
3.1 Sediments and Water Quality

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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 have been analyzed for sediments and water quality:

- Explosives and explosive byproducts
- Metals
- Chemicals other than explosives
- Other materials

Preferred Alternative (Alternative 1)

- Explosives: Impacts of explosive byproducts could be short-term and local; impacts of unconsumed explosives and metals would be long term and local. Chemical, physical, or biological changes to sediments or water quality would be measurable but below applicable standards, regulations, and guidelines, and would be within existing conditions or designated uses.
- Metals: Impacts of metals would 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.
- Chemicals: Impacts of chemicals other than explosives and impacts of other materials associated with ordnance 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.
- Other Materials: Impacts of other materials would 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 sediments and water quality in the Mariana Islands Training and Testing (MITT) Study Area (Study Area), and describe in general terms the methods used to analyze potential impacts on these resources. Open ocean and nearshore environments are considered in this section. Terrestrial environments (including wetlands) are discussed in Section 3.10 (Terrestrial Species and Habitats).

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

Sediments consist of solid fragments of organic matter from vegetation and animals and inorganic matter from the weathering of rock transported by water, wind, and ice (glaciers) and deposited at the bottom of bodies of water. Components of sediments range in size from boulders, cobble, and gravel to sand (particles 0.05 to 2.0 millimeters [mm] in diameter), silt (0.002 to 0.05 mm), and clay (less than or equal to 0.002 mm). Sediment deposited on the continental shelf is mostly transported by rivers, but also by local and regional currents and wind. Most sediment in nearshore areas and on the continental shelf is aluminum silicate derived from rocks on land deposited at rates of more than 10 centimeters (cm) (3.94 inches [in.]) per 1,000 years. Sediments may also be produced locally by nonliving particulate organic matter (“detritus”) that sinks to the bottom (Hollister 1973; Milliman et al. 1972). Some areas of the deep ocean contain an accumulation 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, substances that are otherwise scarce in the water column (e.g., metals) 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, where they are deposited, the properties of seawater, and other inputs and sources of contamination. Because these factors interact to some degree, sediments tend to be dynamic and are not easily generalized. For this discussion, “contaminant” refers to biological, chemical, or physical materials normally absent in sediments, but which, when present or when 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 retained in 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 the water between grains of sediment (“porewater”) and may bind them so strongly that their movement in the environment is limited (U.S. Environmental Protection Agency 2008a). 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, such as from mass wasting events (e.g., underwater slides, debris flows). If resuspended, 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 is a major influence on sediment quality by 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. Redox potential 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 may be 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 sediments provides food for resident microbes. Their metabolism can change the chemical environment in sediments, thereby increasing or decreasing the mobility of various substances and influencing the ability of sediments to retain and transform those substances (Mitsch and Gosselink 2007; U.S. Environmental Protection Agency 2008b). Bottom-dwelling animals often rework sediments in the process of feeding and burrowing, also known as “bioturbation.” In this way, marine organisms can 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 sediments may alter the form and availability of various substances. The metabolic processes of bacteria also influence sediment components directly. For example, sediment microbes may alter 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 and 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 weathering of natural rocks and mineralized deposits carried by rivers and through man-made inputs that often contribute amounts substantially above natural levels. Metals of greatest concern include cadmium, chromium, mercury, lead, selenium, arsenic, and antimony because they bioaccumulate, are toxic in low concentrations to biota, 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 (Keller et al. 2010).

Estuaries provide ecological functions such as sediment retention and nutrient cycling. Examples of these processes include the binding of materials to small particles in the water column and the settling of those particles on the bottom in calm areas (Li et al. 2008). Thus, the concentrations of various substances decrease with distance from shore. Once in the ocean, the locations 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 and Galkin 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 are carried into marine systems by rivers (U.S. Environmental Protection Agency 2008c), wind and rain also deposit materials in coastal waters and contribute to the mass and quality of sediments. For instance, 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 1995). These activities are generally considered 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 marine sediments, including microbial activity and natural hydrocarbon seeps (Boehm and Requejo 1986; Geiselbrecht

et al. 1998). Means (1995) noted that, because of the large binding capacities of organic-rich, 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.”

Morrison et al. (2013) summarized studies conducted along the western coast of Saipan and identified the commercial port (Saipan Harbor) and bulk fuel facility, a sewer outfall, a municipal waste dump, and two small-boat marinas as the primary sources of impacts on the sediments and biota within Tanapag Lagoon. For example, mercury levels were seen to decline in certain species of fish 18 months after a medical waste incinerator was shut down in 2006 (Denton et al. 2006).

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, and salinity and other dissolved elements. The discussion then considers how those characteristics of marine waters are influenced by physical, chemical, and biological processes.

Inshore and nearshore waters in the Study Area include bays and harbors. A bay is a body of water mostly surrounded by land and, as such, has calmer waters than the surrounding sea because the land blocks waves and reduces winds. A harbor is a landform where the adjacent body of water is deep enough to provide anchorage. Natural harbors, such as Apra Harbor in Guam, are surrounded on several sides by prominent land masses, while artificial harbors have breakwaters, sea walls, or jetties that are deliberately constructed, such as by dredging. See Figure 2.1-5, which shows the location of Naval Base Guam Apra Harbor.

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 freshwater delivered by large rivers. Chemical processes involve chemical properties, such as 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 due to 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. The maintenance of shells by specialized marine animals (e.g., mollusks) is made difficult by changes in pH outside of the normal range (Fabry et al. 2008; Veron 2009).

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 lower temperatures decrease reaction rates. 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. 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.

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 (with oxygen saturation levels ranging from 89 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 (27 percent [1.7 ml/L]) at intermediate depths between 1,000 and 3,000 feet (ft.) (300 and 900 meters [m]). Thereafter, the oxygen level increases with depth to about 6,500 ft. (2,000 m) (5.4 to 6.7 ml/L) and remains relatively constant at greater depths (Seiwell 1934).

A dissolved oxygen concentration of less than 2 milligrams per liter (mg/L) is considered to be poor, a condition referred to as hypoxia (Rabalais et al. 2002; U.S. Environmental Protection Agency 2008c). 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 the 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, nitrites, 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 (Anderson et al. 2002; Cloern 2001). 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 applied on land, wastewater, and atmospheric deposition of 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 concentration of elements in open ocean waters. The presence of extremely small organic particles (less than 0.63

micrometers), carbonates, sulfides, phosphates, and other metals, will influence the dominant form of some substances, and determine whether they remain dissolved or form solids.

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 = nanograms, kg = kilograms, ppt = parts per trillion
Source: Nozaki 1997

Salts in ocean waters may come from land, rivers, undersea volcanoes, hydrothermal vents, or other sources. When water evaporates from the surface of the ocean, the salts are left behind, and salinity will depend 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 1994 World Ocean Atlas (National Oceanic and Atmospheric Administration 1994) shows mean sea surface salinity in the Study Area to be in the range of 34 to 36 practical salinity units or parts per thousand (ppt). Observed salinity values in the vicinity of Cabras Island (the northern shore of Outer Apra Harbor in Guam) and the glass breakwater in a 1978 study were 34.43 ppt at the surface and 35.13 ppt at 150 m (492 ft.) depth (Lassuy 1979).

3.1.1.1.2.7 Influence 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 affects the density of seawater and, therefore, its movement relative to the sea surface (Libes 2009). Upwellings bring cold, nutrient-rich waters from deeper areas, increasing the productivity of local surface waters (Mann and Lazier 1996). Storms and hurricanes also result in strong mixing of marine waters (Li et al. 2006).

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). 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. (1,000 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 carbon dioxide, 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 organisms, or they may aggregate with other particles and sink (Mann and Lazier 1996; Wallace et al. 1977).

Runoff from coastal watersheds influences local and regional coastal water conditions, especially near large rivers. Influences include increased sediments and pollutants, and decreased salinity (Turner and Rabalais 2003). Coastal bays and large estuaries serve to filter river outflows and reduce total discharge of water 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 methylmercury (Mitchell and Gilmour 2008; Mitsch and Gosselink 2007).

3.1.1.1.2.8 Coastal Water Quality

A recent coastal condition report by the United States (U.S.) Environmental Protection Agency (EPA) (U.S. Environmental Protection Agency 2008b) 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 (U.S. Environmental Protection Agency 2008c). 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. Additional discussion of contaminants in sediments is provided in Section 3.1.1.1.1 (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 asphaltenes 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 the 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 produced by human activity often have adverse consequences for marine ecosystems (Summers et al. 1996), such as the atmospheric deposition of lead in 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 de Voogt 1999) and plastics. Although they are present in the open ocean and deep ocean waters, they are more common and in higher concentrations in nearshore areas and estuaries (Means 1995; Wurl and Obbard 2004). The surface of the ocean represents 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 significantly more toxic to those organisms than the adjacent sub-surface water (Wurl and Obbard 2004).

Persistent organic pollutants that adhere to particulates may sink to the seafloor. Sauer et al. (1989) noted that concentrations of PCBs and dichlorodiphenyltrichloroethane (DDT) have been declining in the open ocean for several decades. PCBs are mixtures of up to 209 individual chlorinated compounds that are related chemicals of similar molecular structure, 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 they 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).

3.1.1.2 Methods

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 [$\mu\text{g}/\text{L}$] 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 non-regulatory 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 Territory and Commonwealth Standards and Guidelines

Territorial (Guam) and commonwealth jurisdiction over sediments and water quality extends from the low tide line out to 3 nautical miles (nm). 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.¹ Examples of such uses of marine waters include fishing, shellfish harvest, and

¹ Although Guam and the CNMI are not states, the Clean Water Act includes Guam and CNMI in the definition of “state” in accordance with 33 U.S. Code 1362(3). Therefore, the EPA follows procedures for establishing sediment and water quality

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. Yap and Palau are also within the Study Area, but no training or testing activities occur within the territorial waters of these islands. Therefore, standards and guidelines specific to Yap and Palau are not analyzed in this section.

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. Code {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 detailed 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 and guidelines related to sediment and water quality.

Water and sediment quality effects associated with training and testing activities are analyzed for potential impacts to resources addressed in other sections of this Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS). These potential impacts are included in the resource-specific sections. For example, Section 3.9 (Fish) includes an analysis of potential impacts on water and sediment quality in relation to Essential Fish Habitat. Section 3.4 (Marine Mammals), Section 3.5 (Sea Turtles), Section 3.6 (Marine Birds), Section 3.7 (Marine Vegetation), and Section 3.8 (Marine Invertebrates) consider potential water and sediment quality effects and potential impacts to the various resources analyzed, including species protected under the Endangered Species Act.

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.

standards by first designating beneficial use of a water body. In Guam, the lead agency is the Guam Environmental Protection Agency. In the CNMI, the lead agency is the CNMI Department of Environmental Quality.

- 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 or 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 resuspend, transport, and redeposit sediments and associated substances in areas far removed from the source (Hameedi et al. 2002; U.S. Environmental Protection Agency 2008c). 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 (DoD) 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 regarding 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 sediments 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 sediments 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 is discussed thereafter.

3.1.2.1 Sediments

The following subsections discuss sediments in the Study Area.

3.1.2.1.1 Marine Sediments

In support of the *EIS for the Designation of an Ocean Dredged Material Disposal Site Offshore of Guam* (U.S. Environmental Protection Agency 2010a), extensive sediment studies were conducted at two alternative disposal sites that begin approximately 12.4 nm north and 8.9 nm northwest of the entrance to Naval Base Guam Apra Harbor, and at a proposed reference site (required for Tier III testing in accordance with the Marine Protection, Research, and Sanctuaries Act) located inshore of the two alternative sites. Alternative sites and the inshore reference site are located in the MITT Study Area, and were selected to avoid navigation lanes, military use areas, marine protected areas, important fishing areas (including fish aggregating devices), and other environmental constraints. Information presented in the following paragraphs provides a summary of these studies as some indication of sediment characteristics and good sediment quality in the Study Area.

Sediments in all three locations were found to consist of sand, silt, and clay (no gravel) in that order of dominance and with slightly varying distribution. Sediment samples from the northwest alternative site were finer than those from the north alternative site, which is attributed to the contrast in seafloor location of these sites. The northwest site is located on the southeastern slope of a seamount, whereas the north site is located in a depression between seamounts.

Concentrations of total organic carbon, nitrogen, sulfides and solids in the sediments at all three locations were low, although total organic carbon concentrations at the reference location were more than twice as high at the alternative sites most likely because the reference location is closer to shore. Nitrogen concentrations were found to be approximately two orders of magnitude lower than the biologically toxic concentration of 30 parts per million (ppm) in sediment samples from all three locations. Sulfides ranged from 175 to 200 ppm and percent solids averaged about 55 percent in sediment samples from all three locations.

Analyses for 23 metals were conducted on sediment samples from all three locations. Cadmium, zinc, mercury, arsenic, chromium, lead, and silver concentrations at all three locations were below the Effects Range Low value when compared to central Pacific Ocean sediment data collected at comparable depths with similar bathymetric features.² Sediment metal analyses resulted in average copper concentrations slightly exceeding the Effects Range Low but at concentrations well below the Effects Range Median, and average nickel concentrations were approximately two times the Effects Range Low, but slightly less than the Effects Range Median for sediment samples from all three locations.

² Sediment quality criteria, as defined by the National Oceanic and Atmospheric Administration, are based on extensive sediment toxicity test data. The lower 10th percentile of these concentrations that were labeled as toxic is the Effects Range Low. Concentrations below the Effects Range Low are within the defined "no effects range." The Effects Range Median is the median concentration of the sediment test results labeled as toxic. Concentrations between the Effects Range Low and Effects Range Median are within the defined "possible effects range," and concentrations above the Effects Range Median are defined as the "probable effects range."

Sediment metal concentrations for barium, cobalt, copper, lead, manganese, nickel, titanium, vanadium and zinc were below the average concentrations in oceanic crustal material. Average aluminum concentrations were an order of magnitude greater, while average chromium concentrations were more than double the oceanic crustal concentrations measured in the central Pacific Ocean.

Polycyclic aromatic hydrocarbons, organochlorine pesticides, and polychlorinated biphenyls were also analyzed in the sediment samples. Because of its chemical affinity for lipids, polycyclic aromatic hydrocarbons in the marine environment are found primarily in carbon rich sediments. Unlike polycyclic aromatic hydrocarbons, organochlorine pesticides and polychlorinated biphenyls are solely human-related in origin. Organochlorine pesticides and polychlorinated biphenyls were not detected in sediment samples from all locations. In the north site and inshore reference study areas, polycyclic aromatic hydrocarbons were detected in very low concentrations.

Organotins, which have no known natural sources and are assumed to have only human-related origins, were analyzed in the sediment samples. None were detected in sediment samples from all three locations.

Dioxins and furans, which are byproducts of combustion and chemical processes involving chlorine and that can also result from natural processes such as volcanic eruptions and forest fires, were analyzed in the sediment samples. It should be noted that the Study Area contains a number of active volcanoes, including the submerged volcanic areas of the Mariana Trench Marine National Monument. Dioxins and furans were detected in low concentrations in sediment samples from all three locations.

Apra Harbor is a natural harbor, protected by Orote Peninsula on the south and Cabras Island on the north. Development of Naval Base Guam Apra Harbor following World War II required sediment dredging. Historical construction dredging occurred in Inner Apra Harbor in the late 1940s and between 1962 and 1964. Initial deepening of Inner Apra Harbor and development of the Naval Base was conducted between 1946 and 1950 with design depths of -32 ft. (-10 m) mean lower low water. Between 1962 and 1964, a construction dredging project increased water depths of the northern half of Inner Apra Harbor to -35 ft. (-11 m) mean lower low water. Approximately 64,000 cubic yards (49,390 cubic meters) of sediment was likely dredged and placed upland between 1962 and 1964. Historical maintenance dredging occurred in Inner Apra Harbor in 1978 and 2003 and one maintenance dredging project was conducted in Outer Apra Harbor between 1997 and 1998. Between 1997 and 1998, sediment was dredged along Delta and Echo Fuel Piers in Outer Apra Harbor. In 2003, maintenance dredging of Inner Apra Harbor was conducted after a 25-year hiatus (U.S. Department of the Navy 2006b). See Figure 2.1-5 for Naval Base Guam Apra Harbor locations.

Guam's Commercial Port is on Cabras Island. The Port Authority of Guam, which administers the Commercial Port, Agana Boat Basin, and the Agat Marina, has not conducted any dredging projects over the past 30 years (U.S. Department of the Navy 2006b). Historical dredging only occurred at the Agat Marina during its construction in 1992 (U.S. Department of the Navy 2006b).

3.1.2.1.2 Marine Debris, Military Expended Materials, and Sediments

In this discussion, marine debris and marine litter are synonymous. As defined by the United Nations, marine litter is any persistent, manufactured, or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment. Marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds; or accidentally lost, including material lost at sea in

bad weather (United Nations Environment Programme 2011). The main sea/ocean-based sources of marine litter are: (1) merchant shipping, ferries, and cruise liners; (2) fishing vessels; (3) military fleets and research vessels; (4) pleasure craft; (5) offshore oil and gas platforms; and (6) fish farming installations (United Nations Environment Programme 2011).

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 3.1.2.2.1 (Marine Debris and Water Quality). Although plastics are resistant to degradation, they do gradually break down into smaller particles because of sunlight and mechanical wear (Law et al. 2010). 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 1,650–10,500 ft. (503–3,200 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) as well as other synthetic polymers, although the latter occurs more slowly (Shah et al. 2008).

During the 2010 International Coastal Cleanup sponsored by the Ocean Conservancy and conducted on September 25, 2010, marine litter collected along the shores and ocean/waterways near Guam totaled 17,987 pounds (lb.) (8,159 kilograms [kg]). In the Commonwealth of the Northern Mariana Islands (CNMI), collected marine litter along shores and ocean/waterways near Saipan, Tinian, and Rota totaled 5,147 lb. (2,335 kg); 2,572 lb. (1,167 kg); and 999 lb. (453 kg), respectively. A review of the data from the cleanup shows that items collected from underwater cleanups using certified scuba divers in the waters off of Guam and the CNMI included, among other things, rope, fishing line, fishing nets, plastic sheeting/tarps, buoys/floats, plastic bottles, and strapping bands (Ocean Conservancy 2011). Litter collected at these sites originated from ocean-based as well as land-based sources.

There are no readily available data regarding military expended materials in the Study Area. Keller et al. (2010) conducted a survey of marine litter collected from the seafloor off the coasts of Washington, Oregon, and California during annual groundfish surveys in 2007 and 2008, which included the Navy's west coast training complexes. Depth of trawling ranged from 180 to 4,200 ft. (55 to 1,280 m) and marine litter was recovered in 469 tows. Categories of marine litter collected included plastic, metal, glass, fabric and fiber, rubber, fishing, and others. Plastic and metallic litter occurred in the greatest number of hauls, followed by fabric and glass. Data regarding military materials as a component of materials recovered are provided in Table 3.1-2.

Table 3.1-2: Military Materials as Components of Materials Recovered on the West Coast, United States, 2007–2008

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

Notes: kg = kilograms, lb. = pounds

Source: Keller et al. 2010

3.1.2.1.3 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, becoming more soluble and potentially more available.

As noted in the beginning of this section, tropical storms can have significant impacts on the resuspension 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. If storm frequency and intensity increase, the additional disturbance of sediments may negatively impact water quality in nearshore and coastal areas. This issue is addressed in more detail in Section 3.1.2.2.1 (Marine Debris and Water Quality).

3.1.2.2 Water Quality

Data on quality of surface waters are reported by the states to the U.S. EPA and are summarized in the Water Quality Assessment and Total Maximum Daily Loads Information database for waters listed under Section 303(d) of the Clean Water Act. The database includes information on rivers and streams; lakes, reservoirs and ponds; bays and estuaries; coastal shoreline; and wetlands. Only a small portion of the waters in and around Guam and the CNMI have been assessed and the summary presented here only relates to marine waters.

Forty-two percent of the assessed 4 percent of bays and estuaries and all (100 percent) of the assessed 14 percent of coastal shoreline in Guam were determined to be impaired as defined under Section 303(d) of the Clean Water Act. In bays and estuaries, the causes of impairment were determined to be polychlorinated biphenyls (as determined in fish tissue), pesticides, toxic organics and inorganics, metals (other than mercury), nutrients (nitrates), oxygen depletion, pathogens (*Enterococcus* bacteria), and dioxins. In coastal shoreline waters, the causes of impairment were identified to be pathogens (*Enterococcus* bacteria) and polychlorinated biphenyls.

Of the 225.3 miles (mi.) (362.6 kilometers [km]) of coastal shoreline waters assessed in the CNMI, 84.9 mi. (136.6 km) or 36 percent of the assessed coastal shoreline were determined to be impaired.

The causes of impaired coastal shoreline waters in the CNMI were determined to be nutrients (phosphate), pathogens (*Enterococcus* bacteria), oxygen depletion, and impaired biota.

The National Coastal Condition Reports describe the ecological and environmental conditions in U.S. coastal waters. Preparation of these reports represents a coordinated effort among the U.S. EPA, the National Oceanic and Atmospheric Administration, the U.S. Geological Survey, the U.S. Fish and Wildlife Service (USFWS), coastal states, and the National Estuary Programs. The draft National Coastal Condition Report IV reports on data collected from 2003 to 2006 and for the first time includes information on Guam, but not for the CNMI. The report relies heavily on coastal monitoring data from the U.S. EPA's National Coastal Assessment to assess coastal condition by evaluating five indices of condition—water quality, sediment quality, benthic community condition, coastal habitat loss, and fish tissue contaminants. The overall condition of coastal waters in Guam was rated “good” as shown in the National Coastal Condition Report IV factsheet (United Nations Environment Programme 2011).

In addition to the sediment studies conducted to support the *EIS for the Designation of an Ocean Dredged Material Disposal Site Offshore of Guam* (U.S. Environmental Protection Agency 2010a), water column characterization as well as chemical analysis of marine waters at the two alternative disposal sites and at the proposed reference site were conducted. The following paragraphs provide a summary of the information presented in this EIS/OEIS.

Water column characteristics, including temperature, salinity, transmissivity (the rate at which water is transmitted through a unit of the water column), turbidity and dissolved oxygen, measured across the entire study region were consistent with each other and followed oceanographic trends typical for tropical latitudes. Temperature remained relatively constant at around 82.8 degrees Fahrenheit (°F) (28.2 degrees Celsius [°C]) in the surface layer, decreased rapidly through a thermocline layer between water depths of approximately 490 to 1,310 ft. (150 to 400 m), and then steadily decreased to minimum average values of 35.6°F (2.0°C) observed near the seafloor. Salinity concentrations also remained constant in the mixed surface layer at 34.5 ppt, increased sharply near the top of the thermocline to an average value of 35.1 ppt, decreased to a minimum value near the base of the thermocline at an average concentration of 34.3 ppt, and remained relatively constant through the remainder of the water column at 34.6 ppt. Turbidity and transmissivity values were relatively constant throughout the entire water column with minor changes. Turbidity ranged from 43.5 Nephelometric Turbidity Units (NTU) to 44.9 NTU in surface waters, 42.1 NTU to 43.3 NTU just below the thermocline, and 43.5 NTU to 44.9 NTU near the seafloor. Transmissivity values ranged from 84.5 to 85.2 percent in surface waters. Dissolved oxygen concentrations in surface waters averaged approximately 5.98 mg/L; 2.21 mg/L at a depth of 1,800 ft. (549 m); and from 3.66 mg/L to 3.92 mg/L near the seafloor.

In general, chemical characteristics of water samples from the two alternative sites and the reference site were similar. Very few chlorinated pesticides or polyaromatic hydrocarbons were detected in any of the water samples. Concentrations of all chlorinated pesticides, including polychlorinated biphenyls, were not detected at each depth interval, except in one bottom water sample collected at a station at the northwest alternative site. At this station, 4,4'-DDT was detected at an estimated concentration of 4.8 nanograms/L (ng/L). Polyaromatic hydrocarbons analyzed from water samples were not detected except for naphthalene, 2-methylnaphthalene, 1-methylnaphthalene and perylene. Naphthalene was found at all three locations at maximum concentrations five orders of magnitude below the Criterion Maximum Concentration for naphthalene. The analyte 2-methylnaphthalene was detected in very low concentrations in the bottom sample from the north alternative site and the sample from the top of the thermocline at the northwest alternative site. The analyte 1-methylnaphthalene was detected only in

the surface sample from the north alternative site at a concentration of 1.5 ng/L. Perylene was detected in samples taken at the top of the thermocline from the northwest alternative site and the reference site at estimated concentrations below the 5 ng/L Maximum Residue Limit for perylene. With the exception of perylene, the polyaromatic hydrocarbons detected in the water samples may have been attributable to the proximity of the designated smoking area on board the sampling vessel to the deployment and retrieval area of the water samplers.

At the two alternative sites, nutrients tended to increase in concentration with increasing water depth, whereas total organic carbon tended to decrease in concentration with increasing water depth. Ammonia ranged from non-detectable levels at the surface to 0.03 mg/L near the bottom at the north alternative site, but was not detected at the surface and near the bottom at the northwest alternative site. Nitrate concentrations ranged from non-detectable levels in the surface sample to an average concentration of 0.5 mg/L in the near bottom sample. Dissolved orthophosphate concentrations ranged from non-detectable levels at the surface to a maximum concentration of 0.08 mg/L in the near bottom sample. Total organic carbon concentrations ranged from 0.4 to 0.6 mg/L in the surface sample to an estimated value of 0.1 mg/L in the near bottom sample.

At the reference site, ammonia was not detected in any of the depth specific samples. Nitrate concentration ranged from non-detectable levels in the surface to 0.33 mg/L in the near bottom sample. Dissolved orthophosphate concentrations ranged from non-detectable levels at the surface to 0.07 mg/L in the near bottom sample. Total organic carbon concentrations ranged from 0.4 mg/L in the surface to an estimated concentration of 0.1 mg/L in the near bottom sample.

Metals concentrations were relatively low compared to Criterion Continuous Concentration and Criterion Maximum Concentration values and were within the same order of magnitude of other deep ocean reference site samples. (Note: The Criterion Continuous Concentration is also known as the “chronic” aquatic life ambient water quality criterion. These criteria use toxicity tests from the same types of aquatic life used for acute toxicity testing, but these tests measure effects on long-term survival, growth, and reproduction of marine/estuarine aquatic life. Chronic criteria represent the highest four-day average concentration that should not result in unacceptable toxicity during a long time event. The Criterion Maximum Concentration is also known as the “acute” aquatic life ambient water quality criterion. These criteria use toxicity tests from eight different taxonomic families of marine/estuarine aquatic life in which mortality or immobility was the test endpoint. Acute criteria represent the highest one-hour average concentration that should not result in unacceptable effects on aquatic organisms.) All the dissolved metals concentrations were one to three orders below their respective Criterion Continuous Concentration values.

3.1.2.2.1 Marine Debris and 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: land-based, ocean-based, and general (i.e., origin unspecified; Sheavly 2007). Land-based debris may blow in on the wind, wash in with storm water, arise from recreational use of coastal areas, and be 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 amount of debris found (Sheavly 2010). These materials are concentrated at the surface and in the water column.

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; nonylphenol may have come from the pellets themselves or may have been adsorbed from the seawater.

3.1.2.2.2 Climate Change and 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 the normal range can make it difficult for marine organisms with shells 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 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 carbon dioxide. Rising seawater temperatures combined with decreasing ocean pH can be especially detrimental to corals (Anthony et al. 2008). Water pollution and natural disturbance (e.g., hurricanes) can inflict additional stress on corals (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 (Description of Proposed Action and Alternatives) may impact sediments and water quality in the Study Area. Tables 2.8-1 through 2.8-4 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 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
- 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 specific analysis of the training and testing activities presented in this section considers the relevant components and associated data within the geographic location of the activity (see Tables 2.8-1 and 2.8-2) and the resource.

In a previous study of the impact of amphibious landings on corals at Unai Chulu in Tinian during Tandem Thrust 1999, it was observed that sediment plumes were generated in the track of the amphibious vehicles. The plumes remained localized in the track area, dissipated within minutes, and were not qualitatively different from episodes of sediment resuspension during periods of storm-generated waves that occur routinely on Tinian (Marine Research Consultants 1999). Amphibious assault and amphibious raid training do not involve the introduction of military expended materials into the water, therefore, no further analysis of this training activity is provided here.

The potential impact of domestic wastewater was not analyzed as no additional DoD facilities to house temporary military personnel that would train in the Study Area would be constructed as part of the Proposed Action. Training activities on land-based ranges (with the exception of training activities on Farallon de Medinilla [FDM]) would remain at or slightly above existing levels and have been analyzed in the Mariana Islands Range Complex EIS/OEIS. Only the potential impact of runoff to surface drainage areas of FDM is analyzed in this EIS.

Because of the expansive area of the Study Area, recovery of any hazardous military expended materials is unlikely, except in confined shore- and land-based training areas. The Navy has defined best management practices and committed to mitigation measures to offset potential impacts from military training to sediment and water quality in the Study Area.

3.1.3.1 Explosives and Explosive Byproducts

3.1.3.1.1 Introduction

Explosives are complex chemical mixtures that may affect sediment and water quality as a result of byproducts left in the water and distribution of unconsumed byproducts in the sediment. Explosives that detonate on land could contaminate and loosen soils and subsequently get transported into surface drainage areas or nearshore waters. It should be noted that FDM is highly susceptible to natural causes of erosion because it is comprised of highly weathered limestone overlain by a thin layer of clay soil. Sediments entering the nearshore environment as a result of natural processes or explosives could cause temporary water quality impacts, some of which may be in foraging areas used by marine organisms. By limiting the location and extent of target areas, along with the types of ordnance allowed within specific impact areas, the Navy minimizes the potential for soil transport and, thus, water quality impacts.

Underwater explosions resuspend 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 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, 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 (Chemicals Other Than Explosives).

When they are used, explosives may undergo high-order detonation, a low-order detonation, or may fail to detonate. High-order (“complete”) detonations consume 98 to 99 percent of the explosive; 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 to 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 “explosive 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 explosive 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, explosives would be used: (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; (2) underwater during mine countermeasure and mine neutralization training and testing activities and from training and testing activities that use explosive sonobuoys; and (3) on land (at FDM) during weapons firing. Mine countermeasure and neutralization activities occur beneath the surface and on or near the bottom, typically in fairly shallow areas. Explosive charges for training and testing activities range in size from 2 to 20 lb. (1 to 9 kg) net explosive weight (NEW).

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 (Renner and Short 1980; Hewitt et al. 2003). Table 3.1-3 details the byproducts of underwater detonation (UNDET) of royal demolition explosive.

Table 3.1-3: Byproducts of Underwater Detonation of Royal Demolition Explosive

Byproduct	Percent of Total, by Weight	Byproducts	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		

Note: “<” means less than

3.1.3.1.3 Ordnance Failure and Low-Order Detonations

Table 3.1-4 provides information about the rates of failure and low-order detonations for explosives and other munitions.

Table 3.1-4: Rates of Failure and Low-Order Detonations

Ordnance	Failure Rate (Percent)	Low-Order Detonation Rate (Percent)
Guns/artillery	4.68	0.16
Hand grenades	1.78	—
Explosive ordnance	3.37	0.09
Rockets	3.84	—
Submunitions ¹	8.23	—

¹ Submunitions are munitions contained within and distributed by another device such as a rocket.
Sources: MacDonald et al. 2005; U.S. Army Corps of Engineers 2007

3.1.3.1.4 Approach to Analysis

Most activities involving explosives and explosive byproducts would be conducted more than 3 nm off shore in the Study Area. Out to 12 nm, these activities would be subject to federal sediment and water quality standards and guidelines.³

Explosives are also used onshore and in nearshore areas (low tide line to 3 nm) specifically designated for mine countermeasure and mine neutralization activities. These activities would be subject to state sediment and water quality standards and guidelines.

For explosive byproducts, “local” means the water column that is disturbed by an UNDET. For unconsumed explosives, “local” means the area of potential impact from explosives in a zone of sediment about 66 in. (167.6 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

There are no existing Guam and CNMI standards and guidelines for sediments and water quality related to explosives and explosive byproducts.

3.1.3.1.4.2 Federal Standards and Guidelines

Table 3.1-5 summarizes the EPA criteria for explosives and explosive byproducts in saltwater.

Table 3.1-5: Federal Criteria for Explosives and Explosive Byproducts in Saltwater

Explosives, Explosive Byproducts	Criterion Maximum Concentration (µg/L)	Criterion Continuous Concentration (µg/L)
Cyanide	1	1

Notes: (1) “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; (2) µg/L = micrograms per liter

Source: U.S. Environmental Protection Agency 2009

³ Proposed training and testing activities also occur beyond 200 nm, but U.S. legal and regulatory authority does not extend beyond 200 nm. In such cases, impacts will be evaluated against federal standards and guidelines.

3.1.3.1.5 Fate of Military Munitions in the Marine Environment

3.1.3.1.5.1 Explosives and Explosive Byproducts

Little data are available on the fate and degradation of unconsumed explosives in sediments (Zhao et al. 2004b). 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 there is “little published information on TNT degradation in seawater or sediments aside from the work of Carr and Nipper (2003).” Still, Zhao et al. (2004b) 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 sediments.” The studied compounds included 2, 6-dinitrotoluene, tetryl, and picric acid. They remarked that “levels of ordnance compounds that would be of concern in sediments have not yet been identified.”

The behavior of explosives and explosive byproducts in marine environments and the extent to which those constituents have adverse impacts are influenced by numerous 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 3.1-6. 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.

Table 3.1-6: Water Solubility of Common Explosives and Explosive Degradation Products

Compound ¹	Water Solubility ²
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
Pentaerythritol tetranitrate (E)	43
Royal demolition explosive (E)	38
High melting explosive (E)	7

¹ “E” refers to explosive; “D” refers to explosive degradation product.

² Units are milligrams per liter at 20 degrees Celsius.

Source: U.S. Department of the Navy and U.S. Fleet Forces Command 2008

Solubility rates are not affected by pH but increase as temperature increases (Lynch et al. 2002). As Table 3.1-6 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, and 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 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 carbon dioxide, 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 sediments (i.e., finer-grained). Pavlostathis and Jackson (2002) reported the uptake and metabolism of TNT by the marine microalgae *Anabaena* sp. 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-Uribe 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 they 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. (2004a) 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, carbon dioxide, 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 (ppb). Studies examining the impact of ordnance on marine organisms have produced mixed results. More information regarding these studies is provided below. The amount and concentration 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 impact 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 (Darrach 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 ppb or high parts per trillion. The sampling distance was 6–12 in. (15–30 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. (2004a) 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 mi. (8 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 through 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 3–6 ft. (1–2 m). The authors compared their sampling distance to that used by Durrach et al. (1998), that is, 6–12 in. (15.2–30.5 cm). They indicated that the project sampling distance may have been too far to detect any chemical agents or explosives and that sampling distance may be a significant factor determining whether munitions constituents can be detected near discarded munitions. Samples with elevated concentration 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 at known ocean dumping sites. The sites were 85 mi. (137 km) west of Cape Flattery, Washington, and

172 mi. (277 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 sediments 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 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. (48.3 km) long and 2 mi. (3.2 km) wide. The average density of munitions is about 2,225 tons per square mile (mi.^2) (5,700 tons per square kilometer [km^2]). 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 from other Scottish coastal areas.

Nipper et al. (2002) studied the impact of the explosives 2,6-dinitrotoluene, tetryl, and picric acid in 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 acknowledged that "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. Explosives not consumed during these detonations are spread over an area that would, on average, contribute 10 $\mu\text{g}/\text{kg}$ (ppb) 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 3.1-7 provides (1) the amount of explosive remaining after UNDET of 5 and 20 lb. 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 2.7 lb. (1.0 kg) of royal demolition explosive; a 20 lb. block contains 18.2 lb. (8.3 kg) of royal demolition explosive. Pennington et al. (2006) assumed that 0.02 percent of royal demolition explosive residue remained after detonation. 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 3.1-7: Volume of Water Needed to Meet Marine Screening Value for Royal Demolition Explosive

Screening Value for Ecological Marine Surface Water	5-Pound (2.26 kg) Charge		20-Pound (9 kg) Charge	
	Amount of Royal Demolition Explosive Remaining after Detonation	Attenuation Needed to Meet Screening Value	Amount of Royal Demolition Explosive Remaining after Detonation	Attenuation Needed to Meet Screening Value
5,000 $\mu\text{g}/\text{L}$	0.01 ounce (0.41 gram)	22 gallons (82.6 liters)	0.06 ounce (1.65 grams)	87 gallons (330 liters)

Notes: kg = kilograms, $\mu\text{g}/\text{L}$ = micrograms per liter

Source: U.S. Department of the Navy 2010

The amount of pentaerythritol tetranitrate in detonation cord associated with any UNDET activity is low (approximately 13.4 ounces [381 grams {g}]). Assuming 5 percent is not consumed in the detonation, 0.7 ounce (19.0 g) of pentaerythritol tetranitrate would be present. This amount would attenuate to a level below the DoD Range and Munitions Use working group benchmark risk screening value for marine surface water in 60 gallons (gal.) (227.1 liters [L]) of water (U.S. Department of the Navy 2010).

3.1.3.1.5.3 Farallon de Medinilla Specific Impacts

The Navy has conducted annual marine dive surveys in waters surrounding FDM from 1999 to 2010. No survey was conducted in 2011, and the most recent survey was conducted in 2012 (U.S. Department of the Navy 2013a). The dive surveys have included marine ecologists from the National Marine Fisheries Service, USFWS, CNMI Division of Fish and Wildlife, and Navy contractors. All the surveys conducted after 2004 were performed by the Naval Facilities Engineering and Expeditionary Warfare Center Scientific Diving Services group. The Explosive Ordnance Disposal Unit Detachment Marianas provided identification of ordnance items located in waters off of FDM. Figure 3.1-1 shows the location of approximate dive survey tracks in waters surrounding FDM during the most recent dive survey, which was completed in August 2012 (U.S. Department of the Navy 2013a).

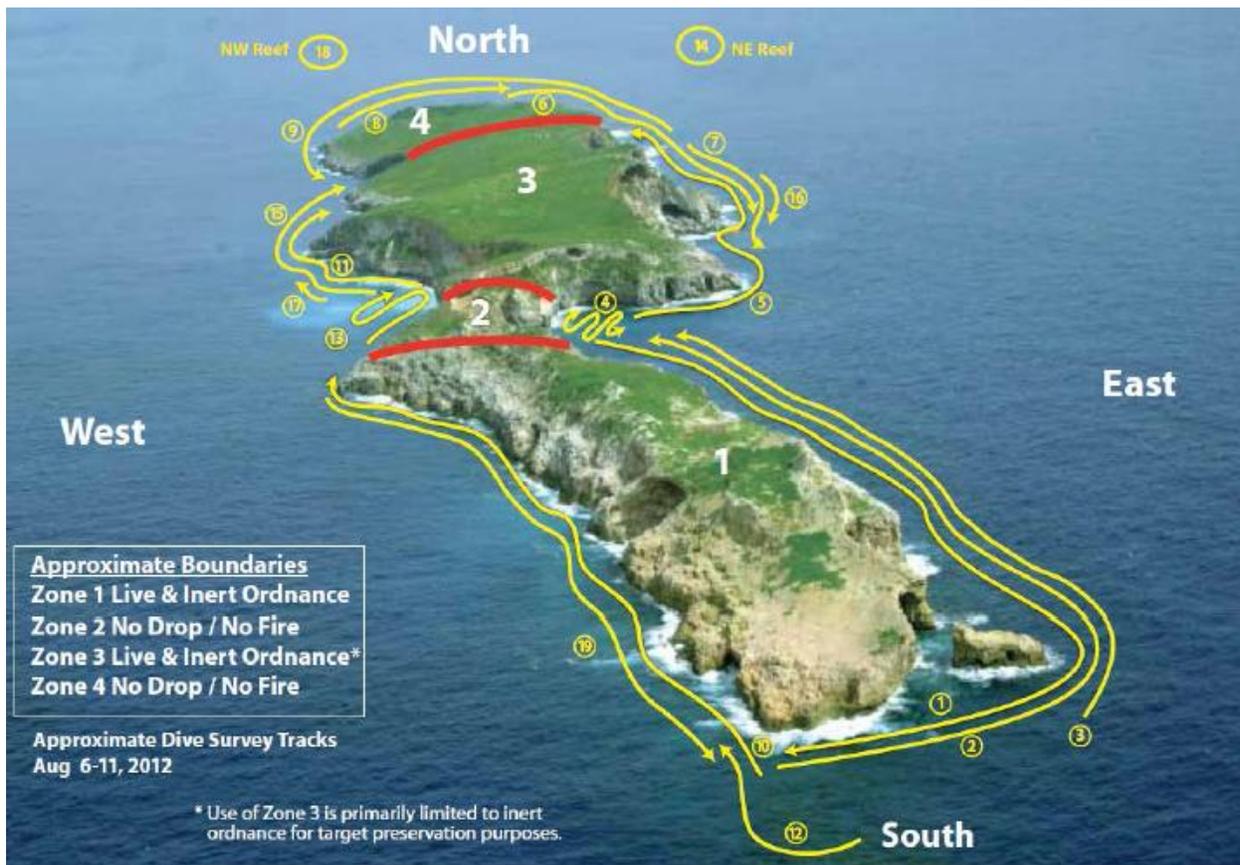


Figure 3.1-1: Location of Approximate Dive Survey Tracks off of Farallon de Medinilla (View from the South)

Based on these surveys, there is no evidence that long-term adverse impacts to the nearshore environment have taken place as a result of military training activities. These findings are based on the number of detectable impacts, the size of those impacts, and the apparent recovery time for the resource to recover. Impacts to the physical environment clearly attributable to military training

activities were noted in 2007, 2008, 2010, and 2012 (U.S. Department of the Navy 2013a). Indirect impacts, such as ordnance skipping or eroding off of FDM and rock and ordnance fragments blasted off of the island, were detected in every survey year. The 2004 report included the following conclusion (U.S. Department of the Navy 2005):

“Although some damage can be directly attributed to ordnance impacts, natural factors also contribute to the changes. Examination of photographs from 1944 indicates that changes in the geologic structure of the island by erosion and mass wasting...have been going on for decades.”

The dive surveys completed in 2004 were completed shortly after Typhoon Ting Ting, which passed through the Mariana Islands in June 2004 and afforded an opportunity to observe damage to the island and nearshore environment of FDM from typhoons. Observations of fresh coral branch breakages, fresh boulder/rock slides, and submerged exposure of bright yellow-orange patches of underlying rock were attributed to concussive force of waves generated by Typhoon Ting Ting (U.S. Department of the Navy 2005).

Dive surveys completed in 2005 noted that disturbed sites in 2004 showed no color differences with surrounding undamaged areas, and new small (less than 3 cm) scattered colonies of coral and crustose coralline algae. By 2006 and observed again through 2012, no visual evidence of abnormalities, damaged, or diseased coral could be detected (U.S. Department of the Navy 2013a). Further, no new submerged cliff blocks were observed between 2005 and 2012. Small to medium size fresh rock fragments (generally less than 1 ft. [30 cm]) have been observed yearly, and are attributed to detonation impacts. In 2007, the first clear indication of a detonation of a bomb on the seafloor was observed. The impact area was measured to be approximately 100 square feet (9 square meters). During the subsequent survey in 2008, the impact area supported new growth of stony corals and crustose algae; by 2009, no trace of the disturbance could be detected by the surveyors (Smith and Marx 2009). It should be noted that the vast majority of unexploded ordnance observed in the water lacked fins and tail assemblies, which indicates that the ordnance either skipped or ricocheted off of the island or were eroded or washed off of FDM at a later date (Smith and Marx 2009).

Based on these direct observations of damage off the coast of FDM, the majority of disturbances to the seafloor sediments, substrates, and mass wasting of FDM can be attributed to typhoons and storm surges. Further, damage attributed to military training activities recovered within 2–3 years at the same rate of damage associated with natural phenomenon.

The dive surveys have also monitored water quality indicators that have been associated with diminished water quality in other locations. For instance, high densities of macrobioeroders (e.g., boring sponges); bleaching of corals, surface lesions, or dead patches on stony corals' or stony coral mucus production have been associated with sedimentation, pollutants, or other stressors that diminish water quality (Hughes and Jackson 1980, Riegl 1995, Stafford-Smith and Ormond 1992, Stafford-Smith 1993, Wild et al. 2005, Bruno 2003, Sutherland et al. 2004, and Cooper 2008). A moderate bleaching event was noted in 2007, and a barnacle infestation was noted in 2012 (U.S. Department of the Navy 2013a). The bleaching event was regional and extended from southern Japan through the Mariana Islands and south through waters surrounding Palau. Subsequent surveys observed soft and fire corals had recovered completely and 75 percent of the stony corals had recovered by 2008 (Smith and Marx 2009).

Throughout all dive surveys, the coral fauna at FDM were observed to be healthy and robust. The nearshore physical environment and basic habitat types at FDM have remained unchanged over the 13 years of survey activity. These conclusions are based on (1) a limited amount of physical damage, (2) very low levels of partial mortality and disease (less than 1 percent of all species observed), (3) absence of excessive mucus production, (4) good coral recruitment, (5) complete recovery by 2012 of the 2007 bleaching event, and (6) a limited number of macrobioeroders and an absence of invasive crown of thorns starfish (*Acanthaster planci*). These factors suggest that sedimentation that may result from military use of FDM is not sufficient as to adversely impact water quality.

3.1.3.1.6 Evaluation of Alternatives

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. UNDETs always occur during mine countermeasure and mine neutralization training and testing, explosives testing, and during the use of explosive torpedoes, percussion grenades, and explosive sonobuoys.

The amount of explosive material in, or NEW of, each military expended material used during training and testing activities in the Study Area was identified using several resources. The amount of residual explosive material was estimated by combining the estimated amount of residual explosive materials after high-order detonations, low-order detonations, and ordnance failures.

3.1.3.1.6.1 No Action Alternative

Training Activities

Subsurface High-Order Explosions and Explosive Byproducts

Under the No Action Alternative, most training activities that use underwater explosives would be during mine countermeasure and neutralization training, with charges up to 10 lb. (4.5 kg). These underwater explosives would occur at Piti Point Floating Mine Neutralization Site, Apra Harbor UNDET Site (located within Outer Apra Harbor), and Agat Bay Floating Mine Neutralization Site. The impacts of explosive 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.

High-Order Explosions at FDM and Explosive Byproducts

Explosive ordnance is used on FDM during strike warfare exercises. The impacts of explosive byproducts on sediment and water quality on FDM and in waters surrounding FDM would be indirect, short term, local, and negative. See Section 3.1.3.1.5.3 (Farallon de Medinilla Specific Impacts) for a discussion of direct observations of impacts related to military use of FDM. Explosive ordnance could result in erosion of soil and runoff of contaminated sediments into surrounding waters. However, chemical, physical, or biological changes in the sediment or water quality would not be detectable because of rapid mineralization and dissolution of explosive byproducts in marine environments.

Unconsumed Explosives

Under the No Action Alternative, approximately 1,687 lb. (767 kg) per year of residual explosives would remain from high-explosive ordnance used during training activities because of ordnance failure and low-order detonations. Over 98 percent of residual explosive materials would result from ordnance failures. Ordnance failure rates are listed in Table 3.1-4. 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 440 high-explosive ordnance items would be expended, most of which would consist of large-caliber projectiles. Approximately 725 lb. (329 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 222 items per nm² (64 items per km²) and 361 lb. (164 kg) of explosive material per nm² (105 lb. [48 kg] of explosive material per km²) would sink to the ocean floor.

Testing Activities

Under the No Action Alternative, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area (refer to Table 2.4-4 for a complete description). No explosives are involved with this ongoing testing activity; therefore, there are no impacts on sediments and water quality from explosives and explosive byproducts from testing under the No Action Alternative.

3.1.3.1.6.2 Alternative 1

Training Activities

Subsurface High-Order Explosions and Explosive Byproducts

Under Alternative 1, most training activities that use underwater explosives would occur during mine countermeasure and neutralization training. Charges up to 10 lb. NEW would occur at Piti Point Floating Mine Neutralization Site and Apra Harbor UNDET Site (located within Outer Apra Harbor). Charges up to 20 lb. NEW would occur at Agat Bay Floating Mine Neutralization Site. The impacts of explosive 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.

High-Order Explosions at FDM and Explosive Byproducts

Under Alternative 1, strike warfare training activities on FDM would include the use of explosive ordnance. The impacts of explosive byproducts on sediment and water quality would be indirect, short term, local, and negative. Explosive ordnance could loosen the soil on FDM, and runoff containing soil and explosive byproducts could contaminate sediments and the surrounding ocean water. Chemical, physical, or biological changes in sediment or water quality would not be detectable because of the rapid mineralization and dissolution of explosive byproducts in marine environments.

Unconsumed Explosives

Alternative 1 would increase the number of training activities and the amount of explosive ordnance used. The estimated amounts of associated residual explosive materials would increase to about 9,772 lb. (4,433 kg) per year. The deposition of explosive materials from sinking exercises would be the same as under the No Action Alternative. While the amount of residual explosive materials would increase by about 500 percent under Alternative 1, impacts on water quality of explosive materials would be short term and localized due to rapid degradation in water. Residual explosive materials would be limited to a small area surrounding military expended materials. Based on previous studies and the low residence time of residual explosive materials in marine sediments, residual explosive materials

would have short-term, localized impacts on marine sediments under Alternative 1, similar to those under the No Action Alternative.

Testing Activities

Under Alternative 1, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area. The Navy would also conduct harpoon shots, anti-submarine warfare tracking tests (using sonobuoys), torpedo testing, broad area maritime surveillance testing (refer to Table 2.8-2), mission (ASW, MCM, and ASUW) package testing and torpedo testing (refer to Table 2.8-3) under Alternative 1. Residual explosive materials from harpoon and surface to surface missiles, sonobuoys, medium caliber explosive rounds and explosive torpedoes during testing are estimated at 1,075 lb. (775 kg) per year. A percent increase for residual explosive materials released from testing activities under Alternative 1 cannot be evaluated because these proposed testing activities are not currently conducted under the No Action Alternative. Based on the amount of residual explosive materials deposited in the Study Area, low leaching rates, and rapid degradation of explosive materials and the low residence time of residual explosive materials in marine sediments, impacts of residual explosive materials on sediments and water quality under Alternative 1 would be localized and short-term.

3.1.3.1.6.3 Alternative 2

Training Activities

Subsurface High-Order Explosions and Explosive Byproducts

Under Alternative 2, charges up to 10 lb. NEW would occur at Piti Point Floating Mine Neutralization Site and Apra Harbor UNDET Site (located within Outer Apra Harbor). Charges up to 20 lb. NEW would occur at Agat Bay Floating Mine Neutralization Site. The impacts of explosive 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.

High-Order Explosions at FDM and Explosive Byproducts

Under Alternative 2, strike warfare training activities on FDM would include the use of explosive ordnance. The impacts of explosive byproducts on sediment and water quality would be indirect, short term, local, and negative. Explosive ordnance could loosen the soil on FDM, and runoff containing soil and explosive byproducts could contaminate sediments and the surrounding ocean water. Chemical, physical, or biological changes in sediment or water quality would not be detectable because of the rapid mineralization and dissolution of explosive byproducts in marine environments.

Unconsumed Explosives

Alternative 2 would increase the number of training activities, which would result in an increase in the amount of explosive ordnance used, compared to the No Action Alternative and Alternative 1. The estimated associated residual explosive materials from Alternative 2 would increase from 1,687 lb. (767 kg) to about 12,141 lb. (5,507 kg) per year from the No Action Alternative. Impacts on sediments and water quality from explosive materials would be similar to those identified under the No Action Alternative and Alternative 1. Change in sediments and water quality would be undetectable because of the low solubility of explosive materials in sea water and because of dilution over a large volume of ocean.

Testing Activities

Under Alternative 2, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area. Alternative 2 would

increase the number of testing activities, which would result in an increase in the amount of explosive ordnance used, compared to the No Action Alternative and Alternative 1. The estimated associated residual explosive materials would increase to about 2,009 lb. (913 kg) per year. A percent increase for residual explosive materials released from testing activities under Alternative 2 cannot be evaluated because these proposed testing activities are not currently conducted under the No Action Alternative. Based on the amount of residual explosive materials deposited in the Study Area under Alternative 2, impacts on sediments and water quality from explosive materials would be similar to those identified under Alternative 1.

3.1.3.1.6.4 Summary and Conclusions for Explosives and Explosive 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 explosive byproducts; long-term impacts arise from unconsumed explosives. Most 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 sediments 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 sediments and seawater by the Proposed Action. These metals represent parts or the whole of vessels, manned aircraft and unmanned aerial vehicles, ordnance (bombs, projectiles, missiles, and torpedoes), sonobuoys, chaff cartridges, 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 1 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 2008). Torpedo guidance wire is composed of copper and cadmium coated with plastic (U.S. Department of the Navy and U.S. Fleet Forces Command 2008). 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 0.03 to 0.1 in. (0.1 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 inert material, (2) empty ammunition or components, and (3) ammunition or components manufactured with inert material in place of all explosive material. These practice munitions vary in size from 25 lb. (11 kg) to 500 lb. (227 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 2010). Non-explosive bombs—also called “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 2006a). 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. (1,829 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.).

On FDM, bomb fragments and unexploded bombs could be a source of metal contamination in terrestrial and marine sediments. In accordance with DoD Directive 4715.11, “Environmental and Explosives Safety Management on Operational Ranges within the United States” (U.S. Department of Defense 2004), the Navy has in place an Operational Range Clearance Plan for FDM (U.S. Department of the Navy 2013b). The operational range clearance plan on FDM includes range clearance, inspection, certification, demilitarization, and recycling or disposal procedures. The plan requires range surfaces at FDM to be cleared of ordnance above a certain size, inert ordnance debris, inert munitions, and other material that may potentially present an explosive hazard. Material greater than 2 ft. (0.6 m) in size is removed from impact areas on FDM. Range clearance on FDM occurs every 2–4 years, which reduces the potential for soil contamination and contamination of nearshore habitats receiving surface runoff.

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 the Study Area. These activities would be subject to federal sediment and water quality standards and guidelines. Military expended materials with metal components are also used onshore and in nearshore areas specifically designated for mine countermeasure and mine neutralization activities in and around Naval Base Guam Apra Harbor. These activities would be subject to state sediment and water quality standards and guidelines. For metals, “local” means the zone of sediment about 0.4 in. (1.0 cm) surrounding the metal where it comes to rest.

3.1.3.2.2.1 State Standards and Guidelines

There are no existing Guam and CNMI standards and guidelines for sediments and water quality related to metals. Guam and the CNMI have adopted the National Recommended Water Quality Criteria in Table 3.1-8, although the specific EPA reference citations in their regulations differ.

3.1.3.2.2.2 Federal Standards and Guidelines

Table 3.1-8 summarizes the EPA “threshold values” for metals in marine waters.

Table 3.1-8: Threshold Values for Exposure to Selected Metals in Saltwater

Metal	Criteria (µg/L)	
	Acute Toxicity (1-hour exposure) ¹	Chronic Toxicity (4-day average exposure) ²
Cadmium	40	8.8
Chromium	1,000	50
Copper	4.8	3.1
Lead	210	8.1
Lithium	6,000	n/a
Mercury	1.8	0.94
Nickel	74	8.2
Silver	1.9	n/a
Zinc	90	81

¹ “Acute toxicity” means a negative response to a substance observed in 96 hours or less (e.g., mortality, disorientation, or immobilization).

² “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 of time, such as one-tenth of the life span of the species. A 28-day test period is used for small fish test species (U.S. Environmental Protection Agency 1991).

Notes: (1) No threshold value established by the Environmental Protection Agency. Value shown is from Kszos et al.(2003). (2) n/a = no chronic value is available, µg/L = micrograms per liter

Source: U.S. Environmental Protection Agency 2009

3.1.3.2.3 Impacts from Metals

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

The majority of metals in military expended materials come from the use of ordnance. During training, the Navy expends about 87,575 pieces of ordnance in the Study Area annually and proposes to expend up to 185,047 and 187,575 pieces of ordnance, respectively, under Alternative 1 and Alternative 2 annually while training. In addition, two ship hulls are also used during Sinking Exercises under the No Action Alternative annually. The same number of ship hulls is proposed under Alternative 1 and Alternative 2 annually. Use of ordnance during proposed testing activities under Alternatives 1 and 2 are minimal compared to those for training.

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 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 (Klink et al. 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.

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 2010). A recent study conducted by the U.S. Marine Corps sampled sediments 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 were also 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 2010).

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 3.1-9 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).

Table 3.1-9: Concentrations and National Oceanic and Atmospheric Administration Screening Levels for Selected Metals in Sediments, Vieques, Puerto Rico

Metal	Sediment Concentration (µg/g)			Sediment Guidelines – National Oceanic and Atmospheric Administration (µg/g)	
	Minimum	Maximum	Average	Threshold Effect Level ¹	Probable Effect Level ²
Cadmium	0	1.92	0.15	0.68	4.21
Chromium	0	178	22.58	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

¹ The "threshold effect level" is the concentration of a contaminant above which adverse biological effects are expected to rarely occur.

² The "probable effect level" is the concentration of a contaminant above which adverse biological effects are expected to occur frequently (MacDonald et al. 1996).

Notes: N/R = not reported, µg/g = micrograms per gram

Source: Buchman 2008

As shown in Table 3.1-9, 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/gram (µg/g), and the highest concentration was 15.4 µg/g. Both values were below the sediment quality guidelines examined; and (2) the average sediment concentration of manganese in sediment was 301 µg/g, and the highest concentration was 967 µg/g (Pait et al. 2010). The National Oceanic and Atmospheric Administration did not report threshold or probable effects levels for manganese. Limited data is available for the amount of explosive ordnance and small arms ammunition expended on Vieques. The Navy has estimated approximately 300,000 items with a combined total NEW of 11.5 million, and 1.8 million rounds of small arms ammunition were expended between 1974 and 1998 (Department of the Navy 2006c).

The impacts of lead and lithium were studied at the Canadian Forces Maritime Experimental and Test Ranges near Nanoose Bay, British Columbia, Canada (Klink et al. 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 ppm in seawater, and from 4 to 16 ppm in sediments. Cores taken 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 cm). This depth corresponds to the late 1970s and early 1980s and the lead concentration was attributed to atmospheric deposition of lead from gasoline additives. The sediment cores showed a general reduction in 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 showed minimal impacts of lead ballasts because they were usually buried deep in marine sediments, and were 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 from 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 2006a).

Several studies have evaluated the potential impacts of batteries expended in seawater (Borener and Maugham 1998; Klink et al. 2005; Naval Facilities Engineering Command 1993; U.S. Coast Guard 1994). Sediment was sampled adjacent to and near fixed navigation sites where batteries are used, and the samples were 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 (U.S. Environmental Protection Agency 2008c).

A sonobuoy battery experiment employed lead (II) chloride batteries in a 17 gal. (64.4 L) seawater bath for 8 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 ppb) in 2 seconds, which is less than the acute criterion of 210 µg/L (210 ppb), a criterion 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 2 seconds, which is less than the acute criterion of 210 µg/L (210 ppb), a criterion applied as a 1-hour mean. Assuming the exponential factor of two dilutions, the concentration is less than the chronic limit of 8.1 µg/L (8.1 ppb) in 7 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 ensures that potential impacts of batteries employing silver chloride or copper thiocyanate are substantially lower than those for 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 and U.S. Fleet Forces Command 2008). The peak concentration of copper released from 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 associated with lead, tungsten has replaced lead in munitions (Defense Science Board 2003). Tungsten was chosen because it was considered nonreactive 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 (Agency for Toxic Substances and Disease Registry 2005). However, no drinking water standard exists for tungsten, and it is not listed as a carcinogen (U.S. Environmental Protection Agency 2008c). Neither inhalation nor groundwater is an issue relative to sediments 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 contribute tungsten to 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 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 some type of sonobuoys. Lithium-sulfur batteries typically contain lithium sulfur dioxide and lithium bromide but may also contain lithium carbon monofluoride, 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 0.03–0.1 in. (0.08–0.25 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.

Klink et al. (2005) reported that 99 percent of the lithium in a sonobuoy battery would be released to 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. (5.5 mm) 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 (Klink et al. 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 taken outside the range, the report concluded that “it is difficult to demonstrate an environmental impact of lithium caused by (test range activities)” (Klink et al. 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 2006a).

3.1.3.2.3.5 Metals in Vessels Used as Targets

Target vessels are used only during sinking exercises. Sinking exercises are conducted at least 50 nm offshore and in waters at least 6,000 ft. (1,829 m) deep, in accordance with 40 C.F.R. §229.2. Target vessels are selected from a list of Navy-approved vessels that have been cleaned in accordance with EPA guidelines.

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).

3.1.3.2.4 Evaluation of Alternatives

3.1.3.2.4.1 No Action Alternative

Training Activities

Under the No Action Alternative, approximately 234 U.S. tons (212,281 kg) of metals with known toxicity would be expended per year in the Study Area. During two sinking exercises per year, approximately 440 objects would be expended, including large bombs, missiles, large projectiles, and two target vessels (with an average weight of 5,826 U.S. tons [5,285,258 kg]). Approximately 58 U.S. tons (52,616 kg) of metals with potential toxicity would be expended during a sinking exercise. Thus, during a sinking exercise, approximately 32 objects per km² and 8.5 U.S. tons (7,711 kg) of metals with potential toxicity per km² would sink to the ocean floor.

In addition, non-reactive metals would be expended under the No Action Alternative. These materials consist of metals with no known toxicity, such as steel, and filler materials (i.e., sand, concrete) used in inert munitions. These materials are not expected to affect water quality because of their non-toxic properties, and would be incorporated into marine sediments. No further consideration of the impacts of these materials on water quality is warranted.

Leaching metals would be from military expended materials on the sea floor. Metals tend to adsorb to sediments, particularly fine sediments and sediments with high organic content. Based on this assumption, concentrations of metals in the water column would be less than estimated concentrations of metals in marine sediments. Concentrations of metals would be greatest where military expended materials are in contact with seawater. Initial rates would decrease as corrosion and biological processes occur, and most leaching metals would bind with suspended sediments and particles and fall out of the water column. Within the immediate area where metals are deposited, metals from military expended materials would have short-term, localized impacts on sediments in the Study Area.

As discussed previously, the Navy has an operational range clearance plan in effect on FDM, which requires removal of ordnance (potential sources of metal pollution on land) every 2–4 years depending on the type of ordnance. The operational range clearance program removes land-based sources of contamination that may impact terrestrial sediments, marine sediments, and nearshore waters.

Under the No Action Alternative, impacts on sediments and water quality from metals from military expended materials would be short term and localized.

Testing Activities

Under the No Action Alternative, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area (refer to Table 2.4-4 for a complete description). Research vessels, acoustic test sources, side scan sonars, ocean gliders, existing moored acoustic tomographic array and distributed vertical line array, and other oceanographic data collection equipment are used to collect information. At the conclusion of these studies, with the exception of the moorings, the data collection equipment will be removed. This activity would continue within the Study Area until May 2019. There would be no impacts on sediments and water quality from the deployment of testing equipment under the No Action Alternative.

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

Training Activities

Under Alternative 1, training activities would increase, which would result in additional metals from military expended materials being introduced into the Study Area. Approximately 237 U.S. tons (215,002 kg) of metals with known toxicity would be expended in the Study Area per year, or an increase of 1.3 percent from the No Action Alternative. Under Alternative 1, impacts on sediments and water quality from metals from military expended materials would be short term and localized.

The Navy's operational range clearance plan would be in effect for FDM under Alternative 1. The operational range clearance program removes land-based sources of contamination that may impact terrestrial sediments, marine sediments, and nearshore waters.

Testing Activities

Under Alternative 1, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area. The Navy would also conduct additional testing activities, which would involve the use of 793 sonobuoys for anti-submarine warfare tracking tests, 8 harpoon and 16 surface to surface missiles, explosive and non-explosive medium caliber rounds and 60 torpedoes. Under Alternative 1, approximately 0.27 U.S. tons (245 kg) of metals with known toxicity would be expended in the Study Area per year. A percent increase for metals with known toxicity released from testing activities under Alternative 1 cannot be evaluated because these proposed testing activities are not currently conducted under the No Action Alternative. Under Alternative 1, impacts on sediments and water quality from metals from military expended materials would be short term and localized.

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 and would be 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

Training Activities

Under Alternative 2, training activities would increase slightly over those proposed in Alternative 1, which would result in a minor increase in metals from military expended materials being introduced in the Study Area. Approximately 238 U.S. tons (215,909 kg) of metals with known toxicity would be expended in the Study Area per year or an increase of 1.7 percent from the No Action Alternative. Impacts on sediments and water quality would be similar to those described under the No Action Alternative due to the minimal increase in metals with potential toxicity.

The Navy's operational range clearance plan would be in effect for FDM under Alternative 2. The operational range clearance program removes land-based sources of contamination that may impact terrestrial sediments, marine sediments, and nearshore waters.

Testing Activities

Under Alternative 2, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area. The Navy would also conduct additional and increased testing activities, which would involve the use of 884 sonobuoys for anti-submarine warfare tracking tests, 8 harpoon and 18 surface to surface missiles, and 70 torpedoes. Under Alternative 2, approximately 0.31 U.S. ton (281 kg) of metals with known toxicity would be expended in the Study Area per year. A percent increase for metals with known toxicity released from testing activities under Alternative 2 cannot be evaluated because these proposed testing activities are not currently conducted under the No Action Alternative. Under Alternative 2, impacts on sediments and water quality from metals from military expended materials would be short term and localized.

Summary of Impacts from Metals

Although the amount of expended materials associated with training and testing under Alternative 2 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 (Section 3.1.3.2.4.1). 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.

3.1.3.2.4.4 Summary and Conclusion 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 they would behave similarly to leached metals from other military expended materials.

On FDM, The Navy's operational range clearance plan would be in effect for all alternatives. The operational range clearance program removes land-based sources of contamination that may impact terrestrial sediments, marine sediments, and nearshore waters.

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) polychlorinated biphenyls in target vessels used during sinking exercises, and (4) other chemicals associated with ordnance.

Hazardous air pollutants associated with explosives and explosive byproducts are discussed in Section 3.2 (Air Quality). Explosives and explosive byproducts are discussed in Section 3.1.3.1 (Explosives and Explosive Byproducts). 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. An extended-range Standard Missile-2 typically contains 1,822 lb. (828 kg) of solid propellant (U.S. Department of the Navy 2008). 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 5 to 21 percent by weight of solid propellant; it is added to increase missile range and payload capacity. Two 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 account for 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 are liquid explosives added to increase the engine burn rate, and n-hexyl carborane and carboranylmethyl propionate are also used 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. (1,678 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, carbon dioxide, 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 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. By rule, a sinking exercise must be conducted at least 50 nm offshore and in water at least 6,000 ft. (1,829 m) deep (40 C.F.R. §229.2). A maximum of two sinking exercises per year are proposed in the Study Area under the No Action Alternative, Alternative 1, and Alternative 2.

The EPA estimates that as much as 100 lb. (45 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.) (U.S. Environmental Protection Agency 1999). Based on these considerations, PCBs will not be considered further.

3.1.3.3.5 Other Chemicals Associated with Ordnance

Table 3.1-10 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 (Metals).

3.1.3.3.6 Approach to Analysis

Training and testing activities related to the chemicals discussed above would be conducted more than 3 nm offshore in the Study Area. These activities would be subject to federal sediment and water quality standards and guidelines, however, there are no state or federal sediment and water quality standards or guidelines specific to the chemicals discussed above. 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 noncombusted propellant in sediments and seawater, perhaps a centimeter or two, and a smaller area if directly exposed to seawater.

Table 3.1-10: Constituents Remaining after Low-Order Detonations and from Unconsumed Explosives

Ordnance Component	Constituent
Pyrotechnics Tracers Spotting Charges	Barium chromate (BaCrO ₄) Potassium perchlorate Chlorides Phosphorus Titanium compounds
Oxidizers	Lead (II) oxide (PbO)
Delay Elements	Barium chromate (BaCrO ₄) Potassium perchlorate Lead chromate
Fuses	Potassium perchlorate
Detonators	Fulminate of mercury [Hg(CNO) ₂] Potassium perchlorate
Primers	Lead azide [Pb(N ₃) ₂]

3.1.3.3.7 Impacts from Chemicals

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

3.1.3.3.7.1 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 2008). The failure rate of rockets is 3.8 percent (MacDonald et al. 2005; U.S. Army Corps of Engineers 2007). The remaining solid propellant fragments (i.e., 1 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. (0.14 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 kg) of solid

propellant would generate less than 1.5 lb. (0.7 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 cm) cubes, about 0.42 percent of the propellant would be wetted during the first 24 hours of immersion. If all the ammonium perchlorate leached out of the wetted propellant, then approximately 0.01 lb. (4.54 g) would enter the surrounding seawater (U.S. Department of the Navy 2008). This leach rate would decrease over time as the concentration of perchlorate in the propellant declined. 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 soil 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 (U.S. Environmental Protection Agency 2008a) 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 result from 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 were 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 are capable of metabolizing 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.

3.1.3.3.7.2 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-nitrodiphenyl-amine 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 from 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 oxides of nitrogen may be present, but they are usually below detectable limits. Oxides of nitrogen 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 insignificant concentrations. Ammonia is present in exhaust from Otto Fuel II at estimated concentrations of 10 ppb (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 (U.S. Environmental Protection Agency 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) (U.S. Environmental Protection Agency 2010b), hydrogen cyanide released from MK-48 torpedoes would result in ambient concentrations ranging from 140 to 150 µg/L (140 to 150 ppb) (U.S. Department of the Navy 1996b), well above the 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 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 Navy test ranges, where there have been no reports of harmful

impacts on water quality from Otto Fuel II or its combustion products. Furthermore, U.S. 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).

3.1.3.3.7.3 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 (MacDonald et al. 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 (Metals).

3.1.3.3.8 Evaluation of Alternatives

Potential impacts on sediments and water quality from chemicals other than explosives should be viewed in the following context: (1) nearshore sediments and water quality in many areas have been negatively impacted; in particular, a wide variety of chemicals are delivered to the ocean by major river systems; and (2) the vast majority of those impacts are from human-generated and land-based activities. The numbers of military expended materials discussed below reflect amounts expended annually for each type of material under each alternative.

3.1.3.3.8.1 No Action Alternative

Training Activities

Under the No Action Alternative, approximately 639 lb. (290 kg) per year of residual solid propellant would be expended during training activities in the Study Area. The amount of perchlorates released to the environment from residual solid propellant would be minimal. Although perchlorate is persistent in the marine environment, the low concentrations of perchlorates in ocean waters that result from Navy training and testing activities would not have an impact on water quality. Based on the small amount of residual propellant and low affinity for sediment, perchlorate from residual solid propellant would not be expected to have an impact on sediments.

Under the No Action Alternative, 53 torpedoes would be expended during training. During torpedo operation, the majority of Otto Fuel would be consumed. Torpedo training in the Study Area is mostly simulated and the torpedoes used are not fully functional torpedoes. Any Otto Fuel II released to the marine environment would be quickly diluted, and would not result in concentrations harmful to marine organisms. Based on these assumptions and past studies of water quality at torpedo testing areas, Otto Fuel II is not expected to have an impact on sediments and water quality.

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.

Testing Activities

Under the No Action Alternative, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area (refer to Table 2.4-4 for a complete description). Research vessels, acoustic test sources, side scan sonars, ocean gliders, existing moored acoustic tomographic array and distributed vertical line array, and other

oceanographic data collection equipment are used to collect information. None of these equipment use solid propellants or Otto Fuel, therefore, testing activities under the No Action Alternative would not have an impact on sediments and water quality in the Study Area.

3.1.3.3.8.2 Alternative 1

Training Activities

Alternative 1 would result in an increase in deposits of associated residual propellant due to increased training activities, compared to the No Action Alternative. Approximately 3,988 lb. (1,809 kg) of residual solid propellant would be deposited in the Study Area from expended missiles and rockets under Alternative 1, an increase of 3,349 lb. (1,522 kg) over the No Action Alternative. Under Alternative 1, impacts on sediments and water quality from residual solid propellants would be similar to those of the No Action Alternative.

Under Alternative 1, 63 torpedoes would be expended during training. This represents an increase of 10 additional torpedoes or 19 percent relative to the No Action Alternative. Analysis under the No Action Alternative concludes that Otto Fuel from the torpedo operation would not impact sediments and water quality; the same conclusion applies to Alternative 1.

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, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area. The Navy would also conduct additional testing activities, which would involve the use of 60 torpedoes for anti-surface warfare testing, 8 harpoon missiles and 16 surface to surface missiles. As discussed previously, Otto Fuel from torpedo operation would be quickly diluted, and would not result in concentrations harmful to marine organisms; therefore, Otto Fuel used during testing activities under Alternative 1 would not impact sediments or water quality. Residual propellant from missiles would amount to 465 lb. (211 kg). A percent increase for residual propellant released from testing activities under Alternative 1 cannot be evaluated because these proposed testing activities are not currently conducted under the No Action Alternative.

Although these changes would be a notable increase compared to the No Action Alternative, impacts would be similar to impacts from training under Alternative 1 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.

3.1.3.3.8.3 Alternative 2

Training Activities

The amount of associated residual solid propellant under Alternative 2 would increase compared to Alternative 1. Approximately 9,370 lb. (4,250 kg) of solid propellant would be deposited in the Study Area from expended missiles and rockets under Alternative 2, an increase of 8,731 lb. (3,969 kg) from the No Action Alternative. Under Alternative 2, 63 torpedoes would be expended during training activities. This represents an increase of 10 additional torpedoes or 19 percent relative to the No Action Alternative. Analysis under the No Action Alternative concludes that Otto Fuel from the torpedo operation would not impact sediments and water quality; the same conclusion applies to Alternative 2.

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 2, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area. The Navy would also conduct additional testing activities, which would involve the use of 64 torpedoes for anti-surface warfare testing, 10 harpoon missiles, and 18 surface-to-surface missiles. As discussed previously, Otto Fuel from torpedo operation would be quickly diluted in the water column, and would not result in concentrations harmful to marine organisms; therefore, Otto Fuel used during testing activities under Alternative 2 would not impact sediments or water quality. Residual propellant from missiles would amount to 503 lb. (229 kg). A percent increase for residual propellant released from testing activities under Alternative 2 cannot be evaluated because these proposed testing activities are not currently conducted under the No Action Alternative.

Although these changes would be a notable increase compared to the No Action Alternative, impacts would be similar to impacts from training under Alternative 2 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.

3.1.3.3.8.4 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

Other materials include marine markers and flares, chaff, towed and stationary targets,⁴ and miscellaneous components of other materials. These materials and components are made mainly of nonreactive 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) slowly dissolve, or (5) be covered by marine organisms such as coral. Plastics may float or descend to the bottom, depending on their buoyancy. Markers and flares are largely consumed during use.

Steel in ordnance normally contains a variety of metals, some of potential concern. However, these other metals are present in low quantities (1 to 5 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 (Metals). Various chemicals and explosives are present in small amounts (mostly as components of flares and markers), but are not considered likely to cause negative impacts. Chemicals other than explosives are discussed in more detail in Section 3.1.3.3 (Chemicals Other Than Explosives) and explosives and explosive byproducts are discussed in more detail in Section 3.1.3.1 (Explosives and Explosive Byproducts).

Other materials as described here are not used on FDM or are not components of ordnance used on FDM, other than those already previously described (explosives and explosive byproducts and metals). Therefore, no further analysis is provided here for the impact of other materials on FDM.

3.1.3.4.1 Marine Markers and Flares

Marine markers are pyrotechnic devices dropped on the water's surface during training exercises to mark a position on the ocean surface, for search and rescue activities, or as bomb targets. The MK-58 marker is a tin tube that weighs about 12 lb. (5 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. [1.0 kg]) and manganese (IV) dioxide (1.40 lb. [0.6 kg]). Other constituents include magnesium powder (0.29 lb. [0.1 kg]), zinc oxide (0.12 lb. [0.05 kg]), nitrocellulose (0.000017 lb. [0.008 g]), nitroglycerin (0.000014 lb. [0.006 g]), and potassium nitrate (0.2 lb. [9.1 g]). The failure rate of marine markers is approximately 5 percent (U.S. Department of the Navy 2010).

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

⁴ Towed and stationary targets include floating steel drums, towed aerial targets, the trimaran, and inflatable, floating targets. Potential impacts from floating steel drums are considered as part of the analysis of non-explosive practice munitions. The trimaran is a three-hulled boat with a four-foot-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 reflects 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 (3 m) and weighs about 75 lb. (34.02 kg). These four targets are recovered after use and will not be considered further.

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} ounce of ammonium perchlorate and 1.0×10^{-7} ounce 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 3.1-11 summarizes the components of markers and flares.

Table 3.1-11: Summary of Components of Marine Markers and Flares

Flare or Marker	Constituents
LUU-2 Paraflare	Magnesium granules, sodium nitrate, aluminum, iron, trinitrotoluene (TNT), royal demolition explosive, ammonium perchlorate, potassium nitrate, lead, chromium, magnesium, manganese, nickel
MK-45 Paraflare	Aluminum, sodium nitrate, magnesium powder, nitrocellulose, TNT, copper, lead, zinc, chromium, manganese, potassium nitrate, pentaerythritol tetranitrate, nickel, potassium perchlorate
MK-58 Marine Marker	Aluminum, chromium, copper, lead, lead dioxide, manganese dioxide, manganese, nitroglycerin, red phosphorus, potassium nitrate, silver, zinc, zinc oxide

Source: U.S. Department of the Navy 2010

3.1.3.4.2 Chaff

Chaff consists of small, thin glass fibers coated in aluminum 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. x 1.5 in. (15.2 cm x 3.8 cm) that weigh about 5 ounces (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. (0.75 to 5.1 cm). The major components of the chaff glass fibers and the aluminum coating are provided in Table 3.1-12.

3.1.3.4.3 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-caps and pistons used in chaff cartridges.

3.1.3.4.4 Approach to Analysis

Most activities involving ordnance containing the other materials discussed above would be conducted more than 3 nm offshore in the Study Area. 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 other materials discussed above.

Table 3.1-12: 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

Note: “≤” means less than or equal to

Source: U.S. Air Force 1994

3.1.3.4.5 Impacts from 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 (Klink et al. 2005). The behavior of these other materials in marine systems is discussed in more detail below.

3.1.3.4.5.1 Marine Markers and Flares

Most of the pyrotechnic components of marine markers are consumed and released as smoke in the air. Thereafter, the aluminum and steel canisters sink 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 2006a). The aluminum and iron canisters are expected to be covered by sand and sediments 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 2010). 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.

3.1.3.4.5.2 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 ounces (900 g) of chaff drifting 200 mi. (321.9 km) from the point of release with the plume covering a volume of greater than 400 cubic miles (1,666 cubic kilometers) (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 x 12 km) (37.1 mi.² or 28 nm²) would be affected by deployment of a single cartridge containing 5.3 ounces (150 g) of chaff. The resulting chaff concentration would be about 5.4 g/nm². This concentration corresponds to less than 179,000 fibers/nm² or less than 0.005 fibers per ft.², assuming that each cartridge contains five million fibers.

Chaff is generally resistant to chemical weathering and likely remains in the environment for long periods. However, all 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 itself is the most common metal in the Earth's crust and is a trace element in natural waters. Ocean waters are constantly exposed 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 nontoxic, do not clump (due to a slip coating), and are very small (ranging from 0.7 to 1 mm in diameter). Chemicals leached from the chaff will be diluted by the surrounding seawater, reducing the potential for chemical concentrations reaching levels that can affect sediment quality and benthic habitats.

Systems Consultants, Inc. (1977) placed chaff samples in Chesapeake Bay water for 13 days. No increases greater than 1 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 (0.02 ppm) detection limit: 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).

3.1.3.4.5.3 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).

Parachutes and other plastic items expended during training and testing activities are designed to sink. Parachutes are typically made of nylon. Nylon and other plastic materials are generally resistant to natural biodegradation. On the seafloor, photodegradation and mechanical wear are limited, and parachutes break down slowly, most likely taking years to fully degrade. Nylon is not toxic and is not expected to affect sediment or water quality. Over time, the breakdown of parachutes and other plastic materials into increasingly smaller fragments could produce microplastics. While microplastics are not generally toxic, persistent organic pollutants present in seawater may adhere to microplastics and be incorporated into the water column and sediments, as described in Section 3.1.2.1.2 (Marine Debris, Military Expended Materials, and Sediments) and Section 3.1.2.2.1 (Marine Debris and Water Quality). Because plastic materials themselves do not affect sediment or water quality, these materials are not analyzed further in this section. Potential effects of ingesting or becoming entangled in plastic materials or parachutes are discussed in the biological resources sections.

3.1.3.4.6 Evaluation of Alternatives

Potential impacts on sediments and water quality from other materials should be viewed in the following context: (1) nearshore sediments and water quality in many areas have been negatively impacted; and (2) the vast majority of those impacts are from human-generated and land-based activities, especially plastics and other ocean debris. The numbers of military expended materials discussed below reflect amounts expended annually for each type of material under each alternative.

3.1.3.4.6.1 No Action Alternative

Training Activities

Under the No Action Alternative, approximately 11,822 military expended materials composed of other materials would be used during training activities. Chaff cartridges represent 50 percent of these materials, and flares represent 49 percent. Potential impacts on sediments and water quality from training activities involving other materials would be short and long term, local, and negative. Chemical, physical, or biological changes to sediments or water quality would not be detectable and would be below or within existing conditions or designated uses.

Testing Activities

Under the No Action Alternative, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area. This testing activity does not involve the use of other materials; therefore, testing activities under the No Action Alternative would not have an impact on sediments and water quality in the Study Area.

3.1.3.4.6.2 Alternative 1

Training Activities

Under Alternative 1, approximately 51,755 military expended materials composed of other materials would be used during training activities, or an increase of over 300 percent. The components of other materials such as plastics, steel, and silicon degrade very slowly in seawater. Aluminum is converted to aluminum hydroxide in seawater and remains insoluble. Other components such as red phosphorus from flares undergo rapid oxidation in seawater, rendering them harmless. For these reasons, the increased use of other materials would have little to no impact on water quality and sediments. Chaff cartridges represent 50 percent of these materials, and flares represent 49 percent. The analysis presented under the No Action Alternative for training with regards to the use of other materials also applies to training activities under Alternative 1. Potential impacts on sediments and water quality from training activities under Alternative 1 involving other materials would be short and long term, local, and negative. Chemical, physical, or biological changes to sediment or water quality would not be detectable and would be below or within existing conditions or designated uses.

Testing Activities

Under Alternative 1, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area. Additional testing activities proposed under Alternative 1 involve the use of other materials from torpedoes and sonobuoys. Approximately 853 military expended materials composed of other materials would be used during testing activities. A percent increase for other materials released from testing activities under Alternative 1 cannot be evaluated because these proposed testing activities are not currently conducted under the No Action Alternative. There would be no impact from other materials from testing activities on sediments and water quality under Alternative 1.

3.1.3.4.6.3 Alternative 2

Training Activities

Under Alternative 2, a total of about 57,099 military expended materials composed of other materials would be used during training activities, or an increase of almost 400 percent. The components of other materials such as plastics, steel, and silicon degrade very slowly in seawater. Aluminum is converted to aluminum hydroxide in seawater and remains insoluble. Other components such as red phosphorus from flares undergo rapid oxidation in seawater, rendering them harmless. For these reasons, the increased use of other materials would have little to no impact on water quality and sediments. Chaff cartridges represent 50 percent of these materials, and flares represent 49 percent. The analysis presented under the No Action Alternative for training with regards to the use of other materials also applies to training activities under Alternative 2. Potential impacts on sediments and water quality from training under Alternative 2 involving other materials would be short and long term, local, and negative. Chemical, physical, or biological changes to sediments or water quality would not be detectable and would be below or within existing conditions or designated uses.

Testing Activities

Under Alternative 2, the Navy would continue conducting deep water sound propagation and temperature-sound velocity profile studies of the water column in the Study Area. Additional testing activities proposed under Alternative 2 involve the use of other materials from torpedoes and sonobuoys. Approximately 954 military expended materials composed of other materials would be used during testing activities. A percent increase for other materials released from testing activities under Alternative 2 cannot be evaluated because these proposed testing activities are not currently conducted

under the No Action Alternative. There would be no impact from other materials from testing activities on sediments and water quality under Alternative 2.

3.1.3.4.6.4 Summary and Conclusions from 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 nonreactive 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.

3.1.4 SUMMARY OF POTENTIAL IMPACTS (COMBINED IMPACT OF ALL STRESSORS) ON SEDIMENTS AND WATER QUALITY

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

3.1.4.1 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 immediately adjacent to the explosives, 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.

3.1.4.2 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, explosive 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 the changes 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 (Section 3.1.4.1).

3.1.4.3 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 (Section 3.1.4.1).

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