.

3.1.3.3.9.1 No Action Alternative

Under the No Action Alternative, chemicals other than explosives would be used in an estimated 3,008 expended military items. Over 78 percent of these materials would be expended during training activities. Numerically, torpedoes, which contain OTTO Fuel II, would account for 46 percent of military expended materials with chemicals other than explosives.

Training Activities

Under the No Action Alternative, chemicals other than explosives would be used in 2,364 ordnance items. Torpedoes represent 40 percent of these items. Within the Study Area, the number of items containing chemicals other than explosives expended during training activities would be similar between HRC and SOCAL Range Complex (1,126 items and 1,238 items, respectively). All practice torpedoes would be recovered after training activities, which would reduce the exposure of Otto Fuel II to the marine environment. Impacts of chemicals from unrecovered military expended materials on sediment and water quality would be short-term, local, and negligible with properly functioning materials and long-term, local, and negative with lost or malfunctioning items.

For properly functioning ordnance items, chemical, physical, or biological changes in sediment or water quality would not be detectable. Impacts would be minimal for the following reasons: (1) the size of the area in which expended materials would be distributed is large; (2) most propellant combustion byproducts are benign, while those of concern would be diluted to below detectable levels within a short time; (3) most propellants are consumed during normal operations; (4) the failure rate is low for such expended materials; and (5) most of the constituents of concern are biodegradable by various marine organisms or by physical and chemical processes common in marine ecosystems.

Table 3.1-24: Military Expended Materials with Chemical Components – All Alternatives

Type of Military Expended Material and Chemical Component	Hawaii Range Complex			Southern California Range Complex			HSTT Transit Corridor		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
Missiles (solid fuel propellants)									
Training	220	210	210	168	360	360	0	0	0
Testing	8	122	126	103	198	214	0	0	0
Total	228	332	336	271	558	574	0	0	0
Rockets (solid fuel propellant)									
Training	0	760	760	0	3,800	3,800	0	0	0
Testing	0	0	0	15	980	1,078	0	0	0
Total	0	760	760	15	4,780	4,878	0	0	0
Torpedoes (OTTO Fuel II)									
Training	536	631	631	400	511	511	0	0	0
Testing	194	408	620	268	468	648	0	0	0
Total	730	1,039	1,251	668	979	1,159	0	0	0
Expendable Subsurface Targets (OTTO Fuel II)									
Training	370	405	405	670	550	550	0	10	10
Testing	32	165	177	24	225	243	0	0	0
Total	402	570	582	694	775	793	0	10	10

Notes: HSTT = Hawaii-Southern California Training and Testing

For properly functioning items, chemical, physical, or biological changes in sediment or water quality would not be detectable. Impacts would be minimal for the following reasons: (1) the size of the area in which expended materials would be distributed is large; (2) most propellant combustion byproducts are benign, while those of concern would be diluted to below detectable levels within a short period; (3) most propellants are consumed during normal operations; (4) the failure rate is low for such expended materials; and (5) most of the constituents of concern are biodegradable by various marine organisms or by physical and chemical processes common in marine ecosystems.

Testing Activities

Under the No Action Alternative, chemicals other than explosives would be used in 644 ordnance items during testing activities. Within the Study Area, approximately 64 percent (410 items) would be expended in SOCAL Range Complex during testing activities, with the remaining 36 percent (244 items) expended in HRC. Torpedoes represent 72 percent of these materials. All practice torpedoes would be recovered after testing activities, which would reduce the exposure of Otto Fuel II to the marine environment. Since chemicals other than explosives used during testing activities would be similar to those expended during training activities, impacts would be similar to training activities under No Action Alternative for the reasons enumerated above. Potential impacts on sediment and water quality of chemicals other than explosives from properly functioning ordnance would be short-term, local, and negative. Potential impacts on sediment and water quality of chemicals other than explosives from lost or malfunctioning ordnance would be long-term, local, and negative. In both cases, chemical, physical, or biological changes in sediment or water quality would not be detectable.

3.1.3.3.9.2 Alternative 1

Under Alternative 1, the number expended military items using chemicals other than explosives would increase from 3,008 to 9,803 (250 percent increase) compared to the No Action Alternative. Of those materials, rockets would account for 57 percent of the military expended materials, compared to less than 1 percent under the No Action. Torpedoes, which would be recovered following training and testing activities, would still account for 20 percent of military expended materials under Alternative 1.

Training Activities

Under Alternative 1, chemicals other than explosives would be used in 7,227 ordnance items. Within the Study Area, approximately 72 percent (5,221 items) would be expended in SOCAL Range Complex and 28 percent (2,006 items) would be expended in HRC. In addition, 10 expendable subsurface targets would be expended in the HSTT Transit Corridor. The increased number of items compared to the No Action Alternative (200-percent increase) would be from the introduction of rockets used during training activities. If rockets function properly, nearly all propellant would be consumed during operation. Torpedoes would represent 13 percent of ordnance items with chemicals. All practice torpedoes would be recovered after training activities.

Although these changes would be a notable increase compared to the No Action Alternative, impacts would be similar to the No Action Alternative for the reasons enumerated above. Potential impacts on sediment and water quality of chemicals other than explosives from properly functioning ordnance would be short-term, local, and negative. Potential impacts on sediment and water quality of chemicals other than explosives from lost or malfunctioning ordnance would be long-term, local, and negative. In both cases, chemical, physical, or biological changes in sediment or water quality would not be detectable.

Testing Activities

Under Alternative 1, chemicals other than explosives would be used in 2,566 ordnance items, a 300-percent increase compared to the No Action Alternative. Within the Study Area, approximately 73 percent (1,871 items) would be expended in SOCAL Range Complex during testing activities, with the remaining 27 percent (695 items) expended in HRC. Torpedoes represent 34 percent of these materials. All practice torpedoes would be recovered after testing activities, which would reduce the exposure of Otto Fuel II to the marine environment. Although these changes would be a notable increase compared to the No Action Alternative, impacts would be similar to the No Action Alternative for the reasons enumerated above. Potential impacts on sediment and water quality of chemicals other than explosives from properly functioning ordnance would be short-term, local, and negative. Potential impacts on sediment and water quality of chemicals other than explosives from lost or malfunctioning ordnance would be long-term, local, and negative. In both cases, chemical, physical, or biological changes in sediment or water quality would not be detectable.

3.1.3.3.9.3 Alternative 2

Under Alternative 2, the number of expended military items containing chemicals other than explosives would increase from 3,008 to 10,343 (240-percent increase) compared to the No Action Alternative. Of those materials, rockets would account for 55 percent of military expended materials. Torpedoes would account for 23 percent of the number of military expended materials. The majority of torpedoes would be recovered following training and testing activities.

Training Activities

Under Alternative 2, the number of training activities and amounts of expended ordnance would be the same as under Alternative 1. Therefore, chemicals in military expended materials would have the same environmental impacts as under Alternative 1.

Testing Activities

Under Alternative 2, chemicals other than explosives would be used in 3,106 ordnance items. Within the Study Area, approximately 70 percent (2,183 items) would be expended in SOCAL Range Complex during testing activities, with the remaining 30 percent (923 items) expended in HRC. Torpedoes represent 41 percent of these materials. All practice torpedoes would be recovered after testing activities, which would reduce the exposure of Otto Fuel II to the marine environment. Although these changes would be a notable increase compared to the No Action Alternative, impacts would be similar to the No Action Alternative for the reasons enumerated above. Potential impacts on sediment and water quality of chemicals other than explosives from properly functioning ordnance would be short-term, local, and negative. Potential impacts on sediment and water quality of chemicals other than explosives from lost or malfunctioning ordnance would be long-term, local, and negative. In both cases, chemical, physical, or biological changes in sediment or water quality would not be detectable.

3.1.3.3.9.4 Summary and Conclusions for Chemicals Other than Explosives

Chemicals other than explosives from military expended materials in the Study Area would be from residual solid propellant, OTTO Fuel II, and pyrotechnic materials. Solid propellants would leach perchlorates. Perchlorates are readily soluble, with a low affinity for sediments. Based on the small amount of residual propellant from training and testing activities, perchlorates would not be expected in concentrations that would be harmful to aquatic organisms in the water column or in marine sediments. OTTO Fuel II and its combustion byproducts would be introduced into the water column in small amounts. All torpedoes would be recovered following training and testing activities, and OTTO Fuel II would not be expected to come into direct contact with marine sediments. Most combustion

byproducts would form naturally occurring gases in the water column, and cyanide concentrations would be well below harmful concentrations.

3.1.3.4 Other Materials

3.1.3.4.1 Introduction

Under the Proposed Action, other materials include marine markers and flares, chaff, towed and stationary targets, and miscellaneous components of other materials. These materials and components are made mainly of non-reactive or slowly reactive materials (e.g., glass, carbon fibers, and plastics) or they break down or decompose into benign byproducts (e.g., rubber, steel, iron, and concrete). Most of these objects would settle to the sea floor where they would (1) be exposed to seawater, (2) become lodged in or covered by sea floor sediments, (3) become encrusted by chemical processes such as rust, (4) dissolve slowly, or (5) be covered by marine organisms such as coral. Plastics may float or descend to the bottom, depending upon their buoyancy. Markers and flares are largely consumed during use.

Steel in ordnance normally contains a variety of metals; some of them are a potential concern. However, these other metals are present at low concentrations (one to five percent of content), such that steel is not generally considered a potential source of metal contamination. Metals are discussed in more detail in Section 3.1.3.2. Various chemicals and explosives are present in small amounts (mostly as components of flares and markers) that are not considered likely to cause adverse impacts. Chemicals other than explosives are discussed in more detail in Section 3.1.3.3, and explosives and explosion byproducts are discussed in more detail in Section 3.1.3.1.

Towed and stationary targets include floating steel drums, towed aerial targets, the trimaran, and inflatable, floating targets. The trimaran is a three-hulled boat with a 4-ft. (1.2 m) square sail that is towed as a moving target. Large, inflatable, plastic targets can be towed or left stationary. Towed aerial targets are either (1) rectangular pieces of nylon fabric 7.5 ft. by 40 ft. (2.3 m by 12.2 m) that reflect radar or lasers; or (2) aluminum cylinders with a fiberglass nose cone, aluminum corner reflectors (fins), and a short plastic tail section. This second target is about 10 ft. long (30.5 m) and weighs about 75 lb. (34 kg). These four targets are recovered after use, and will not be considered further.

3.1.3.4.2 Marine Markers and Flares

Marine markers are pyrotechnic devices that are dropped on the water's surface during training exercises to mark a position, to support search and rescue activities, or as a bomb target. The MK 58 marker is a tin tube that weighs about 12 lb. (5.4 kg). Markers release smoke at the water surface for 40 to 60 minutes. After the pyrotechnics are consumed, the marine marker fills with seawater and sinks. Iron and aluminum constitute 35 percent of the marker weight. To produce the lengthy smoke effect, approximately 40 percent of the marker weight is made up of pyrotechnic materials. The propellant, explosive, and pyrotechnic constituents of the MK 58 include red phosphorus (2.19 lb. [0.99 kg]) and manganese (IV) dioxide (1.40 lb. [0.64 kg]). Other constituents include magnesium powder (0.29 lb. [0.13 kg]), zinc oxide (0.12 lb. [0.05 kg]), nitrocellulose (0.000017 lb. [0.000008 kg]), nitroglycerin (0.000014 lb. [0.000006 kg]), and potassium nitrate (0.2 lb. [0.1 kg]). The failure rate of marine markers is approximately 5 percent (U.S. Department of the Navy 2010b).

Flares are used to signal, to illuminate surface areas at night in search and attack operations, and to assist with search and rescue activities. They range in weight from 12 to 30 lb. (5 to 14 kg). The major constituents of flares include magnesium granules and sodium nitrate. Containers are constructed of aluminum, and the entire assembly is usually consumed during flight. Flares may also contain a primer

such as TNT, propellant (ammonium perchlorate), and other explosives. These materials are present in small quantities (e.g., 1.0×10^{-4} oz. of ammonium perchlorate and 1.0×10^{-7} oz. of explosives). Small amounts of metals are used to give flares and other pyrotechnic materials bright and distinctive colors. Combustion products from flares include magnesium oxide, sodium carbonate, carbon dioxide, and water. Illuminating flares and marine markers are usually entirely consumed during use; neither is intended to be recovered. Table 3.1-25 summarizes the components of markers and flares (U.S. Department of the Navy 2010b).

Table 3.1-25: Summary of Components of Marine Markers and Flares

Flare or Marker	Constituents
LUU-2 Paraflare	Magnesium granules, sodium nitrate, aluminum, iron, TNT, royal demolition explosive, ammonium perchlorate, potassium nitrate, lead, chromium, magnesium, manganese, nickel
MK45 Paraflare	Aluminum, sodium nitrate, magnesium powder, nitrocellulose, TNT, copper, lead, zinc, chromium, manganese, potassium nitrate, pentaerythritol-tetranitrate, nickel, potassium perchlorate
MK58 Marine Marker	Aluminum, chromium, copper, lead, lead dioxide, manganese dioxide, manganese, nitroglycerin, red phosphorus, potassium nitrate, silver, zinc, zinc oxide

3.1.3.4.3 Chaff

Chaff consists of small, thin glass fibers coated in aluminum that are light enough to remain in the air anywhere from 10 minutes to 10 hours. Chaff is an electronic countermeasure designed to confuse enemy radar by deflecting radar waves and thereby obscuring aircraft, ships, and other equipment from radar tracking sources. Chaff is typically packaged in cylinders approximately 6 in. by 1.5 in. (15.2 cm by 3.8 cm), weigh about 5 oz. (140 g), and contain a few million fibers. Chaff may be deployed from an aircraft or may be launched from a surface vessel.

The chaff fibers are approximately the thickness of a human hair (generally 25.4 microns in diameter), and range in length from 0.3 to 2 in. (0.8 to 5.1 cm). The major components of the chaff glass fibers and the aluminum coating are provided in Table 3.1-26 (U.S. Air Force 1994).

3.1.3.4.4 Additional Examples of Other Materials

Miscellaneous components of other materials include small parachutes used with sonobuoys and flares, nylon cord, plastic casing, and antenna float used with sonobuoys; natural and synthetic rubber, carbon or Kevlar fibers used in missiles; and plastic end-cap and piston used in chaff cartridges.

3.1.3.4.5 Approach to Analysis

Most activities involving ordnance containing the other materials discussed above would be conducted more than three nautical miles offshore in each range complex. Most of the other materials are benign. In the analysis of alternatives, "local" means the area in which the material comes to rest. No state or federal sediment and water quality standards or guidelines specifically apply to major components of the other materials discussed above.

Table 3.1-26: Major Components of Chaff

Component	Percent by Weight
Glass Fiber	
Silicon dioxide	52-56
Alumina	12-16
Calcium oxide, magnesium oxide	16-25
Boron oxide	8-13
Sodium oxide, potassium oxide	1-4
Iron oxide	≤ 1
Aluminum Coating	
Aluminum	99.45 (min.)
Silicon and Iron	0.55 (max.)
Copper	0.05
Manganese	0.05
Zinc	0.05
Vanadium	0.05
Titanium	0.05
Others	0.05

3.1.3.4.6 Impacts of Other Materials

The rate at which materials deteriorate in marine environments depends on the material and conditions in the immediate marine and benthic environment. Usually when buried deep in ocean sediments, materials decompose at lower rates than when exposed to seawater (Ankley 1996). With the exception of plastic parts, sediment burial appears to be the fate of most ordnance used in marine warfare (Canadian Forces Maritime Experimental and Test Ranges 2005). The behavior of these other materials in marine systems is discussed in more detail below.

3.1.3.4.6.1 Flares

Most of the pyrotechnic components of marine markers are consumed and released as smoke in the air. Thereafter, the aluminum and steel canister sinks to the bottom. Combustion of red phosphorus produces phosphorus oxides, which have a low toxicity to aquatic organisms. The amount of flare residue is negligible. Phosphorus contained in the marker settles to the sea floor, where it reacts with the water to produce phosphoric acid until all phosphorus is consumed by the reaction. Phosphoric acid is a variable, but normal, component of seawater (U.S. Department of the Navy 2006). The aluminum and iron canisters are expected to be covered by sand and sediment over time, to become encrusted by chemical corrosion, or to be covered by marine plants and animals. Elemental aluminum in seawater tends to be converted by hydrolysis to aluminum hydroxide, which is relatively insoluble and adheres to particulates, and transported to the bottom sediments (Monterey Bay Research Institute 2010).

Red phosphorus, the primary pyrotechnic ingredient, constitutes 18 percent of the marine marker weight. Toxicological studies of red phosphorus revealed an aquatic toxicity in the range of 10 to 100 mg/L (10 to 100 ppm) for fish, *Daphnia* (a small aquatic crustacean), and algae (European Flame Retardants Association 2011). Red phosphorus slowly degrades by chemical reactions to phosphine and phosphorus acids. Phosphine is very reactive and usually undergoes rapid oxidation (California Environmental Protection Agency 2003). The final products, phosphates, are harmless (U.S. Department

of the Navy 2010b). A study by the U.S. Air Force (1997) found that, in salt water, the degradation products of flares that do not function properly include magnesium and barium.

3.1.3.4.6.2 Chaff

Chaff can remain suspended in air from 10 minutes to 10 hours, and can travel considerable distances from its release point (Arfsten et al. 2002; U.S. Air Force 1997). Factors influencing chaff dispersion include the altitude and location where it is released, prevailing winds, and meteorological conditions (Hullar et al. 1999). Doppler radar has tracked chaff plumes containing approximately 31.8 oz. (901.5 g) of chaff drifting 200 mi. (321.9 km) from the point of release, with the plume covering a volume of greater than 400 mi.³ (Arfsten et al. 2002). Based on the dispersion characteristics of chaff, large areas of open water would be exposed to chaff, but the chaff concentrations would be low. For example, Hullar et al. (1999) calculated that an area 4.97 mi. by 7.46 mi. (8 km by 12 km) (37 mi.² [96 km²] or 28 nm² [96 km²]) would be affected by deployment of a single cartridge containing 5.3 oz. (150 g) of chaff. The resulting chaff concentration would be about 5.4 g/nm². This corresponds to less than 179,000 fibers/nm², or less than 0.005 fiber/ft.², assuming that each canister contains five million fibers.

Chaff is generally resistant to chemical weathering, and likely remains in the environment for long periods. However, all the components of chaff's aluminum coating are present in seawater in trace amounts, except magnesium, which is present at 0.1 percent (Nozaki 1997). Aluminum and silicon are the most common minerals in the earth's crust as aluminum oxide and silicon dioxide, respectively. Aluminum is the most common metal in the Earth's crust, and is a trace element in natural waters. Ocean waters are in constant exposure to crustal materials, so the addition of small amounts of chaff should not affect water or sediment composition (Hullar et al. 1999).

The dissolved concentration of aluminum in seawater ranges from 1 to 10 µg/L (1 to 10 ppb). For comparison, the concentration in rivers is 50 µg/L (50 ppb). In the ocean, aluminum concentrations tend to be higher on the surface, lower at middle depths, and higher again at the bottom (Li et al. 2008). Aluminum is a very reactive element, and is seldom found as a free metal in nature except under highly acidic (low pH) or alkaline (high pH) conditions. It is found combined with other elements, most commonly with oxygen, silicon, and fluorine. These chemical compounds are commonly found in soil, minerals, rocks, and clays (Agency for Toxic Substances and Disease Registry 2008; U.S. Air Force 1994). Elemental aluminum in seawater tends to be converted by hydrolysis to aluminum hydroxide, which is relatively insoluble, and is scavenged by particulates and transported to bottom sediments (Monterey Bay Research Institute 2010).

Because of their light weight, chaff fibers tend to float on the water surface for a short period. The fibers are quickly dispersed by waves and currents. They may be accidentally or intentionally ingested by marine life, but the fibers are non-toxic. Chemicals leached from the chaff would be diluted by the surrounding seawater, reducing the potential for chemical concentrations to reach levels that can affect sediment quality or benthic habitats.

Systems Consultants, Inc. (1977), placed chaff samples in Chesapeake Bay water for 13 days. No increases in concentration of greater than one ppm of aluminum, cadmium, copper, iron, or zinc were detected. Accumulation and concentration of chaff constituents is not likely under natural conditions. A U.S. Air Force study of chaff analyzed nine elements under various pH conditions: silicon, aluminum, magnesium, boron, copper, manganese, zinc, vanadium, and titanium. Only four elements were detected above the 0.02 mg/L detection limit (0.02 ppm): magnesium, aluminum, zinc, and boron (U.S.

Air Force 1994). Tests of marine organisms detected no negative impacts of chaff exposure at levels above those expected in the Study Area (Systems Consultants 1977; Farrell and Siciliano 2007).

3.1.3.4.6.3 Additional Components of Other Materials

Most components of other materials are plastics. Although plastics are resistant to degradation, they do gradually breakdown into smaller particles as a result of photodegradation and mechanical wear (Law et al. 2010). The fate of plastics that sink beyond the continental shelf is largely unknown, although marine microbes and fungi are known to degrade biologically-produced polyesters (Doi et al. 1992) as well as other synthetic polymers, although the latter occurs more slowly (Shah et al. 2008).

3.1.3.4.7 Evaluation of Alternatives

The following sections evaluate each alternative in terms of the information provided in Section 3.1.3.4. The types and amounts of expended materials in the tables were drawn from the summary tables in Chapter 2. Table 3.1-27 summarizes the annual number of flares and chaff for the No Action Alternative and Alternatives 1 and 2.

Table 3.1-27: Summary of Annual Military Expended Materials Involving Other Materials – All Alternatives

Type of Military Expended Material	Hawaii Range Complex			Southern California Range Complex		
	No Action Alternative	Alternative 1	Alternative 2	No Action Alternative	Alternative 1	Alternative 2
Flares						
Training	1,750	1,750	1,750	8,300	8,300	8,300
Testing	0	0	0	0	100	110
Total	1,750	1,750	1,750	8,300	8,400	8,410
Chaff Canisters						
Training	200	2,600	2,600	20,750	20,750	20,750
Testing	0	300	300	0	204	254
Total	200	2,900	2,900	20,750	20,954	21,004

Notes: HSTT = Hawaii-Southern California Training and Testing

3.1.3.4.7.1 No Action Alternative

Under the No Action Alternative, an estimated 31,000 military items composed of other materials would be expended in the Study Area during training and testing activities. Training activities would account for all of military expended materials composed of other materials. Within the Study Area, approximately 94 percent (29,050 items) would be expended in SOCAL Range Complex during training and testing activities, with the remaining 6 percent (1,050 items) expended in HRC.

Training Activities

Under the No Action Alternative, approximately 31,000 training items composed of other materials would be expended in the Study Area. These items consist of chaff cartridges (67 percent) and flares (33 percent). Potential impacts of these other materials on sediment and water quality would be short- and long-term, local, and negative. Chemical, physical, or biological changes in sediment or water quality would not be detectable. The composition of chaff is much like clay minerals common in ocean sediments (“aluminosilicates”), and studies indicate that negative impacts are not anticipated even at

concentrations many times the level anticipated during proposed training activities. Most pyrotechnics in marine markers and flares are consumed during use and expended in the air. The failure rate is low (5 percent), and the remaining amounts are small, and subject to additional chemical reactions and subsequent dilution in the ocean. Plastics and other floating expended materials would either degrade over time or wash ashore. Materials would be widely scattered on the sea floor in areas used for training.

Testing Activities

No testing items composed of other materials would be used during testing activities under the No Action Alternative. Therefore, these activities would have no effect on sediments or water quality.

3.1.3.4.7.2 Alternative 1

Under Alternative 1, an estimated 34,004 items composed of other materials would be expended, a 10 percent increase compared to the No Action Alternative. Training activities would account for over 98 percent of military expended materials composed of other materials. Within the Study Area, approximately 86 percent (29,354 items) would be expended in SOCAL Range Complex during training and testing activities, with the remaining 14 percent (4,650 items) expended in HRC.

Training Activities

Under Alternative 1, the number of training items composed of other materials would increase to an estimated 33,400 items. These items would consist of chaff cartridges (70 percent) and flares (30 percent). The potential impacts of other materials on sediment and water quality would be short- and long-term, local, and negative. The small increase in other materials, coupled with the nature of those materials, indicate that the potential impacts would be similar to those under the No Action Alternative. Chemical, physical, or biological changes in sediment or water quality would not be detectable.

Testing Activities

Under Alternative 1, the number of testing items composed of other materials would introduce 604 items per year into the Study Area. These items would consist of chaff cartridges (83 percent) and marine markers and flares (17 percent). The potential impacts of other materials on sediment and water quality would be short- and long-term, local, and negative. The small increase in other materials, coupled with the nature of those materials, indicate that the potential impacts would be similar to those under the No Action Alternative. Chemical, physical, or biological changes in sediment or water quality would not be detectable.

3.1.3.4.7.3 Alternative 2

Under Alternative 2, approximately 34,064 items composed of other materials would be expended, a 10-percent increase compared to the No Action Alternative. Within the Study Area, approximately 86 percent (29,414 items) would be expended in SOCAL Range Complex during testing activities, with the remaining 14 percent (4,650 items) expended in HRC.

Training Activities

Under Alternative 2, the number of training activities and expended training items would be the same as under Alternative 1. Therefore, the other materials in training items would have the same impacts as they would under Alternative 1.

Testing Activities

Under Alternative 2, the number of testing items composed of other materials would increase to 664 items per year. These items would consist of chaff cartridges (83 percent) and marine markers and flares (17 percent). The potential impacts of other materials on sediment and water quality would be short- and long-term, local, and negative. The small increase in other materials, coupled with the nature of those materials, indicate that the potential impacts would be similar to those under the No Action Alternative. Chemical, physical, or biological changes in sediment or water quality would not be detectable.

3.1.3.4.7.4 Summary and Conclusions for Other Materials

Other military expended materials include plastics, marine markers, flares, and chaff. Some expended plastics from training and testing activities are unavoidable because they are used in ordnance or targets. Targets, however, would typically be recovered following training and testing activities. Chaff fibers are composed of non-reactive metals and glass, and would be dispersed by ocean currents as they float and slowly sink toward the bottom. The fine, neutrally buoyant chaff streamers would act like particulates in the water, temporarily increasing the turbidity of the ocean's surface. The chaff fibers would quickly disperse and turbidity readings would return to normal.

3.1.3.5 Summary of Potential Impacts (Combined Impact of All Stressors) on Sediments and Water Quality

The stressors that may impact sediment and water quality include explosives and explosion byproducts, metals, chemicals other than explosives, and other military expended materials.

3.1.3.5.1 No Action Alternative

When considered together, the impact of the four stressors would be additive. Under the No Action Alternative, chemical, physical, or biological changes in sediment or water quality would not be detectable, and would be below or within existing conditions or designated uses. This conclusion is based on the following reasons:

- Although individual training and testing activities may occur within a fairly small area, overall military expended materials and activities are widely dispersed in space and time.
- When multiple stressors occur at the same time, it is usually for a brief period.
- Many components of expended materials are inert or corrode slowly.
- Numerically, most of the metals expended are small- and medium-caliber projectiles, metals of concern comprise a small portion of the alloys used in expended materials, and metal corrosion is a slow process that allows for dilution.
- Most of the components are subject to a variety of physical, chemical, and biological processes that render them benign.
- Potential areas of negative impacts would be limited to small zones adjacent to the explosive, metals, or chemicals other than explosives.
- The failure rate is low for explosives and materials with propellant systems, limiting the potential impacts from the chemicals other than explosives involved.

3.1.3.5.2 Alternative 1

Under Alternative 1, when considered separately, the impacts of the four stressors would not be additive:

- The impact of chemicals other than explosives and other materials on sediment and water quality would be short- and long-term and local. Chemical, physical, or biological changes in sediment or water quality would not be detectable, and would be below or within existing conditions or designated uses.
- The impact of explosives, explosion byproducts, and metals on sediment and water quality would also be short- and long-term and local. However, chemical, physical, or biological changes in sediment or water quality would be measurable, but below applicable standards and guidelines, and would be below or within existing conditions or designated uses.

When considered together, the impact of the four stressors would be additive. Chemical, physical, or biological changes in sediment or water quality would be measurable, but would still be below applicable standards and guidelines. Although most types of expended materials would increase, some considerably, over the No Action Alternative, this conclusion is based on the reasons provided under the No Action Alternative.

3.1.3.5.3 Alternative 2

Under Alternative 2, when considered separately, the impact of the four stressors on sediment and water quality would be the same as discussed under Alternative 1 because the types and amounts of military expended materials are similar under the two alternatives.

When considered together, the impact of the four stressors would be additive, and changes in sediment or water quality would be measurable, but would still be below applicable standards and guidelines. Because the types and amounts of military expended materials are similar under Alternatives 1 and 2, the reasons for this conclusion are the same as those discussed under the No Action Alternative.

This Page Intentionally Left Blank

REFERENCES

- Agency for Toxic Substances and Disease Registry. (1995). Toxicological Profile for Otto Fuel II and Its Components. Atlanta, GA: Public Health Service, U.S. Department of Health and Human Services.
- Agency for Toxic Substances and Disease Registry. (1999). Toxicological Profile for Mercury. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
- Agency for Toxic Substances and Disease Registry. (2000) Toxicological Profile for Polychlorinated Biphenyls (PCBs). U.S. Department of Health and Human Services, Public Health Service. November.
- Agency for Toxic Substances and Disease Registry.(2005) Public Health Assessment for Pearl Harbor Naval Complex, Pearl Harbor, Hawaii. EPA Facility ID: HI4170090076. December 28.
- Agency for Toxic Substances and Disease Registry. (2007). Toxicological Profile for Lead. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Services.
- Agency for Toxic Substances and Disease Registry. (2008). Toxicological Profile for Perchlorates. U.S. Department of Health and Human Services, Public Health Service. September 2008.
- Anderson, D. M., Gilbery, P. M. & Burkholde, J. M. (2002). Harmful Algal Blooms and Eutrophication: Nutrient Sources, Composition, and Consequences. *Estuaries*, 25(4), 704-726.
- Ankley, G. T. (1996). Evaluation of metal/acid-volatile sulfide relationships in the prediction of metal bioaccumulation by benthic macroinvertebrates. *Environmental Toxicology and Chemistry*, 15, 2138-2146.
- Anthony, K. R. N., Kline, D. I., Diaz-Pulido, G., Dove, S. & Heogh-Guldberg, O. (2008). Ocean acidification causes bleaching and productivity loss in coral reef builders. *Proceedings of the National Academy of Sciences of the United States of America*, 105(45), 17442-17446.
- Arfsten, D.P., C.L. Wilson, and B.J. Spargo. (2002). Radio frequency chaff: The effects of its use in training on the environment. *Ecotoxicology and Environmental Safety* 53:1-11.
- Blumer, M., Ehrhardt, M. & Jones, J. H. (1973). The environmental fate of stranded crude oil. *Deep-Sea Research*, 20, 239-259.
- Boehm, P. D. & Requejo, A. G. (1986). Overview of the Recent Sediment Hydrocarbon Geochemistry of Atlantic and Gulf Coast Outer Continental Shelf Environments. *Estuarine, Coastal and Shelf Science*, 23, 29-58.
- Boesch, D. F., Anderson, D. M., Horner, R. A., Shumway, S. E., Tester, P. A. & Whitledge, T. E. (1997). Harmful algal blooms in coastal waters: Options for prevention, control and mitigation NOAA Coastal Ocean Program (Decision Analysis Series No. 10, pp. 46 & appendix). Silver Spring, Maryland: NOAA Coastal Ocean Office.
- Borener, S. & Maugham, J. (1998). Volpe AtoN [Aid to Navigation] Battery Scientific Assessment *United States Coast Guard AtoN Battery Scientific Assessment, DOT NVTSC-CG-98-01*.

- Bottger, S. A., McClintock, J. B. & Klinger, T. S. (2001). Effects of inorganic and organic phosphates on feeding, feeding absorption, nutrient allocation, growth and righting responses of the sea urchin *Lytechinus variegatus*. *Marine Biology*, 138, 741-751.
- Boudreau, B. P. (1998). Mean mixed depth of sediments: the wherefore and the why. *Limnology and Oceanography*, 43(3), 524-526.
- Brandao, P. F. B. & Bull, A. T. (2003). Nitrile hydrolysing activities of deep-sea and terrestrial mycolate actinomycetes. *Antonie van Leeuwenhoek*, 84, 89-98.
- Breitbarth, E., E. P. Achterberg, M. V. Ardelan, A. R. Baker, E. Bucciarelli, F. Chever, P. L. Croot, S. Duggen, M. Gledhill, M. Hasselov, C. Hassler, L. J. Hoffmann, K. A. Hunter, D. A. Hutchins, J. Ingri, T. Jickells, M. C. Lohan, M. C. Nielsdottir, G. Sarthou, V. Schoemann, J. M. Trapp, D. R. Turner, and Y. Ye. (2010). Iron biogeochemistry across marine systems – progress from the past decade. *Biogeosciences* 7: 1075–1097.
- Bricker, S. B., Clement, C. G., Pirhalla, D. E., Orlando, S. P. & Farrow, D. R. G. (1999). National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries. Silver Spring, MD: NOAA National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science.
- Bruland, K. W. (1992). Complexation of cadmium by natural organic ligands in the Central North Pacific. *Limnology and Oceanography*, 37(5), 1008-1017.
- Buchman, M. F. (2008). NOAA Screening Quick Reference Tables. NOAA OR&R Report 08-1. Office of Response and Restoration Division. National Oceanic and Atmospheric Administration. Retrieved from http://response.restoration.noaa.gov/book_shelf/122_NEW-SQuiRTs.pdf, 2011, February 18.
- Byrne, R. H., Kump, L. R. & Cantrell, K. J. (1988). The influence of temperature and pH on trace metal speciation in seawater. *Marine Chemistry*, 25, 163-181.
- Byrne, R. H. (1996). Specific problems in the measurement and interpretation of complexation phenomena in seawater. *Pure and Applied Chemistry*, 68(8), 1639-1656.
- California Environmental Protection Agency. (2003). Red Phosphorus. Technical Support Document: Toxicology Clandestine Drug Labs/Methamphetamine, Volume 1, Number 12. Sacramento, CA: Office of Environmental Health Hazard Assessment.
- Canadian Forces Maritime Experimental and Test Ranges. (2005). CFMETR Environmental Assessment. Environmental Sciences Group. Royal Military College of Canada. Kingston, Ontario.
- Carberry, H. (2008). New Jersey's Reefs: An Underwater Metropolis. *New Jersey Fish and Wildlife Digest*.
- Carmody, D. J., Pearce, J. B. & Yasso, W. E. (1973). Trace metals in sediments of New York Bight. *Marine Pollution Bulletin*, 4, 132-135.
- Carr, R. S. & Nipper, M. (2003). Assessment of Environmental Effects of Ordnance Compounds and Their Transformation Products in Coastal Ecosystems. (Technical Report TR-2234-ENV). Port Hueneme, CA: Naval Facilities Engineering Service Center.

- Center for Ocean Solutions. (2009). Pacific Ocean Synthesis: Scientific Literature Review of Coastal and Ocean Threats, Impacts, and Solutions. The Woods Center for the Environment, Stanford University, California.
- Chang, G. C., Dickey, T. D. & Williams, A. J., III (2001). Sediment resuspension over a continental shelf during Hurricanes Edouard and Hortense. *Journal of Geophysical Research*, 106(C5), 9517-9531.
- Chapman, P. M., Wang, F., Janssen, C. R., Goulet, R. R. & Kamunde, C. N. (2003). Conducting Ecological Risk Assessments of Inorganic Metals and Metalloids: Current Status. *Human and Ecological Risk Assessment*, 9(4), 641-697.
- Chaudhuri, S. K., O'Connor, S. M., Gustavson, R. L., Achenbach, L. A. & Coates, J. D. (2002). Environmental factors that control microbial perchlorate reduction. *Applied Environmental Microbiology*, 68, 4425-4430.
- Chester, R. (2003). *Marine Geochemistry* (2nd ed.). Oxford, UK: Blackwell Science, Ltd.
- Churchill, J. H. (1989). The effect of commercial trawling on sediment resuspension and transport over the Middle Atlantic Bight continental shelf. *Continental Shelf Research*, 9(9), 841-864.
- City of San Diego. (2003). Annual Receiving Waters Monitoring Report for the South Bay Outfall.
- Clausen, J. L., Scott, C. & Cramer, R. J. (2007). Development of Environmental Data for Navy, Air Force, and Marine Munitions. (ER-1480) U.S. Army Corps of Engineers. Prepared for Strategic Environmental Research and Development Program.
- Cloern, J. E. (2001). Our evolving conceptual model of the coastal eutrophication problem. *Marine Ecology Progress Series*, 210, 223-253.
- Coleman, J. M. & Prior, D. B. (1988). Mass wasting on continental margins. *Annual Review of Earth Planet Science*, 16, 101-119.
- Crocker, F. H., Indest, K. J. & Fredrickson, H. L. (2006). Biodegradation of the cyclic nitramine explosives RDX, HMX, and CL-20. *Applied Microbiology and Biotechnology*, 73, 274-290.
- Cruz-Uribe, O., Cheney, D. P. & Rorrer, G. L. (2007). Comparison of TNT removal from seawater by three marine macroalgae. *Chemosphere*, 67, 1469-1476.
- Defense Science Board. (2003). Final Report of the Defense Science Board Task Force on Unexploded Ordnance. Washington, D.C.: Office of the Under Secretary of Defense For Acquisition, Technology, and Logistics.
- Demina, L. L. & Galkin, S. V. (2009). Geochemical features of heavy metal bioaccumulation in the Guaymas Basin of the Gulf of California. *Oceanology*, 49(5), 697-706.
- Diaz, R. J. & Rosenberg, R. (1995). Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. *Oceanography and Marine Biology: An Annual Review*, 33, 245-303.

- Doi, Y., Kanesawa, Y., Tanahashi, N. & Kumagai, Y. (1992). Biodegradation of microbial polyesters in the marine environment. *Polymer Degradation and Stability*, 36, 173-177.
- Drzyzga, O. & Blotevogel, K. H. (1997). Microbial Degradation of Diphenylamine Under Anoxic Conditions. *Current Microbiology*, 35, 343-347.
- Durrach, M. R., Chutjian, A. & Plett, G. A. (1998). Trace Explosives Signatures from World War II Unexploded Undersea Ordnance. *Environmental Science and Technology*, 32, 1354-1358.
- Duursma, E. K. & Gross, M. G. (1971). Marine Sediments and Radioactivity Radioactivity in the Marine Environment (pp. 147-160). Washington, D.C.: National Academy of Sciences.
- Edwards, K. P., Hare, J. A., Werner, F. E. & Blanton, B. O. (2006). Lagrangian circulation on the Southeast U.S. continental shelf: implications for larval dispersal and retention. *Continental Shelf Research*, 26(12-13), 1375-1394.
- Eggleton, J. & Thomas, K. V. (2004). A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. *Environment International*, 30, 973-980.
- European Flame Retardants Association. Flame Retardant Fact Sheet, Red Phosphorus (RP). Retrieved from <http://www.cefic-efra.com/Objects/2/Files/RedPhosphorusFactSheet.pdf> as accessed on 2011, February 24.
- Fabry, V. J., Seibel, B. A., Feely, R. A. & Orr, J. C. (2008). Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science*, 65(3), 414-432.
- Farrell, R. E. & Siciliano, S. D. (2007). Environmental Effects of Radio Frequency (RF) Chaff Released during Military Training Exercises: A Review of the Literature. Prepared for Goose Bay Office of the Department of National Defense.
- Fitzgerald, W. F., Lamborg, C. H. & Hammerschmidt, C. R. (2007). Marine Biogeochemical Cycling of Mercury. *Chemical Reviews*, 107, 641-662.
- Fisheries Research Services Report. (1996). Surveys of the Beaufort's Dyke Explosives Disposal Site, November 1995 - July 1996. (Final Report No. 15/96). Aberdeen, Scotland: Marine Laboratory, Scottish Office Agriculture, Environmenta and Fisheries Department.
- Fournier, E.W. and B.B. Brady. (2005). Perchlorate Leaching from Solid Rocket Motor Propellant in Water. *Journal of Propulsion and Power*, Vol. 21, No. 5, September-October 2005.
- Geiselbrecht, A. D., Hedlund, B. P., Tichi, M. A. & Staley, J. T. (1998). Isolation of Marine Polycyclic Aromatic Hydrocarbon (PAH)-Degrading Cycloclasticus Strains from the Gulf of Mexico and Comparison of Their PAH Degradation Ability with that of Puget Sound Cycloclasticus Strains. *Applied and Environmental Microbiology*, 64(12), 4703-4710.
- Haderlein, S. B., Weissmahr, K. & Schwarzenbach (1996). Specific Adsorption of Nitroaromatic Explosives and Pesticides to Clay Minerals. *Environmental Science and Technology*, 20, 612-622.

- Hameedi, M. J., Pait, A. S. & Warner, R. A. (2002). Environmental Contaminant Monitoring in the Gulf of Maine. Silver Spring, Maryland: Center for Coastal Monitoring and Assessment, National Oceanic and Atmospheric Administration.
- Hawaii Department of Health. (2000). Hawaii's Implementation Plan for Polluted Runoff Control, Appendix F: Detailed Descriptions of Hawaii's 18 Water Quality Limited Segments. Hawaii Department of Business and Department of Health. July.
- Hawaii Department of Health. (2008). 2006 State of Hawaii Water Quality Monitoring and Assessment Report: Integrated Report to the U.S. Environmental Protection Agency and the U.S. Congress Pursuant to Sections §303(d) and §305(b), Clean Water Act (P.L. 97-117). Honolulu, Hawaii.
- Hawaii Department of Health. (2009). Water Quality Standards. Amendment and Compilation of Chapter 11-54 Hawaii Administrative Rules.
- Hawaii Undersea Military Munitions Assessment. (2010). Final Investigation Report HI-05 South of Pearl Harbor, O'ahu, Hawai'i. Prepared by University of Hawai'i at Monoa and Environet, Inc. Honolulu, HI. Prepared for The National Defense Center for Energy and Environment.
- Hedges, J. I. & Oades, J. M. (1997). Comparative organic geochemistries of soils and marine sediments. *Organic Geochemistry*, 27(7/8), 319-361.
- Helly, J. J. & Levin, L. A. (2004). Global distribution of naturally occurring marine hypoxia on continental margins. *Deep-Sea Research I*, 51, 1159-1168.
- Ho, T. Y., Wen, L. S., You, C. F. & Lee, D. C. (2007). The trace-metal composition of size-fractionated plankton in the South China Sea: biotic versus abiotic sources. *Limnology and Oceanography*, 52(5), 1776-1788.
- Hoffsommer, J. C., Glover, D. J. & Rosen, J. M. (1972). Analysis of Explosives in Sea Water and in Ocean Floor Sediments and Fauna. Silver Spring, MD: Naval Ordnance Laboratory.
- Hughes, T. P. & Connell, J. H. (1999). Multiple stressors on coral reefs; a long-term perspective. *Limnology and Oceanography*, 44(3, part 2), 932-940.
- Howarth, M. J., Simpson, J. H., Sundermann, J. & Van Haren, H. (2002). Processes of Vertical Exchange in Shelf Seas (PROVESS). *Journal of Sea Research*, 47(199-208).
- Hullar, T.L., S.L. Fales, H.F. Hemond, P. Koutrakis, W.H. Schlesinger, R.R. Sobonya, J.M. Teal, & J.G. Watson. (1999). Environmental Effects of RF Chaff: A Select Panel Report to the Undersecretary of Defense for Environmental Security, NRL/PU/6110--99-389, Naval Research Laboratory.
- Jones, K. C. & de Voogt, P. (1999). Persistent organic pollutants (POPs): state of the science. *Environmental Pollution*, 100, 209-221.
- Juhasz, A. L. & Naidu, R. (2007). Explosives: Fate, Dynamics, and Ecological Impact in Terrestrial and Marine Environments. *Reviews of Environmental Contamination and Toxicology*, 191, 163-215.

- Kalmaz, E. V. & Kalmaz, G. D. (1979). Transport, Distribution and Toxic Effects of Polychlorinated Biphenyls in Ecosystems: Review. *Ecological Modelling*, 6, 223-251.
- Keller, A. A., Fruh, E. L., Johnson, M. M., Simon, V. & McGourty, C. (2010). Distribution and abundance of anthropogenic marine debris along the shelf and slope of the US West Coast. *Marine Pollution Bulletin*, 60, 692-700.
- Kletzin, A. & Adams, M. W. W. (1996). Tungsten in biological systems. *FEMS Microbiology Reviews*, 18(1), 5-63.
- Koutsospyros, A., Braida, W., Christodoulatos, C., Dermatas, D. & Strigul, N. (2006). A review of tungsten: From environmental obscurity to scrutiny. *Journal of Hazardous Materials*, 136, 1-19.
- Kszos, L. A., Beauchamp, J. J. & Stewart, A. J. (2003). Toxicity of lithium to three freshwater organisms and the antagonistic effect of sodium. *Ecotoxicology*, 12(5), 427-437.
- Kvenvolden, K. A. & Cooper, C. K. (2003). Natural seepage of crude oil into the marine environment. *Geo-Marine Letter*, 23, 140-146.
- Law, K. L., Moret-Ferguson, S., Maximenko, N. A., Proskurowski, G., Peacock, E. E., Hafner, J. & Reddy, C. M. (2010). Plastic Accumulation in the North Atlantic Subtropical Gyre. *Science*, 329(3), 1185-1188.
- Li, M., Zhong, L., Boicourt, W., Zhang, S. & Zhang, D. L. (2006). Hurricane-induced storm surges, currents and destratification in a semi-enclosed bay. *Geophysical Research Letters*, 33, 4.
- Li, J., Ren, J., Zhang, J. & Liu, S. (2008). The distribution of dissolved aluminum in the Yellow and East China seas. *Journal of the Ocean University of China*, 7(1), 48-54.
- Libes, S. M. (2009). *Introduction to Marine Biogeochemistry* (2nd ed.). London, UK: Elsevier.
- Logan, B. E., Wu, J. & Unz, R. F. (2001). Biological Perchlorate Reduction in High-salinity Solutions. *Water Resources*, 35(12), 3034-3038.
- Long, E. R., MacDonald, D. D., Smith, S. L. & Calder, F. D. (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management*, 19(1), 81-97.
- Lynch, J. C., Brannon, J. M. & Delfino, J. J. (2002). Dissolution rates of three high explosive compounds: TNT, RDX, and HMX. *Chemosphere*, 47(7), 725-734.
- Mackay, D. & McAuliffe, C. D. (1988). Fate of Hydrocarbons Discharged at Sea. *Oil & Chemical Pollution*, 5, 1-20.
- Mann, K. H. & Lazier, J. R. N. (1996). *Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans* (2nd ed.). Boston, Massachusetts: Blackwell Scientific Publications.
- Martinelango, P. (2006). Oxalate and Perchlorate: Two Trace Components in the Environment. [Ph.D Dissertation].

- Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C. & Kaminuma, T. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental Science and Technology*, 35(2), 318-324.
- McCain, B.B., D.W. Brown, S.-L. Chan, J.T. Landahl, W.D. MacLeod, Jr., M.M. Krahn, C.A. Sloan, K.L. Tilbury, S.M. Pierce, D.G. Burrows, and U. Varanasi (2000). National benthic surveillance project: Pacific Coast. Organic chemical contaminants, cycle I to vii (1984-90). U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-NWFSC-40, 121 p.
- Means, J. C. (1995). Influence of salinity upon sediment-water partitioning of aromatic hydrocarbons. *Marine Chemistry*, 51, 3-16.
- Milliman, J. D., Pilkey, O. H. & Ross, D. A. (1972). Sediments of the Continental Margin off the Eastern United States. *Geological Society of America Bulletin*, 83(5), 1315-1334.
- Missile Technology Control Regime (1996). *Missile Technology Control Regime Annex Handbook*.
- Mitchell, C. P. & Gilmour, C. C. (2008). Methylmercury production in a Chesapeake Bay salt marsh. *Journal of Geophysical Research*, 113, 14.
- Mitsch, W. J. & Gosselink, J. G. (2007). *Wetlands* (4th ed.). New York, New York: John Wiley and Sons.
- Monteil-Rivera, F., Paquet, L., Giroux, R. & Hawari, J. (2008). Contribution of Hydrolysis in the Abiotic Attenuation of RDX and HMX in Coastal Waters. *Journal of Environmental Quality*, 37, 858-864.
- Monterey Bay Research Institute (2010). Periodic Table of Elements in the Ocean The MBARI Chemical Sensor Program. Retrieved from www.mbari.org/chemsensor/pteo.htm as accessed on 2011, January 27.
- Montgomery, M. T., Walker, S. W., Boyd, T. J., Hamdan, L. J. & Osburn, C. L. (2008). Bacterial Degradation of Nitrogenous Energetic Compounds (NEC) in Coastal Waters and Sediments. (NRL/MR/6110-08-9139). Washington, D.C.: Naval Research Laboratory, United States Navy.
- Morel, F. M. M. & Price, N. M. (2003). The biogeochemical cycles of trace metals in the oceans. *Science*, 300, 994-947.
- National Oceanic and Atmospheric Administration (1999). *Sediment Quality Guidelines Developed for the National Status and Trends Program*.
- National Oceanographic Data Center (2011a). Coastal Water Temperature Guide: Pacific Coast: South. National Oceanographic and Atmospheric Administration. Website: <http://www.nodc.noaa.gov/dsdt/cwtg/spac.html>. Data Accessed: 21 September 2011.
- National Oceanographic Data Center (2011b). Coastal Water Temperature Guide: Hawaiian Island Coast. National Oceanographic and Atmospheric Administration. Website: <http://www.nodc.noaa.gov/dsdt/cwtg/hawaii.html>. Data Accessed: 21 September 2011.
- Naval Facilities Engineering Command (1993). Report on Continuing Action: Standard Range Sonobuoy Quality Assurance Program, San Clemente Island, California. San Diego, CA.

- Naval Ocean Systems Center (2002). Sediment Bioassays for NAVSTA San Diego Dredging Project. 49.
- Nipper, M., Carr, R. S., Biedenbach, J. M., Hooten, R. L. & Miller, K. (2002). Toxicological and chemical assessment of ordnance compounds in marine sediments and porewaters. *Marine Pollution Bulletin*, 44, 789-806.
- Nixon, S. W., Ammerman, J. W., Atkinson, L. P., Berounsky, V. M., Billen, G., Boicourt, W. C., Seitzinger, S. P. (1996). The fate of nitrogen and phosphorus at the land-sea margin of the North Atlantic. *Ocean Biochemistry*, 35, 141-180.
- Nozaki, Y. (1997). A Fresh Look at Element Distribution in the North Pacific. EOS, Transactions of the American Geophysical Union, 78(21), 221. Retrieved from <http://www.agu.org/pubs/eos-news/supplements/1995-2003/97025e.shtml>.
- Okeke, B. C., Giblin, T. & Frankenberger, W. T., Jr. (2002). Reduction of perchlorate and nitrate by salt tolerant bacteria. *Environmental Pollution*, 118, 357-363.
- Organization for Economic Cooperation and Development. n.d. Triethylphosphate.
- Pait, A. S., Mason, A. L., Whittall, D. R., Christensen, J. D. & Hartwell, S. I. (2010). Chapter 5: Assessment of Chemical Contaminants in Sediments and Corals in Vieques L. J. Bauer and M. S. Kendall (Eds.), *An Ecological Characterization of the Marine Resources of Vieques, Puerto Rico*. (pp. 101-150). Silver Spring, MD: NOAA MCCOS 110.
- Pavlostathis, S. G. & Jackson, G. H. (2002). Biotransformation of 2,4,6-trinitrotoluene in a continuous-flow *Anabaena* sp. system. *Water Research*, 36, 1699-1706.
- Pennington, J. C. & Brannon (2002). Environmental fate of explosives. *Thermochimica Acta*, 384(1-2), 163-172.
- Pennington, J.C., Jenkins, T.F., Ampleman, G., Thiboutot, S., Brannon, J.M., Hewitt, A.D., Dontsova, K. (2006). Distribution and Fate of Energetics on DoD Test and Training Ranges: Final Report. (ERDC TR-06-13). Arlington, VA: U.S. Army Corps of Engineers.
- Petrisor, I. G. & Wells, J. T. (2008). Perchlorate - Is Nature the Main Manufacturer? Environmental Forensics. *Environmental Science and Technology*, 26, 105-129.
- Port of San Diego (2002). San Diego Harbor Deepening EIS/EIR. Prepared by USACOE November 25, 2002.
- Powell, S., Franzmann, P. D., Cord-Ruwisch, R. & Toze, S. (1998). Degradation of 2-nitrodiphenylamine, a component of Otto Fuel II, by *Clostridium* spp. *Anaerobe*, 4, 95-102.
- Rabalais, N. N., Turner, R. E. & Scavia, D. (2002). Beyond Science into Policy: Gulf of Mexico Hypoxia and the Mississippi River. *BioScience*, 52(2), 129-142.
- Rand Corporation (2005). Unexploded ordnance cleanup costs: implications of alternative protocols. Santa Monica, CA.

- Regional Water Quality Control Board (2007). Water Quality Control Plan for the San Diego Basin. <http://www.swrcb.ca.gov/rwqcb9/>. Accessed December 2008.
- Rodacy, P. J., Walker, P. K., Reber, S. D., Phelan, J. & Andre, J. V. (2000). Explosive Detection in the Marine Environment and on Land Using Ion Mobility Spectroscopy. (Sandia Report SAD2000-0921). Albuquerque, NM: Sandia National Laboratory.
- Sauer, T. C., Jr., Durell, G. S., Brown, J. S., Redford, D. & Boehm, P. D. (1989). Concentrations of Chlorinated Pesticides and PCBs in Microlayer and Seawater Samples Collected in Open-Ocean Waters off the U.S. East Coast and in the Gulf of Mexico. *Marine Chemistry*, 27, 235-257.
- Shah, A. A., Hasan, F., Hameed, A. & Ahmed, S. (2008). Biological degradation of plastics: a comprehensive review. *Biotechnology Advances*, 26, 246-265.
- Sheavly, S. B. (2007). National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary. Washington, D.C.: Ocean Conservancy. Prepared for U.S. Environmental Protection Agency.
- Sheavly, S. B. (2010). National Marine Debris Monitoring Program, Lessons Learned. (EPA 842-R-10-001). Prepared for U.S. Environmental Protection Agency Oceans and Coastal Protection Division Marine Pollution Control Branch.
- Seiwell, H. R. (1934). The distribution of oxygen in the western basin of the North Atlantic. *Papers in Physical Oceanography and Meteorology*, 3(1).
- Singh, R., Soni, P., Kumar, P., Purohit, S. & Singh, A. (2009). Bidegradation of high explosive production effluent containing RDX and HMX by dentrifying bacteria. *World Journal of Microbiology and Biotechnology*, 25, 269-275.
- Spencer, K. L. & MacLeod, C. L. (2002). Distribution and partitioning of heavy metals in estuarine sediment cores and implications for the use of sediment quality standards. *Hydrology and Earth Systems Sciences*, 6(6), 989-998.
- Southern California Coastal Water Research Project (2003). Southern California Bight 1998, regional monitoring program, executive summary.
- Srokosz, M.A. (no date). Ocean Surface Salinity – The Why, What, and Whether. Remote Sensing Applications Development Unit. National Oceanography Centre, Southampton. University of Southampton and Natural Environmental Research Council.
- State of California (2009). California Ocean Plan: Water Quality Control Plan for the Ocean Water of California. California Environmental Protection Agency.
- Stevenson, C. (2011). Plastic Debris in the California Marine Ecosystem: A Summary of Current Research, Solution Strategies, and Data Gaps. University of Southern California Sea Grant. Synthetic Report. California Ocean Science Trust, Oakland, CA.
- Stoffyn-Egli, P. & Machenzie, F. T. (1984). Mass balance of dissolved lithium in the oceans' *Geochemical et Cosmochimica Acta*, 48, 859-872.

- Summers, J. K., Wade, T. L., Engle, V. D. & Malaeb, Z. A. (1996). Normalization of metal concentrations in estuarine sediments from the Gulf of Mexico. *Estuaries*, 19(581-594).
- Sun, W. Q., Meng, M., Kumar, G., Geelhaar, L. A., Payne, G. F., Speedie, M. K. & Stacy, J. R. (1996). Biological denitration of propylene glycol dinitrate by *Bacillus* sp. ATCC 51912. *Applied Microbiology and Biotechnology*, 45, 525-529.
- Systems Consultants, Inc. (1977). Effects of Aluminized Fiberglass on Representative Chesapeake Bay Marine Organisms. Prepared for Naval Research Laboratory, Washington, D.C.
- Tanabe, S. & Tatsukawa, R. (1983). Vertical Transport and Residence Time of Chlorinated Hydrocarbons in the Open Ocean Column. *Journal of the Oceanographical Society of Japan*, 39, 53-62.
- Teuten, E. L., Rowland, S. J., Galloway, T. S. & Thompson, R. C. (2007). Potential for Plastics to Transport Hydrophobic Contaminants. *Environmental Science and Technology*, 41, 7759-7764.
- Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., Russell, A. E. (2004). Lost at Sea: Where Is All the Plastic? *Science*, 304(5672), 838.
- Tsuchii, A. & Tokiwa, Y. (2006). Microbial Degradation of the Natural Rubber in Tire Tread Compound by a Strain of *Nocardia*. *Journal of Polymers and the Environment*, 14, 403-409.
- Turekian, K. K. (1977). The fate of metals in the oceans. *Geochimica et Cosmochimica Acta*, 41, 1139-1144.
- Turner, R. E. & Rabalais, N. N. (2003). Linking landscape and water quality in the Mississippi River Basin for 200 Years. *BioScience*, 53(6), 563-572.
- U.S. Air Force (1994). *Technical reports on chaff and flares. Technical report No. 5: Laboratory analysis of chaff and flare materials*. Prepared for U.S. Air Force Headquarters Air Combat Command, Langley Air Force Base, VA.
- U.S. Air Force (1997). Environmental Effects of Self-Protection Chaff and Flares. Final Report. U.S. Air Force Air Combat Command, Langley Air Force Base, VA.
- U.S. Army Corps of Engineers (2002). Silver Strand Shoreline Final General Reevaluation Report.
- U.S. Army Corps of Engineers (2003). Estimates for Explosives Residue from the Detonation of Army Munitions. Cold Regions Research and Engineering Laboratory. ERDC/CRREL TR-03-16. September 2003.
- U.S. Army Corps of Engineers (2007). *Explosives residues resulting from the detonation of common military munitions: 2002-2006*. (ERDC/CRREL TR-07-2). Prepared by Cold Regions Research and Engineering Laboratory. Hanover, NH. Prepared for Strategic Environmental Research and Development Program. Arlington, VA.
- U.S. Coast Guard (1994). *Aids to navigation (AtoN) battery release reporting requirements*. (COMDTINST 16478.10).

- U.S. Commission on Ocean Policy (2004). *An Ocean Blueprint for the 21st Century*. (Final Report). Washington, D.C.
- U.S. Department of the Navy (1996a). *Draft Environmental Assessment of the Use of Selected Navy Test Sites for Development Tests and Fleet Training Exercises of the MK46 and MK50 Torpedoes*. (U) (CONFIDENTIAL). Program Executive Office Undersea Warfare, Program Manager for Undersea Weapons.
- U.S. Department of the Navy (1996b). *Environmental Assessment of the Use of Selected Navy Test Sites for Development Tests and Fleet Training Exercises of the MK48 Torpedoes*. (U) (CONFIDENTIAL). Program Executive Office Undersea Warfare, Program Manager for Undersea Weapons.
- U.S. Department of the Navy (1998). *Environmental Assessment; MCON Project P-144, Explosive Ordnance Disposal Mobile Unit Three Waterfront Operations Facility*. Naval Amphibious Base, Coronado. Naval Facilities Engineering Command, Southwest Division. June.
- U.S. Department of the Navy (1999). *Scientific Management Decision Point (a) USEPA Step and 2/U.S. Navy Tier 1 Screening Ecological Risk Assessment, Pearl Harbor Sediment RI/FS – Section 2: Problem Formulation. Comprehensive Long-Term Environmental Action Navy, Contract No. N62742-90-D-0019*. Prepared by Ogden Environmental and Energy Services Co., Inc. Honolulu, Hawaii.
- U.S. Department of the Navy (2000). *Quantifying In Situ Metal Contaminant Mobility in Marine Sediments*. Technical Report 1826.
- U.S. Department of the Navy (2004). *Overseas environmental assessment for use of glacial acetic acid (GAA) and triethylphosphate (TEP) as chemical warfare agent stimulants during testing of the joint services lightweight stand-off chemical agent detector (JSLSCAD)*.
- U.S. Department of the Navy (2006). *Final environmental assessment, San Clemente Island wastewater treatment plant increase in maximum allowable discharge volume*.
- U.S. Department of the Navy (2007). *Overseas Environmental Assessment/Environmental Assessment for MK 48 Mod 6 Torpedo Exercises in Hawaiian Waters*. Naval Undersea Warfare Center Division, Newport, Rhode Island. June-July 2007.
- U.S. Department of the Navy (2008a). *Atlantic Fleet Active Sonar Training Environmental Impact Statement/Overseas Environmental Impact Statement. Chapter 4: Environmental Consequences*. Naval Facilities Engineering Command, Atlantic, Norfolk Virginia. December 2008.
- U.S. Department of the Navy (2008b). *Southern California Range Complex environmental impact statement/overseas environmental impact statement*. (Final). San Diego, CA: Naval Facilities Engineering Command Southwest.
- U.S. Department of the Navy (2010a). *Remedial Investigation Addendum, Pearl Harbor Sediment (Draft Final)*. Pearl Harbor Hawaii. Naval Facilities Engineering Command, Pacific. Contract Number N62742-03-D-1837, CTO 0034.

- U.S. Department of the Navy (2010b). *Water range assessment for the VACAPES Range Complex*. (Final Report). Prepared by Parsons, Norfolk, VA. Prepared for Naval Facilities Engineering Command, Atlantic Division.
- U.S. Environmental Protection Agency (1981). *An Exposure and Risk Assessment for Cyanide*. (EPA 440/4-85-008). Washington, D.C.: Office of Water Regulations and Standards.
- U.S. Environmental Protection Agency (1991). *Technical Support Document for Water Quality-based Toxics Control*. (EPA 505/2-90-001). Washington, D.C.: Office of Water.
- U.S. Environmental Protection Agency (1999). *August 1999 SINKEX Letter of Agreement between the Environmental Protection Agency and the Navy*.
- U.S. Environmental Protection Agency (2006). *National Guidance: Best Management Practices for Preparing Vessels Intended to Create Artificial Reefs*. Prepared by U.S. Environmental Protection Agency and the U.S. Maritime Administration.
- U.S. Environmental Protection Agency (2008a). *National Coastal Condition Report III. Chapter 8: Coastal Condition of Alaska, Hawaii, and the Island Territories, Part 2 of 2*. December 2008.
- U.S. Environmental Protection Agency (2008b). *Interim Drinking Water Health Advisory For Perchlorate*. (EPA 822-R-08-025).
- U.S. Environmental Protection Agency (2008c). *Toxicity Characteristic Leaching Procedure (TCLP) for VOCs, SVOCs, Chlorinated Pesticides and Herbicides, and Metals by SW-846 Method 1311 and Analysis*.
- U.S. Environmental Protection Agency (2009). *National Recommended Water Quality Criteria*.
- U.S. Environmental Protection Agency (2010). *Water Quality Criteria - Suspended and Bedded Sediments*. Appendix 3.
- U.S. Environmental Protection Agency (2011). *Palos Verdes Shelf. Region 9 Superfund*. Date Accessed: 09 November 2011. Website:
<http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dec8ba3252368428825742600743733/e61d5255780dd68288257007005e9422!OpenDocument>.
- Valette-Silver, N. J. (1993). *The Use of Sediment Cores to Reconstruct Historical Trends in Contamination of Estuarine and Coastal Sediments*. *Estuaries*, 16(3B), 577-588.
- Van Wijk, D.J. & Hutchinson, T.H. (1995). *The ecotoxicity of chlorate to aquatic organisms: a critical review*. *Exotoxicology and Environmental Safety*, 32, 244-253.
- Vitousek, P. M. & Howarth, R. W. (1991). *Nitrogen Limitation on Land and in the Sea: How Can it Occur?* *Biogeochemistry*, 13(2), 87-115.
- Walker, J. E. & Kaplan, D. L. (1992). *Biological degradation of explosives and chemical agents*. *Biodegradation*, 3, 369-385.

- Walker, S. W., Osburn, C. L., Boyd, T. J., Hamdan, L. J., Coffin, R. B., Smith, J. P., Montgomery, M. (2006). Mineralization of 2,4,6-Trinitrotoluene (TNT) *Coastal Waters and Sediments*.
- Wallace, G. T., Hoffman, G. L., Jr. & Duce, R. A. (1977). The influence of organic matter and atmospheric deposition on the particulate trace metal concentration of northwest Atlantic surface seawater. *Marine Chemistry*, 5, 143-170.
- Wang, W. X., Yan, Q. L., Fan, W. & Xu, Y. (2002). Bioavailability of sedimentary metals from a contaminated bay. *Marine Ecology Progress Series*, 240, 2-38.
- Wiseman, W. J. & Garvine, R. W. (1995). Plumes and coastal currents near large river mouths. *Estuaries*, 18(3), 509-517.
- Wren, P. A. & Leonard, L. A. (2005). Sediment transport on the mid-continental shelf in Onslow Bay, North Carolina during Hurricane Isabel. *Estuarine, Coastal and Shelf Science*, 63, 43-56.
- Wu, J. & Boyle, E. A. (1997). Lead in the western North Atlantic Ocean: completed response to leaded gasoline phaseout. *Geochimica et Cosmochimica Acta*, 61(15), 3279-3283.
- Wurl, O. & Obbard, J. P. (2004). A review of pollutants in the sea-surface microlayer (SML): a unique habitat for marine organisms. *Marine Pollution Bulletin*, 48, 1016-1030.
- Young, G. A. & Willey, R. A. (1977). *Techniques for Monitoring the Environmental Effects of Routine Underwater Explosion Tests*. Naval Surface Weapons Center.
- Zehr, J. P. & Ward, B. B. (2002). Nitrogen Cycling in the Ocean: New Perspectives on Processes and Paradigms. *Applied Environmental Microbiology*, 68(3), 1015-1024.
- Zhao, J. S., Greer, C. W., Thiboutot, S., Ampleman, G. & Hawari, J. (2004). Bidodegradation of the nitramine explosives hexahydro-1,3,5-triazine and octahydro-1,3,5,7-tetranitro. *Canadian Journal of Microbiology*, 50, 91-96.

This Page Intentionally Left Blank