

**Environmental Impact Statement/  
Overseas Environmental Impact Statement  
Point Mugu Sea Range**

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## 3.2 Sediments and Water Quality

### 3.2.1 Introduction

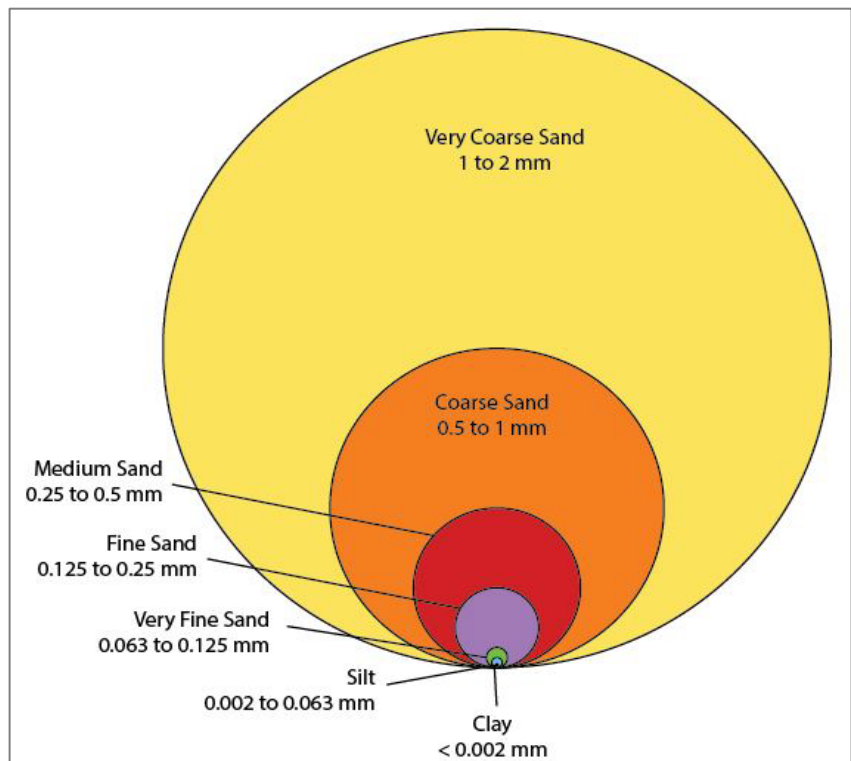
The following sections provide an overview of the characteristics of sediments and water quality in the Point Mugu Sea Range (PMSR) Study Area (Study Area) and describe, in general terms, the methods used to analyze potential impacts of the Proposed Action on these resources.

#### 3.2.1.1 Sediments

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

##### 3.2.1.1.1 Characteristics of Sediments

Sediments consist of solid fragments of organic and inorganic matter forming the bottom, or substrate, of bodies of water. Sediments in the marine environment (e.g., in ocean basins) are either terrigenous, meaning that they originate from land, or are biogenic (i.e., formed from the remains of marine organisms). Terrigenous sediments come from the weathering of rock and other land-based substrates and are transported by water, wind, and ice (glaciers) to the seafloor. Biogenic sediments are produced in the oceans by the skeletal remains of single-celled benthic and planktonic organisms (e.g., foraminiferans and diatoms). When an organism dies, its remains are deposited on the seafloor. The remains are



**Figure 3.2-1: Sediment Particle Size Comparison**

composed primarily of either calcium carbonate (e.g., a shell) or silica; when mixed with clays, they form either a calcareous or siliceous ooze (Chester, 2003). Sediments in the Atlantic Ocean are predominantly composed of calcareous oozes, while the Pacific Ocean has more siliceous oozes (Kennett, 1982). In addition to composition, sediments are also classified by size. Blott and Pye (2012) reviewed commonly used historical classification systems and offered a refined system that is adopted for describing sediments in this section. Sediments are grouped into five size classes: boulders, gravel, sand, silt, and clay. Sand grains range in size from 0.063 millimeter (mm) (very fine sand) to 2 mm (very coarse sand) (Figure 3.2-1). For comparison, the thickness of a nickel is approximately 2 mm. Sediment types smaller than sand are silts (0.002–0.063 mm in diameter) and clays (particles less than 0.002 mm in diameter). Sediments larger than sand are various types of gravel ranging in size from 2 mm (granules) to 64 mm (cobbles). Sediments greater than 64 mm in diameter are defined as boulders and range up to 2,048 mm

(Blott & Pye, 2012; U.S. Department of Agriculture, 1993). Fine-grained silts and clays are often found mixed together in areas beyond the continental slope, such as on abyssal plains, and are referred to generally as mud (Kennett, 1982). Sediments in nearshore waters and on the continental shelf contain more sand that are primarily terrigenous, and sediments farther from shore in deep ocean basins are primarily biogenic. As organic and inorganic particles move downward through the water column and ultimately to the seafloor, many substances, including contaminants, that adhere to the particles and are otherwise scarce in the water column become concentrated in bottom sediments (Chapman et al., 2003; Kszos et al., 2003).

#### **3.2.1.1.2 Factors Affecting Marine Sediment Quality**

The quality of sediments is influenced by their physical, chemical, and biological components; by where they are deposited; by the properties of seawater; and by other inputs and sources of contamination. Sediments tend to be dynamic, where factors affecting marine sediments often interact and influence each other. These factors are summarized below.

##### **Physical Characteristics and Processes**

At any given site, the texture and composition of sediments are important physical factors that influence the types of substances that are retained in the sediments, and subsequent biological and chemical processes. For example, clay-sized and smaller sediments and similarly sized organic particles tend to bind potential sediment contaminants and potentially limit their movement in the environment (U.S. Environmental Protection Agency, 2008b). Conversely, fine-grained sediments are easily disturbed by currents and bottom-dwelling organisms, dredging, storms, and bottom trawling (Eggleton & Thomas, 2004; Hedges & Oades, 1997). Disturbance is also possible in deeper areas, where currents are minimal (Carmody et al., 1973), from mass wasting events such as underwater slides and debris flows (Coleman & Prior, 1988). If re-suspended, fine-grained sediments (and any substances bound to them) can be transported long distances.

##### **Chemical Characteristics and Processes**

The concentration of oxygen in sediments strongly influences sediment quality through its effect on the binding of materials to sediment particles. At the sediment surface, the level of oxygen is usually the same as that of the overlying water. Deeper sediment layers, however, are often low in oxygen (i.e., hypoxic) or have no oxygen (i.e., anoxic), and have a low oxidation-reduction potential, which predicts the stability of various compounds that regulate nutrient and metal availability in sediments. Certain substances combine in oxygen-rich environments and become less available for other chemical or biological reactions.

##### **Biological Characteristics and Processes**

Organic matter in sediment provides food for resident microbes. The metabolism of these microbes can change the chemical environment in sediments and thereby increase or decrease the mobility of various substances and influence the ability of sediments to retain and transform those substances (Mitsch et al., 2009; U.S. Environmental Protection Agency, 2008a). Bottom-dwelling animals often rework sediments in the process of feeding or burrowing. In this way, marine organisms influence the structure, texture, and composition of sediments, as well as the horizontal and vertical distribution of substances in the sediment (Boudreau, 1998). Moving substances out of or into low or no-oxygen zones in the sediment may alter the form and availability of various substances. The metabolic processes of bacteria also influence sediment components directly. For example, sediment microbes may convert mercury to

methyl mercury, increasing its toxicity (Mitchell & Gilmour, 2008). However, it is more common that biological processes break down contaminants and reduce toxicity in sediments (White et al., 1997).

#### **Location**

The quality of coastal and marine sediments is influenced substantially by inputs from adjacent watersheds (Turner & Rabalais, 2003). Proximity to watersheds with large cities or intensively farmed lands often increases the amount of both inorganic and organic contaminants that find their way into coastal and marine sediments. A wide variety of organic substances, such as polycyclic aromatic hydrocarbons, polychlorinated biphenyls, 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 (U.S. Environmental Protection Agency, 2008a). Metals are also discharged into coastal waters from similar sources. Location on the ocean floor also influences the distribution and concentration of various elements through local geology and volcanic activity (Demina & Galkin, 2009), as well as through landslides and debris flow events (Coleman & Prior, 1988).

#### **Other Contributions to Sediments**

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

#### **3.2.1.2 Water Quality**

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

##### **3.2.1.2.1 Characteristics of Marine Waters**

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

##### **3.2.1.2.2 Influences of Marine Properties and Processes on Seawater Characteristics**

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

productivity of local surface waters (Mann & Lazier, 1996). Storms and hurricanes also cause strong mixing of marine waters (Li et al., 2008).

Temperature and pH influence the behavior of trace metals in seawater, such as the extent to which they dissolve in water (i.e., the metal's solubility) or their tendency to adsorb to organic and inorganic particles. However, the degree of influence differs widely among metals (Byrne, 1996). 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 & Price, 2003; Nozaki, 1997). On the other hand, dissolved aluminum concentrations are highest at the surface, lowest at mid-depths, and increase again at depths below about 1,000 meters (m) (Li et al., 2008).

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

Runoff from coastal watersheds influences local and regional coastal water conditions, especially large rivers. Influences include increased sediments and pollutants, and decreased salinity (Rabalais et al., 2002; Turner & Rabalais, 2003; Wiseman & Garvine, 1995). Coastal bays and large estuaries serve to filter river outflows and reduce total discharge of runoff to the ocean (Edwards et al., 2006; Mitsch et al., 2009). Depending on their structure and components, estuaries can directly or indirectly affect coastal water quality by recycling various compounds (e.g., excess nutrients); sequestering elements in more inert forms (e.g., trace metals); or altering them, such as the conversion of mercury to methyl mercury (Mitchell & Gilmour, 2008; Mitsch & Gosselink, 2007).

#### **3.2.1.2.3 Coastal Water Quality**

Most water quality problems in coastal waters of the United States are from degraded water clarity or increased concentrations of phosphates or chlorophyll-*a* (U.S. Environmental Protection Agency, 2012b). Water quality indicators measured are 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 and is 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 impacts arise from onshore 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.

#### **3.2.2 Region of Influence**

The region of influence for marine sediments and water quality consists of waters from the shoreline out to the eastern border of Point Mugu Sea Range, Mugu Lagoon, and the PMSR (Figure 3.2-2). Mugu Lagoon is one of the largest salt marshes in Southern California. Unlike most lagoons along the California coast, it is relatively undisturbed and provides a habitat for a diverse assemblage of marine organisms. Mugu Lagoon is regionally significant as it is one of the last lagoons left in Southern California containing unique and sensitive resources.

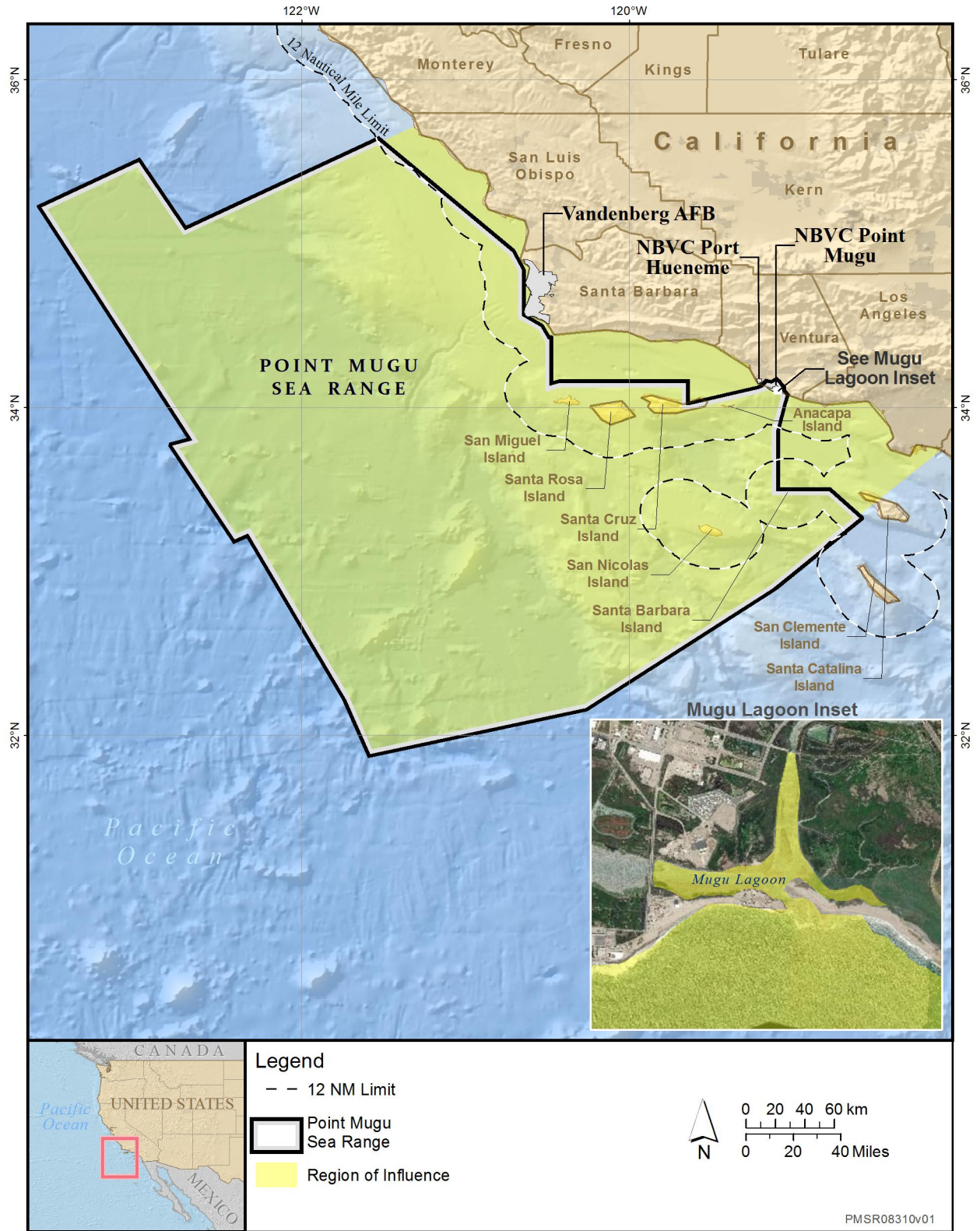


Figure 3.2-2: Water and Sediment Region of Influence Map

The Sea Range extends offshore of San Luis Obispo County and includes the northern portion of the Southern California Bight (SCB). The SCB, which is a concave bend in the coastline, includes the coastal and offshore areas from Point Conception in Santa Barbara County to Punta Colonet in Mexico as well as the eight Channel Islands. These resources are valuable for economic, municipal, and recreational purposes, as well as for their relationship to the natural environment.

### 3.2.3 Approach to Analysis

The following four stressors may impact sediments or water quality: (1) explosives and explosive byproducts; (2) propellants, fuels, and initiators; (3) metals; and (4) other materials (e.g., plastics). The term “stressor” is used because the military expended materials in these four categories may affect sediments 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 could 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) 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.

#### 3.2.3.1 State Standards and Guidelines

State jurisdiction regarding sediments and water quality extends from the low tide line to 3 nautical miles (NM) offshore of California. Creating state-level sediments and water quality standards and guidelines begins with establishing a use for the water, which is referred to as its “designated” use. Examples of such uses of marine waters include fishing, shellfish harvesting, and recreation. For this section, a water body is considered “impaired” if any one of its designated uses is not met. Once this use is designated, standards or guidelines are established to protect the water at the desired level of quality. Applicable State standards and guidelines specific to each stressor are detailed in Section 3.2.5 (Environmental Consequences).

At the state level, the Porter-Cologne Water Quality Control Act (California Water Code 13000–13953.4) gives the State Water Resources Control Board and nine Regional Water Quality Control Boards responsibility for protection of the waters within their regions. The regional boards are also responsible for implementing provisions of the Clean Water Act delegated to states, such as the National Pollutant Discharge Elimination System, which regulates point sources of pollutants.

The State Water Resources Control Board adopted the Water Quality Control Plan for Ocean Waters of California in 1974. The most current amended plan (State Water Resources Control Board, 2015) establishes beneficial uses and water quality objectives for waters of the Pacific Ocean adjacent to the California coast outside of enclosed bays, estuaries, and coastal lagoons (State Water Resources Control Board, 2015). The Ocean Plan prescribes effluent quality requirements and management principles for waste dischargers and specific waste discharge prohibitions. It also contains a prohibition against discharge of specific hazardous substances and sludge, bypass of untreated waste, and discharges that impact Areas of Special Biological Significance (ASBS). However, the State Water Resources Control Board may grant exceptions to allow a discharge into an ASBS provided that the exception will not compromise protection of ocean waters for beneficial uses, and that the public interest will be served (State Water Resources Control Board, 2015). More detail regarding ASBS boundaries within and near the PMSR is provided in Section 3.2.4.2.1 (Water Quality in Nearshore and Offshore Areas of the Point Mugu Sea Range Study Area).

### 3.2.3.2 Federal Standards and Guidelines

Federal jurisdiction regarding sediments and water quality extends from 3 to 200 NM along the Pacific Coast of the United States. These standards and guidelines are mainly the responsibility of the United States (U.S.) Environmental Protection Agency (USEPA), specifically ocean discharge provisions of the Clean Water Act (33 United States Code section 1343). Ocean discharges may not result in “unreasonable degradation of the marine environment.” Specifically, 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 due to the particular volumes or concentrations of the dumped materials, and (4) unacceptable negative effects on the ocean for other uses as a result of direct environmental impact (40 Code of Federal Regulations section 125.122). Applicable federal standards and guidelines specific to each stressor are detailed in Section 3.2.5 (Environmental Consequences).

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 United States Code sections 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 discharge of sewage by military vessels is regulated by Section 312(d) of the Clean Water Act. The Convention contains handling requirements and specifies where materials can be discharged at sea, but it does not contain standards related to sediments or water quality.

The National Defense Authorization Act of 1996 amended section 312 of the Clean Water Act, directing the USEPA and the Department of Defense (DoD) to jointly establish the Uniform National Discharge Standards for discharges (other than sewage) incidental to the normal operation of military vessels. The Uniform National Discharge Standards program establishes national discharge standards for military vessels in U.S. coastal and inland waters extending seaward to 12 NM. Twenty-five types of discharges were identified as requiring some form of pollution control (e.g., a device or policy) to reduce or eliminate the potential for impacts. The discharges addressed in the program include ballast water, deck runoff, and seawater used for cooling equipment. For a complete list of discharges refer to 40 Code of Federal Regulations part 1700.4.

These national discharge standards reduce the environmental impacts associated with vessel discharges, stimulate the development of improved pollution control devices aboard vessels, and advance the development of environmentally sound military vessels. The U.S. Navy adheres to regulations outlined in the Uniform National Discharge Standards program; as such, the analysis of impacts in this Environmental Impact Statement/Overseas Environmental Impact Statement will be limited to potential impacts from testing and training activities, including impacts from military expended materials, but not impacts from discharges addressed under the Convention or the Uniform National Discharge Standards program.

### 3.2.3.3 Intensity and Duration of Impact

The intensity or severity of impacts is defined as follows (listed by increasing level of impact):

- Chemical, physical, or biological changes in sediment or water quality would not be detectable as a result of the use of military materials. The proposed activities would not violate water quality standards.
- Chemical, physical, or biological changes in sediments or water quality would be measurable, but total concentrations would not violate applicable standards, regulations, and guidelines. Sediment and water quality would be equivalent to existing conditions, and designated uses of the water body or substrate would not change.
- Chemical, physical, or biological changes in sediments or water quality would be measurable and readily apparent, but total concentrations would not violate applicable standards, regulations, and guidelines. Sediment or water quality would be altered compared to the historical baseline or desired conditions, and designated uses of the water body or substrate would be changed. 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 as measured by total concentrations. Sediment or water quality would be frequently altered from the historical baseline or desired conditions, and designated uses of the water body or substrate would be changed. Mitigation measures would be necessary to limit or reduce impacts on sediment or water quality, although the efficacy of those measures 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.

### 3.2.3.4 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, polychlorinated biphenyls). After their initial deposition, normal physical, chemical, and biological processes can re-suspend, transport, and redeposit sediments and associated substances in areas far removed from the source (Hameedi et al., 2002; U.S. Environmental Protection Agency, 2012b), although these processes also degrade contaminant concentrations. The conditions noted above further complicate predictions of the impact of various substances on the marine environment.

### 3.2.3.5 Sources of Information

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

Because of the proximity of inshore and nearshore areas to humans, information on the condition of sediments and water quality in those areas tends to be relatively readily available. However, much less is known about deep ocean sediments and open ocean water quality. Since sediments and water quality in inshore and nearshore areas tend to be affected by various human social and economic activities, two general assumptions are used in this discussion: (1) sediments and water quality generally improve as distance from the shore increases, and (2) sediments and water quality generally improve as depth increases.

### 3.2.3.6 Areas of Analysis

The locations where specific military expended materials would be used are discussed under each stressor in Section 3.2.5 (Environmental Consequences).

## 3.2.4 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 conditions thereafter.

### 3.2.4.1 Sediments

The following subsections discuss sediments found from the nearshore out to the deep-sea bottom within the Study Area. Table 3.2-1 provides the sediment quality criteria and index for the U.S. West Coast.

#### 3.2.4.1.1 Sediment Quality in Nearshore and Offshore Areas of the Point Mugu Sea Range Study Area

Soft-bottom underwater habitat is prevalent throughout the PMSR study area, particularly on the mainland shelf, slopes, and basins. These soft-bottom habitat areas consist of fine to moderately coarse sandy and muddy sediments with much less relief than hard-bottom habitat. Sandy substrates are found predominantly on the continental shelf, while the smaller diameter silts (<62 microns in diameter) and mud dominate the bottom composition in the basins and on basin slopes of the continental borderland (U.S. Department of the Navy, 1999a, 2013c). Greater detail on the composition and distribution of bottom substrates in the PMSR Study Area are discussed in Section 3.3 (Marine Habitats).

**Table 3.2-1: Sediment Quality Criteria and Index, United States West Coast**

Parameter	Site Criteria			Regional Criteria		
	Good	Fair	Poor	Good	Fair	Poor
Sediment Toxicity	Amphipod <sup>1</sup> survival rate ≥ 80%	n/a	Amphipod <sup>1</sup> survival rate < 80%	< 5% of coastal area in poor condition	n/a	≥ 5% of coastal area in poor condition
Sediment Contaminants	No Effects Range Median concentration exceeded, and < 5 Effects Range Low concentrations exceeded	No Effects Range Median concentration exceeded and ≥ 5 Effects Range Low concentrations exceeded	An Effects Range Median concentration exceeded for one or more contaminants	< 5% of coastal area in poor condition	5–15% of coastal area in poor condition	> 15% of coastal area in poor condition
Excess Sediment TOC	TOC concentration < 2%	TOC concentration 2% to 5%	TOC concentration > 5%	< 20% of coastal area in poor condition	20–30% of coastal area in poor condition	> 30% of coastal area in poor condition
Sediment Quality Index	No poor ratings, sediment contaminants criteria are rated “good”	No poor ratings, sediment contaminants criteria are rated “fair”	One or more individual criteria rated poor	< 5% of coastal area in poor condition, and > 50% in good condition	5–15% of coastal area in poor condition, and > 50% in combined fair and poor condition	> 15% of coastal area in poor condition

<sup>1</sup>Amphipods are small animals found in a wide variety of aquatic habitats. Because they are so widely distributed, they are often used as an indicator of toxicity in sediments and water bodies.

Notes: % = percent. ≥ = equal to or greater than, < = less than, > = greater than, n/a = not applicable, TOC = total organic carbon

Source: Long et al. (1995); (U.S. Environmental Protection Agency, 2012b); State of California (2009)

In the *National Coastal Condition Report IV* (U.S. Environmental Protection Agency, 2012b), estuarine and coastal ocean areas in the USEPA’s West Coast Region, which extends along the entire U.S. West Coast, were rated good, fair, or poor for sediment contaminants, toxicity, and total organic carbon. Overall, sediment quality for the coastal waters of the West Coast region was rated fair (Figure 3.2-3).

For total organic carbon, 97 percent of the West Coast Region was rated good and 3 percent was rated fair. Less than 1 percent, represented by only two sites located in the Channel Islands, received a poor rating. Although these sites are located adjacent to the Study Area, neither fall within the Study Area boundaries. Higher levels of total organic carbon in sediments can be an indicator of higher concentrations of chemical pollutants and poor sediment quality (U.S. Environmental Protection Agency, 2012b).

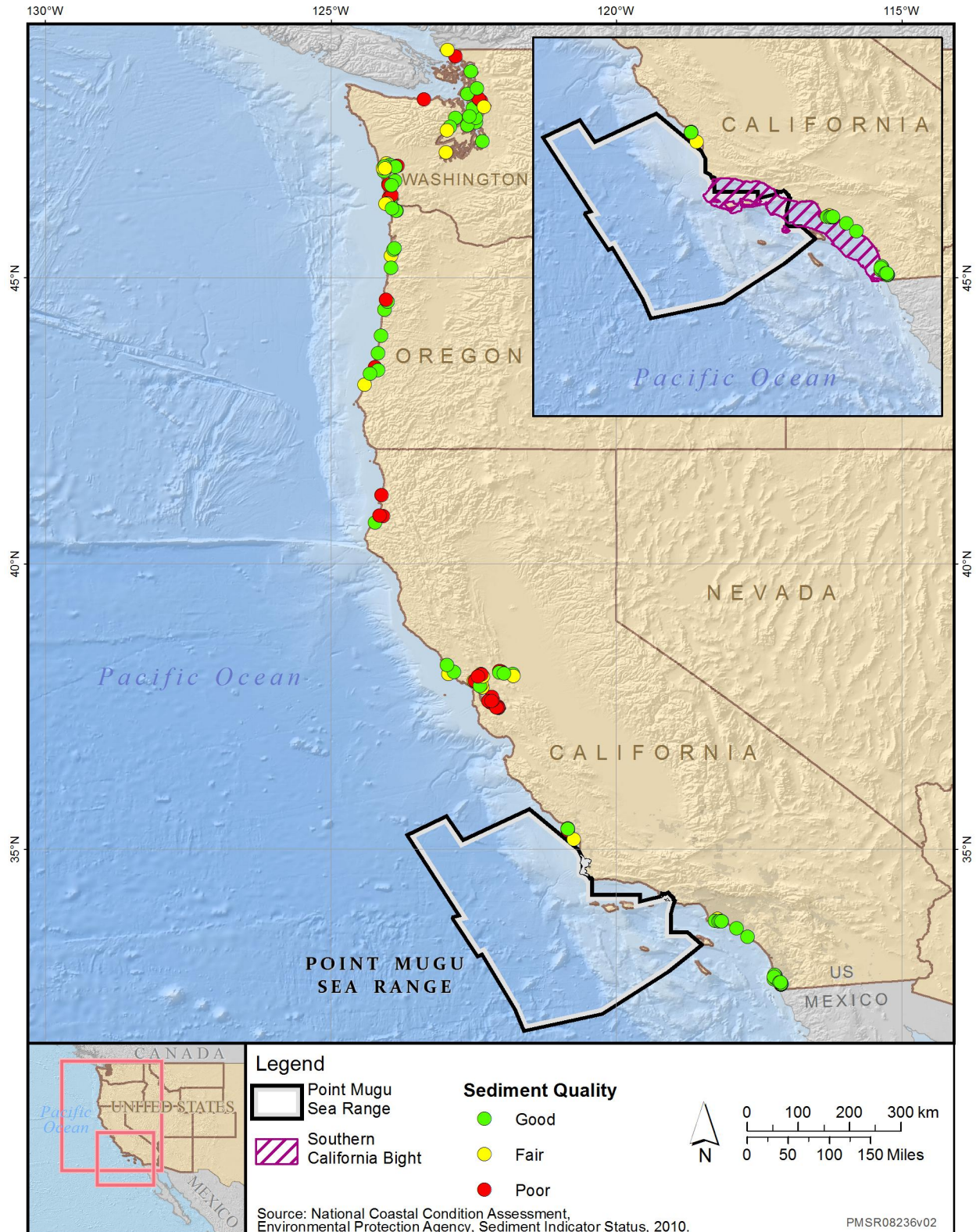


Figure 3.2-3: Sediment Quality for the West Coast Region

For sediment contaminants, the USEPA rated 99 percent of the West Coast Region's coastal ocean sediments good, less than 1 percent fair, and less than 1 percent poor. The most prevalent chemicals exceeding Effects Range Low threshold, which is the level measured in the sediment below which adverse biological effects were measured 10 percent of the time, in terms of coastal areas were chromium (31 percent), arsenic (8 percent), 2-methylnaphthalene (6 percent), cadmium (5 percent), and mercury (4 percent). The 2-methylnaphthalene exceedances were grouped around the Channel Islands National Marine Sanctuary, which encompasses the waters that surround Anacapa, Santa Cruz, Santa Rosa, San Miguel, and Santa Barbara Islands (five of the eight Channel Islands). Four of these sites (Anacapa, Santa Cruz, Santa Rosa, and San Miguel Islands) fall within the Study Area boundaries. Overall, coastal ocean and estuarine waters within the Study Area were rated good for contaminants (U.S. Environmental Protection Agency, 2012b).

The *Southern California Bight 2013 Regional Monitoring Program* (Bight'13) is the fifth in a series of regional marine monitoring efforts beginning in 1994 and repeated in 1998, 2003, and 2008. The program had five components: Contaminant Impact Assessment, Water Column Nutrients, Shoreline Microbiology, Marine Protected Areas, and Trash and Debris (see Section 3.2.4.1.2, Marine Debris in Nearshore and Offshore Areas of the Point Mugu Sea Range Study Area). Volume IV assessed sediment chemistry within the SCB; the northern half of the SCB overlaps with the southern half of the Study Area, from Point Conception in Santa Barbara County to just north of San Clemente Island (Figure 3.2-4). Although the northern half of the Study Area is not included, Bight'13 is the most recent comprehensive analysis of sediment quality in both nearshore and offshore areas within the region of influence. A total of 346 sites were sampled between July and September 2013, and analyzed for grain size, total organic carbon, 15 trace metals, total polynuclear aromatic hydrocarbons (PAHs), total polychlorinated biphenyls (PCBs), total dichlorodiphenyltrichloroethane (DDT), and total chlordane. Two groups of emerging contaminants were measured in Bight'13, including 13 polybrominated diphenyl ether (PBDE) flame retardants and 8 pyrethroid pesticides. As shown in Figure 3.2-5, there were 11 strata selected, including 3 continental shelf strata (5–30 m, 30–120 m, 120–200 m), upper slope (200–500 m), lower slope and basin (500–1,000 m), and embayment strata (marinas, ports, open bays and harbors, estuaries) (Figure 3.2-5). Two new strata, offshore submarine canyon bottoms and marine protected areas, were introduced for the first time (Dodder et al., 2016). Sediment chemistry and contamination results for these strata are discussed below.

Sixty-eight percent of sediments in the SCB have minimal or low contamination, and less than 1 percent have high contamination, the worst category (Dodder et al., 2016). Higher levels of sediment contamination occurred generally in nearshore embayments rather than in offshore area sediments on the continental shelf and slope; the distribution of contaminants was dependent on the location of the source of the contaminant. For example, concentrations of DDT are higher in sediments off Los Angeles due to long-term discharges from the Los Angeles sanitation district ocean outfall, whereas copper concentrations are higher in sediments in San Diego Bay, which is home to several large marinas, due to the use of anti-fouling paints on recreational and commercial vessels. PAHs were also higher in embayment areas, but that is likely due to land-based runoff. Total pyrethroid pesticides were highest in marinas (in particular estuaries) compared to ports and bays. Total PBDE concentrations were approximately the same for nearshore and offshore areas (Dodder et al., 2016; Neira et al., 2009).

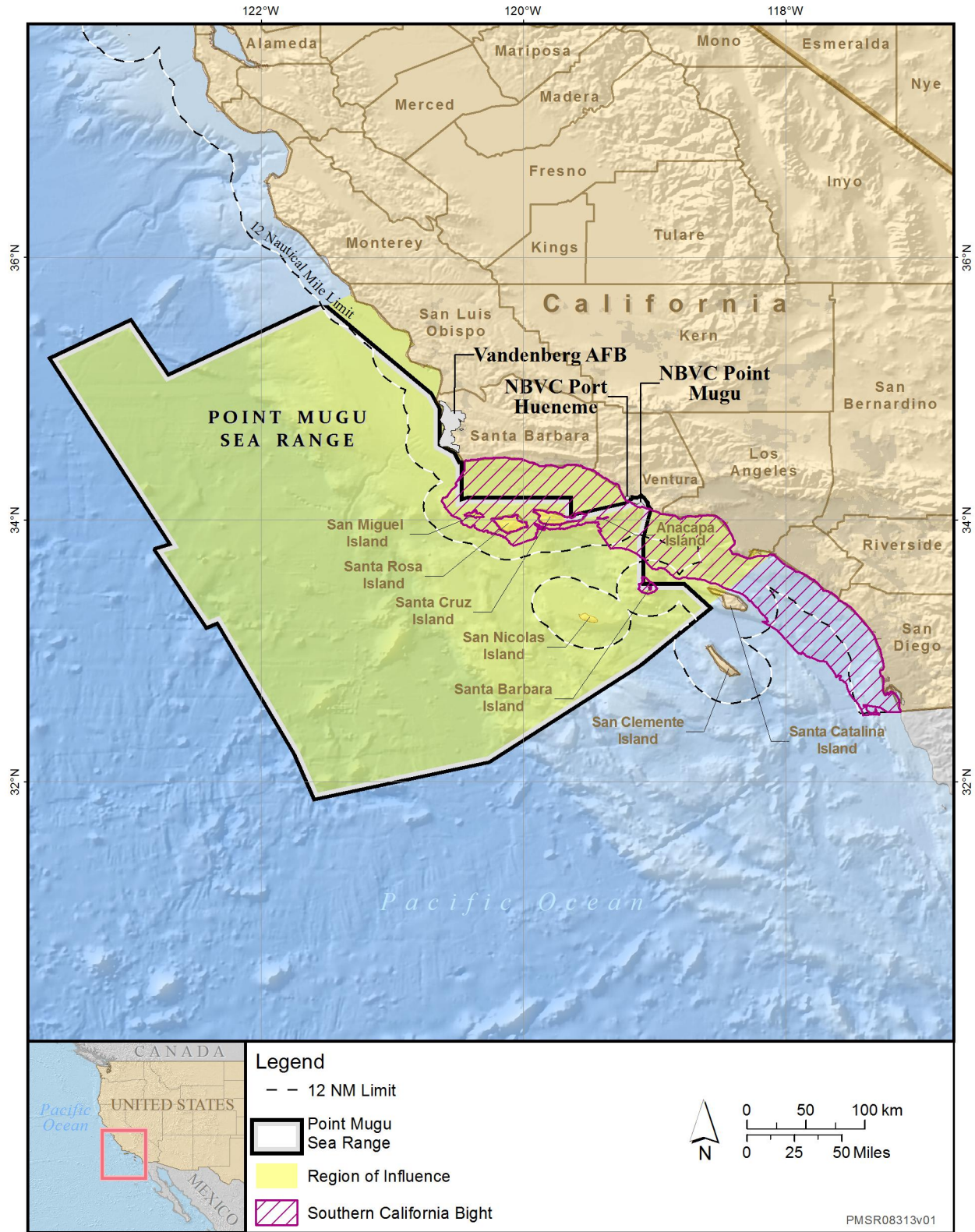
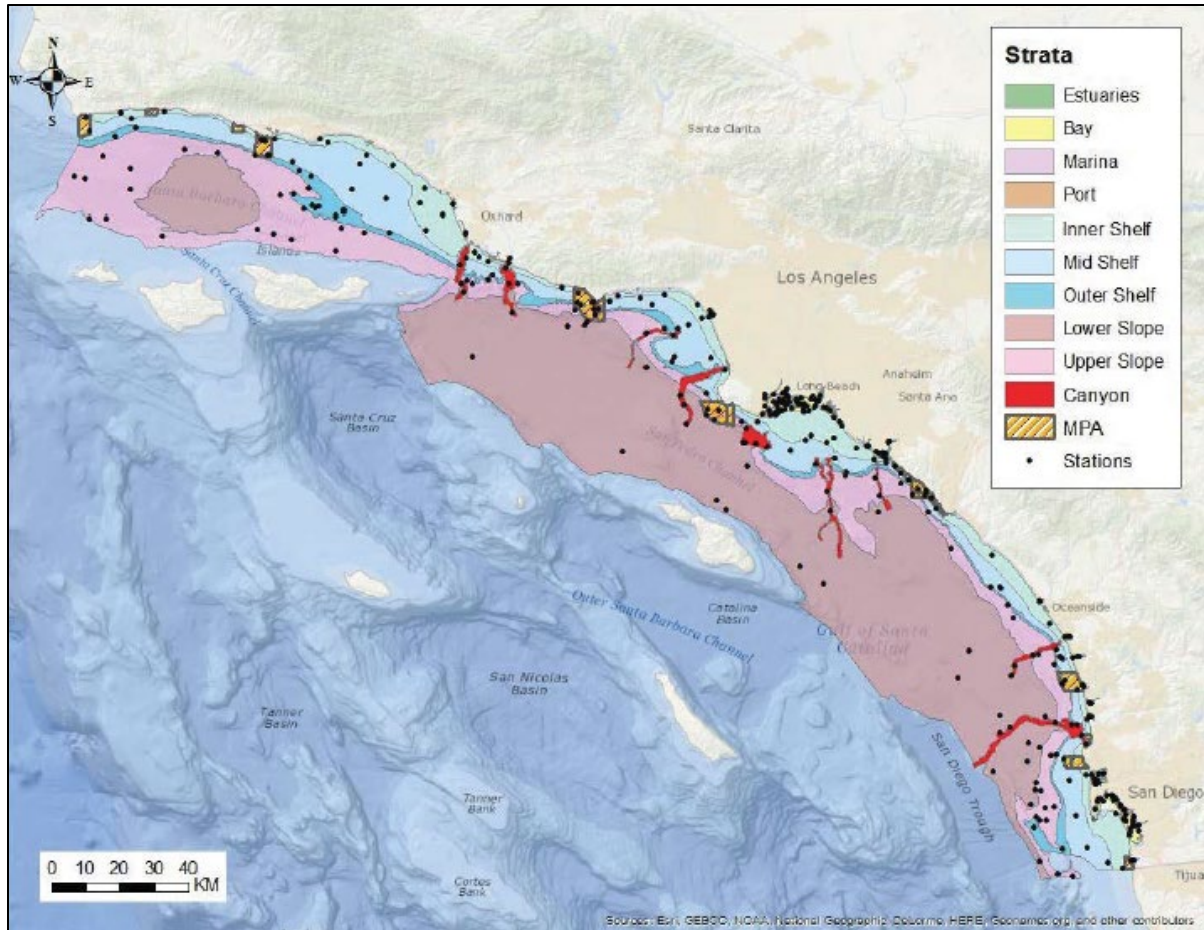


Figure 3.2-4: Point Mugu Sea Range Intersection with Southern California Bight



**Figure 3.2-5: Stratum Boundaries in Bight’13 (Dodder et al., 2016)**

As mentioned previously, Bight’13 surveyed sediments in offshore submarine canyons and marine protected areas for the first time (Dodder et al., 2016). As suspected, the concentration of sediment contaminants was higher in canyons and marine protected areas that were adjacent to continental shelf areas with higher levels of contaminants, indicating that contaminated sediments on the shelf are being transported into adjacent canyons and marine protected areas. The range of contaminant(s) responsible for the observed sediment toxicity in submarine canyons remains largely unknown. There are multiple offshore submarine canyons and marine protected areas located within the Study Area, which are discussed in Section 3.3 (Marine Habitats) and Chapter 6 (Other Regulatory Considerations). Contaminant concentrations within each stratum, including canyons and marine protected areas, can be found in Table 3.2-2.

**Table 3.2-2: Mean Concentrations of Sediment Contaminants in Geographic Subpopulations of the Southern California Bight**

Chemical Group	Shelf			Slope and Basin		Embayments					Marine Protected Areas
	Inner (5–30m)	Mid (30–120m)	Outer (120–200m)	Upper (200–500m)	Lower (500–1,000m)	Marinas	Estuaries	Ports	Bays	Canyons	
Aluminum	7,000	13,000	49	75	89	25,000	24,000	26,000	27,000	27,000	22,000
Antimony	0.43	0.92	1.1	1.4	0.76	0.56	0.66	0.76	0.44	0.61	1.0
Arsenic	2.4	2.7	5.3	5.4	3.9	7.1	5.9	12	8.5	4.5	3.9
Barium	75	130	130	160	360	100	100	190	120	190	150
Beryllium	0.13	0.21	0.36	0.27	0.45	0.54	0.49	0.69	0.57	0.45	0.15
Cadmium	0.66	0.68	0.82	1.5	1.5	1.3	0.60	0.49	0.41	2.0	0.91
Chromium	17	30	37	57	72	49	37	56	45	52	47
Copper	3.7	7.9	11	21	35	120	33	75	55	28	17
Iron	11,000	18,000	28,000	29,000	28,000	28,000	27,000	32,000	27,000	27,000	22,000
Lead	4.3	7.0	10	12	12	38	17	30	32	14	11
Mercury	0.041	0.051	0.067	0.083	0.11	0.30	0.058	0.53	0.22	0.096	0.11
Nickel	9.	15	18	30	43	22	18	28	19	27	21
Selenium	0.068	0.096	0.21	0.89	2.1	0.23	0.34	0.55	0.34	0.74	0.42
Silver	0.22	0.29	0.39	0.24	0.53	0.38	0.060	0.44	0.92	0.44	0.24
Zinc	29	48	57	88	100	190	100	150	130	84	73
PAH	24	55	92	160	130	660	380	420	300	130	100
PCB	0.62	2.7	4.5	15	2.7	15	5.4	6.2	10	3.5	23
DDT	12	18	79	490	97	22	3.2	1.2	4.4	140	790
Chlordanes	0.036	0.024	0.066	1.1	<RL	3.7	0.48	0.040	0.31	0.041	0.029
Pyrethroids	n/a	n/a	n/a	n/a	n/a	7.8	100	0.057	2.3	n/a	n/a
PBDE	0.99	2.8	4.2	3.5	2.5	3.6	0.42	3.5	2.5	4.1	n/a

Note: (1) Metal concentrations are in microgram/gram dry weight, and organic contaminant concentrations are in nanogram/gram dry weight. (2) n/a = not applicable  
Source: Dodder et al. (2016)

Overall, the relative extent of sediment contamination was generally greater in embayments than offshore; up to 20 percent of the embayment strata had high exposure to sediment contamination, compared to 3 percent of the offshore strata. The greatest sediment concentrations of contaminants such as PAHs, zinc, and copper occurred near embayment sources, including marinas with vessel anti-fouling paints and estuaries that receive land-based runoff. The greatest concentrations of DDT in the SCB, likely from historical inputs, were located on the continental shelf near the Palos Verdes shelf (Dodder et al., 2016). Since 2003, trends in the entire SCB have been stable, but the sediment condition for some habitats within the SCB has changed. For example, the spatial extent of sediments with acceptable chemistry in ports, bays, and marinas steadily improved from 40 percent in 1998 to 72 percent in 2013. However, the extent of acceptable sediment chemistry in continental shelf sediments declined from 93 percent in 1998 to 80 percent in 2013, suggesting a possible decline in offshore benthic habitat. The concentrations of some contaminants of emerging concern, such as PBDE flame retardants, have been reduced, likely due to the implementation of regulations that restrict the production and use of these chemicals beginning in 2010 (Dodder et al., 2016). Between 2008 and 2013, Bight '13 results indicated a 10-fold reduction in the average concentration of PBDE flame retardants in embayments.

In a separate analysis of data accumulated by the *Southern California Bight Regional Monitoring Program*, Maruya and Schiff (2009) found that the majority of accumulated contaminants in surficial (<2 centimeters [cm]) sediments of the SCB were found in the deep ocean of the mainland slope and basins; sediments at these depths were contaminated with at least one constituent, and between 58 and 86 percent of the contaminant mass in the top 2 cm was found in depths greater than 200 m. This accumulation is largely due to pollutants being transported downslope. Large publicly owned treatment works discharges, located between 60 and 100 m in the SCB, are often located near submarine canyons that form a conduit to the deep ocean. Once anthropogenic contaminants are accumulated in the deep ocean, advection is less likely to occur due to lack of significant mixing and dispersion in basins (Maruya & Schiff, 2009).

Although sediment quality is generally rated good throughout the region, past sediment issues have not implicated military operations as a key source of contamination. Studies conducted at World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016) and at an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) confirmed that nearby sediments had no detection for explosive materials. Assessments done at the Potomac River Test Range at Dahlgren, Virginia, which is the nation's largest fully instrumented over-the-water gun-firing range and has been used as a test range since the Civil War era, indicated that munitions expended at Dahlgren have not contributed significant sediment contamination and that any contributions made, with respect to heavy metals or organic hazardous constituents, are orders of magnitude less than concentrations already present in the Potomac River (U.S. Department of the Navy, 2013d).

Additionally, Lotufo et al. (2017) examined concentrations of explosives in marine sediments. The authors found concentrations that exceeded the ecological screening level for at least one explosive at multiple sites, including in nearshore waters of Ostrich Bay near Bremerton, WA and along Elliott Bay near Seattle, WA at piers formerly used by the Navy as a supply depot during World War II. The piers, referred to as Terminal 91, are now managed by the Port of Seattle under the DoD Military Munitions Response Program. It is likely that the small quantities of munitions found off piers were dropped overboard during vessel loading; there are no records of detonations occurring at the piers. Out of the seven sites with exceedances, only three (Hawaii, Terminal 91, and Halifax Harbor, Canada) had a

sufficient number of samples to allow for a site-wide characterization of contamination. At the Hawaii site, 56 samples were collected and 4 had constituent concentrations that exceeded ecological screening levels for dinitrotoluene (DNT) or Royal Demolition Explosive (RDX) (Lotufo et al., 2017). Off Terminal 91, 1 out of 12 samples exceeded the screening level for the explosives constituent 2,4,6-trinitrophenylmethylnitramine (or “tetryl”), and in Halifax Harbor, 6 out of 23 samples exceeded screening levels for either DNT or 1,3-dinitrobenzene. The data from these three sites appear to be consistent with previous reports that the spatial distribution of munitions constituents in sediments at a given geographic site is highly variable but generally decreases with distance from the munition, such that munitions constituents are not detectable beyond 1 to 2 meters from the munition (Lotufo, 2018; Rosen & Lotufo, 2010; University of Hawaii, 2014). A more detailed discussion of these research efforts and marine operations in relation to sediment quality is presented in Section 3.2.5 (Environmental Consequences).

Common sediment contaminants can be introduced into marine environments through a variety of sources, including but not limited to: urban and industrial activities (e.g., sewage discharge, atmospheric emissions), anthropogenic activities (e.g., anti-fouling paints, agricultural activities, offshore oil drilling), maritime traffic (e.g., oil, fuel, cargo spills), military activities (e.g., discharge from maritime training exercises, range activity), and naturally occurring processes (e.g., runoff due to erosion and weathering of the land surface, storm events). Unless a significant pollution event occurs, such as an oil or fuel spill, it is difficult to pinpoint exactly where the source of sediment contamination is coming from, especially in offshore areas.

#### **3.2.4.1.2 Marine Debris in Nearshore and Offshore Areas of the Point Mugu Sea Range Study Area**

For the first time, the Bight’13 has conducted a comprehensive regional assessment of trash and marine debris in streams and nearshore waters of the SCB (Moore et al., 2016). While macro-marine debris (debris greater than 5 mm in diameter) found on the seafloor has been quantified in past studies of the Bight, Moore et al. (2016) sampled, for the first time, micro-marine debris (particles 5 mm or less in diameter) imbedded in seafloor sediments. The study analyzed 164 benthic trawl samples and found that one-third of the seafloor in the SCB contained anthropogenic macro-debris with plastics being the most widespread type of debris. Debris consisted of plastic, cans, glass bottles, metal, lumber, and other debris (e.g., cloth, tape, fiberglass, and caulk). Of the six different habitat areas surveyed, the greatest extent of seafloor containing debris was in Marine Protected Areas (Table 3.2-3). This may be a result of intensive fishing that took place in these areas prior to their designation as marine protected areas, which did not occur until after 2011. The extent of seafloor macro-debris nearly doubled from 1994 to 2013, and the extent of plastic increased threefold. Plastic macro-debris was found throughout the SCB.

**Table 3.2-3: Percent of Macro-Debris Found on Seafloor Habitats in the Southern California Bight**

<i>Habitat</i>	<i>Depth Range (m)</i>	<i>Area of Habitat (km<sup>2</sup>)</i>	<i>Percent of Seafloor Containing Macro-Debris</i>
Bays	5–30	67	13
Inner Continental Shelf	5–30	975	18
Middle Continental Shelf	31–120	1,528	22
Outer Continental Shelf	121–200	438	35
Upper Continental Slope	201–500	2,857	41
Marine Protected Areas	Variable	137	43

Notes: m = meter(s), km<sup>2</sup> = square kilometer(s)  
Source: Moore et al. (2016)

The extent and abundance of micro-debris (< 5 mm in diameter) in the SCB was assessed by collecting 358 sediment samples across 12 different habitats. Benthic microplastics were found in 38 percent of sediments (Moore et al., 2016). Embayments were the habitat with the greatest relative extent and abundance of microplastics, with the vast majority of the seafloor in ports, marinas, and bays containing microplastics (Table 3.2-4). Continental shelf habitats had the lowest extent and abundance of benthic microplastic. Nylon and high-density polyethylene were the most common polymer types.

Watters et al. (2010) conducted a visual survey of the seafloor that included the PMSR area as part of a 15-year quantitative assessment of marine debris on the seafloor off the California coast. Plastics were the most abundant material and, along with recreational monofilament fishing line, dominated the debris encountered on the seafloor. Throughout the duration of the survey, only a single object that was potentially “military” in origin (it appeared to be a shell casing) was encountered. U.S. Navy vessels have a zero-plastic discharge policy and return all plastic waste to appropriate disposal or recycling sites on shore.

In 2007–2008, Groundfish Bottom Trawl Surveys were used to study marine debris along the U.S. West Coast. This study characterized the composition and abundance of man-made marine debris at 1,347 randomly selected stations (Keller et al., 2010). The sample sites included locations within the PMSR Study Area. A subset of the sites sampled included historically used post-World War II dump sites. Recovered items identifying the sites as post-World War II-era dump sites included equipment described as helmets, gas masks, uniforms, and other miscellaneous and diverse items such as plastic, file cabinets, and buckets. Since approximately the 1970s, items such as these are no longer disposed of at sea. The items listed here are not military expended material and would not be expended during testing and training activities in the PMSR Study Area. For this reason, the characterization of “military debris” in Keller et al. (2010) has little if any relevance to the Proposed Action or to present-day standard Navy conduct that (among other procedures) restricts the discharge of plastic at sea.

**Table 3.2-4: Extent and Abundance of Microplastics Found on Seafloor Habitats in the Southern California Bight**

<i>Habitat Type</i>	<i>Percent of Seafloor Containing Microplastics</i>	<i>Mean Number of Pieces per Area (Number/0.1 m<sup>2</sup>)</i>
Ports	88	63
Marinas	79	34
Bays	71	8
Estuaries	39	14
Inner Continental Shelf	28	1
Middle Continental Shelf	25	1
Outer Continental Shelf	39	2
Upper Continental Slope	38	2
Marine Protected Area	58	4
Canyon Bottom Sediments	41	4

Note: m<sup>2</sup> = square meter(s)  
Source: Moore et al. (2016)

Also in 2008, the Ocean Protection Council (OPC) and the National Oceanic and Atmospheric Administration’s Marine Debris Program released *An Implementation Strategy to Reduce and Prevent Ocean Litter*. This strategy was successful at promoting actions such as the ratification of the single-use plastic carryout bag ban and the adoption of the State Water Resources Control Board’s Trash Amendments (California Ocean Protection Council & National Oceanic and Atmospheric Administration Marine Debris Program, 2018). The OPC and the National Oceanic and Atmospheric Administration’s Marine Debris Program partnered to update the 2008 Strategy; the 2018 California Ocean Litter Prevention Strategy (Strategy) was adopted by the OPC in April 2018. The 2018 update expands the previous Strategy to include projects of a variety of scales and scopes so that entities including government agencies, industry, academia, nonprofits, and tribes can collaborate on meaningful contributions to reducing ocean litter in California. The Strategy includes OPC Priorities to address ocean litter and stakeholder-identified Goals, Objectives, and Action Items to address ocean litter in three broad categories: land-based ocean litter, microplastics and microfibers, and fishing and aquaculture gear. In addition to these efforts, the *Southern California Bight 2018 Regional Monitoring Program*, which is a continuation of the cooperative regional-scale monitoring in Southern California, is planning an Epibenthic Debris Survey as part of the larger SCB Regional Survey. This effort will look at the extent and magnitude of debris as well as debris trends over all SCB surveys (Southern California Coastal Water Research Project, 2018). States and local governments can use the Clean Water Act, which provides regulatory tools to address aquatic trash, in conjunction with other non-regulatory measures, to reduce trash loadings into water. Total Maximum Daily Loads for trash have been established for multiple California localities, which identifies the source of the pollutant, and each source is assigned a maximum amount of the pollutant is allowed to release. In Los Angeles, for example, there are more than ten trash Total Maximum Daily Loads in the region (U.S. Environmental Protection Agency, 2017).

### 3.2.4.1.3 Climate Change and Sediment Quality

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 and become more soluble and potentially more available.

The effects of climate change over the next century will impact water and sediment quality within coastal protected areas within the study area in a variety of ways. Most notably will be the effects of sea level rise and increased tidal surges on natural resources and shore infrastructure, and a diminution of freshwater inputs (U.S. Department of the Navy, 2013a). Marginal bay habitats without protective buffers are most at risk, especially those that require special salinity conditions, intermittent inundation, or light penetration. Changes in water temperature affect mud temperature and influence nutrient processing (Stillman & Paganini, 2015).

Tropical storms can also have significant impacts on the resuspension and distribution of bottom sediment (Wren & Leonard, 2005). However, no consensus appears to exist on whether climate change will generate more tropical storms or whether those storms will be more intense. If storm frequency and intensity increase, the additional disturbance of sediment may impact water quality in nearshore and coastal areas.

### 3.2.4.2 Water Quality

The current state of water quality in the Study Area, from nearshore areas to the open-ocean and deep-sea bottom, is discussed below. Table 3.2-5 provides the water quality criteria and an associated index for the U.S. West Coast.

#### 3.2.4.2.1 Water Quality in Nearshore and Offshore Areas of the Point Mugu Sea Range Study Area

The waters of the PMSR includes nearshore waters and coastal bays as well as offshore waters beyond the U.S. Exclusive Economic Zone (the “high seas”). Small- and large-scale oceanographic processes, including coastal upwelling and advection by offshore currents, result in broad vertical mixing throughout the upper water column and horizontal transport of water from nearshore to offshore areas, which maintain generally high water quality levels that meet or exceed criteria set forth by the California Ocean Plan (State Water Resources Control Board, 2015) and by the National Ambient Water Quality Criteria. The water quality index, based on measurements of dissolved inorganic nitrogen, dissolved inorganic phosphorus, chlorophyll-*a*, water clarity, and dissolved oxygen, for the coastal waters of the West Coast region, extending from Southern California to Canada, is rated good, with 19 percent of the coast rated fair and only 2 percent rated poor (Figure 3.2-6) (U.S. Environmental Protection Agency, 2012b).

**Table 3.2-5: Water Quality Criteria and Index, United States West Coast**

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

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

Source: (U.S. Environmental Protection Agency, 2012b)

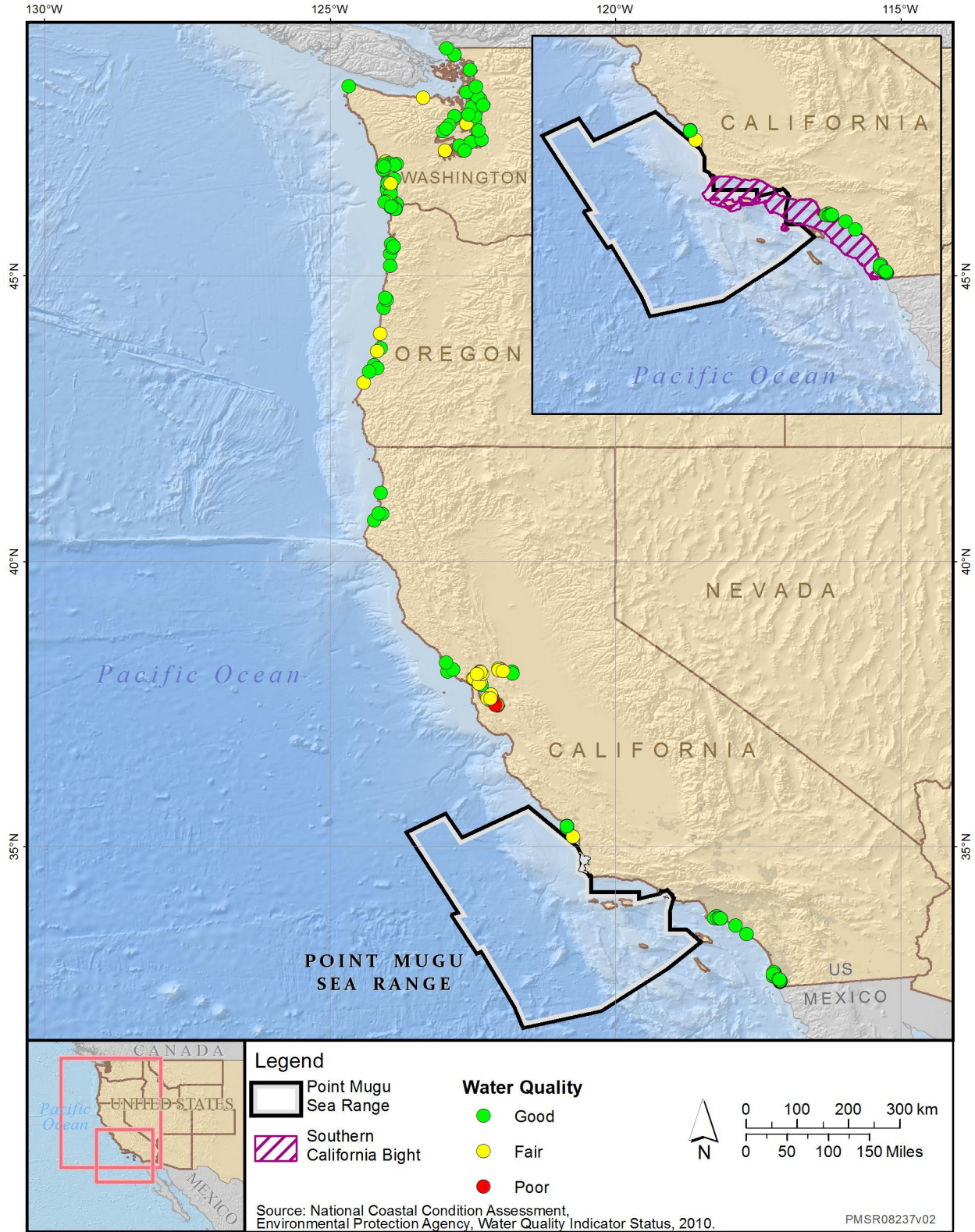


Figure 3.2-6: Water Quality Index for the West Coast Region

### General Characteristics

Water quality in the nearshore area of PMSR is dependent upon the presence of particulates and contaminants in the outflow from Mugu Lagoon. In general, dissolved oxygen levels are high and anaerobic conditions do not occur within Mugu Lagoon. Residual perchlorate, a contaminant resulting from the use of rocket-assisted takeoff (RATO) bottles<sup>1</sup> expended in Mugu Lagoon, was calculated for both short-term and long-term surface water concentrations for the Final PMSR EIS/OEIS (U.S. Department of the Navy, 2002). Short-term surface water concentration of perchlorate in the expended RATO bottle drop zone was calculated to be 3.90 parts per billion (ppb) for small drone targets and 13.40 ppb for large drone targets. Long-term concentrations for all targets was calculated to be 0.30 ppb. These estimates are below the current DoD level of concern for managing perchlorate (24.5 ppb) (U.S. Department of Defense, 2009) and USEPA's established reference level (15 ppb) (U.S. Environmental Protection Agency, 2014). The Navy's Range Sustainment Program is designed to ensure ranges remain operational and that the Navy protects human health and the environment for nearby communities. The Range Sustainment Environmental Program Assessment process is designed to assess environmental impacts of testing and training operations and to implement measures to protect the environment when needed. Munitions constituents are defined in the Range Sustainment Environmental Program Assessment Policy Implementation Manual (U.S. Department of the Navy, 2008b) as materials originating from military munitions, including explosive and non-explosive materials, and the emissions, degradation, or breakdown of such munitions. For live munitions, the primary munitions constituents are RDX, high melting explosive (commonly referred to as HMX), 2,4,6-Trinitrotoluene (commonly referred to as TNT), and aluminum. Primary munitions constituents for practice munitions are nitroglycerin and nitrocellulose. For surface-to-air missiles, the primary munitions constituent is perchlorate (U.S. Department of the Navy, 2008b). The modeled calculation was based on perchlorate being 99 percent expended from the RATO bottles, conservative estimate of water volumes, and no naturally occurring perchlorates present. Although there are no federal/State standards for perchlorate in surface water (non-drinking water source), based on the estimated concentrations in Mugu Lagoon, perchlorate concentrations are several orders of magnitude below the 9,300 ppb ecological marine surface water screening value developed by the DoD Range and Munitions Use Subcommittee (U.S. Department of Defense, 2009). It is also important to note that there are natural sources of perchlorate (Hatzinger et al., 2017).

Water temperatures inside Mugu Lagoon are usually similar to those of PMSR, although they may be higher and much more variable in the lagoon's shallows and salt marsh ponds. The average water temperature for the June to September months is 66 degrees Fahrenheit (°F) (19 degrees Celsius [°C]); the average water temperature for January is 55°F (13°C). Temperatures up to 85°F (29°C) have been recorded during low tide conditions on hot summer days. Salinities within the lagoon are also generally similar to those of the ocean, with an average daily salinity of about 34 parts per thousand (U.S. Department of the Navy, 2013b).

The surface salinity within the PMSR is typical of an oceanic environment, ranging from 32.9 to 34.5 practical salinity units (U.S. Department of the Navy, 1999a). Salinities are generally stable but have slight seasonal variation; maximum salinities occur in late spring (May) during periods of low rainfall and low freshwater runoff, while minimum salinities occur in winter (December) during periods of high

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<sup>1</sup> RATO bottles are a solid-fueled rocket motor that have the sole purpose of boosting a missile or target from a launcher.

rainfall and high freshwater runoff (U.S. Department of the Navy, 1999a). The lowest salinities are found in the north due to the influx of less saline Pacific Subarctic Water.

Salinities increase in the southern portion of the Study Area due to the influx of saline Pacific Equatorial Water from the south (Schneider et al., 2005). Surface salinity in the region shows the greatest variability near the mouths of coastal rivers, such as the Ventura/Santa Clara River System in the Santa Barbara Channel.

### **Biological Productivity**

Within the PMSR Study Area, phytoplankton production is moderately high (150–300 grams [g] of carbon per square meter per year) (Burtenshaw et al., 2004; Kudela et al., 2005); however, there is heterogeneity in the distribution of chlorophyll both spatially and temporally (Legaard & Thomas, 2006). Primary production, as measured by chlorophyll-*a* concentrations, varies on both seasonal and interannual time scales (Chen et al., 2004; Legaard & Thomas, 2006), although concentrations are consistently greatest along the coastline and decrease with distance from shore. Estimates close to shore, including around the coastline of the Channel Islands, approach 10 milligrams per cubic meter during the cool-water period (December 16 to June 14), which includes the spring upwelling season. Highest levels of productivity occur in spring and summer, and the lowest levels of production occur during winter (Burtenshaw et al., 2004). Phytoplankton biomass is typically highest near the shorelines of the mainland and Channel Islands (Burtenshaw et al., 2004) where small-scale eddies, upwelling, and turbulence provide the necessary nutrients for increased levels of production.

In the open water areas of the SCB (see Figure 3.2-4), seasonal surface water fluctuations occur in association with upwelling, seasonal and interannual changes in climate, and latitude. On average, there is an annual flux in surface temperature throughout the year up and down the California coast. Over the course of the year, there is an increase along a north-south gradient ranging from 52°F (11°C) in the north during winter to 72°F (22°C) in the south during summer (Bearzi, 2003). Maximum surface water temperature variations within the Study Area range from 50 to 73°F (10 to 23°C). Both the El Niño and La Niña events can alter the surface temperatures. Since the El Niño weakens the California Current, warmer subtropical waters from the coastal countercurrent can flow northward (Dailey et al., 1993; Hayward, 2000). During La Niña events, the southward flow of the California Current strengthens, transporting cold, subarctic waters farther south within the SCB; enhancing coastal upwelling; and creating anomalously cold sea surface temperature off of the California coast 37 to 39°F (3 to 4°C) below normal (Burtenshaw et al., 2004; Hayward et al., 1999; Schwing et al., 1999).

The Northern Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa Islands) that lie off the northern region of the SCB provide an ecologically rich area that is among the most productive and diverse in the world. This area is home to over 500 species of fish and 1,500 species of marine invertebrates (Morgan et al., 2005). Its diversity is partly due to unique water circulation patterns that incorporate warm equatorial waters from the south and subarctic waters from the north. These mixing water masses form a large semi-permanent eddy composed of warm nearshore waters and cool offshore waters.

### **Areas of Special Biological Significance**

Within the PMSR Study Area, there are four ASBS areas designated by the State Water Resources Control Board: Laguna Point to Latigo Point; Santa Barbara Island and Anacapa Island; San Nicolas Island (SNI) and Begg Rock; and San Miguel, Santa Rosa, and Santa Cruz Islands (Figure 3.2-7). The ASBS designation was enacted in 1974 and established regulations and guidelines pertaining to water quality

concerns and focused on the beneficial uses of water resources related to surface water runoff, point source discharge, and the potential biological impacts for the water input.

At the SNI and Begg Rock ASBS, discharges incidental to military research, development, testing and training, and evaluation of, and training with guided missile and other weapons systems, fleet training exercises, small-scale amphibious warfare training, and special warfare training are allowed.

Discharges must not result in a violation of the water quality objectives, including the protection of the marine aquatic life beneficial use, anywhere in the ASBS (U.S. Department of the Navy, 2015). This exception to the California Ocean Plan for selected discharges into the SNI and Begg Rock ASBS was established by the State Water Resources Control Board Resolution 2012-0012.

At SNI, the nearshore areas, waters that discharge into the ocean (e.g., springs), and groundwater resources are the most vulnerable to contamination or decreased water quality. Storm water pollution is the biggest threat to the nearshore waters at SNI. Historically, hexavalent chromium, pesticides, and chlorine have been found along the shore at Coast Guard Beach, Daytona Beach, Blue Whale Cove, and Tranquility Beach. These are all locations representative of areas that receive storm water discharges associated with Navy operation activities, such as residential areas, water desalination, and rocket launch operations. All contaminant levels were below the maximum and have had no impact on beneficial uses at SNI (U.S. Department of the Navy, 2007). Perchlorate had been detected in drinking water samples from Windmill and Zitnic Springs on the northwestern portion of SNI at concentrations ranging from 6.8 to 20 ppb, which exceeds the California Maximum Contaminant Level (6 ppb) for drinking water. However, since both locations were disconnected from the potable water system in 2006, there are no human receptors for the Windmill and Zitnic Springs water and the California Maximum Contaminant Level is not applicable. Small amounts of water from the Zitnic Springs aquifer emerge at the coastline. Based on attenuation model calculations, tidal forces and longshore currents would attenuate the highest detected concentration (20 ppb) to 0.2 ppb within a few feet of the cliff zone; therefore, there is no potential for off-range release of perchlorate to offshore waters.

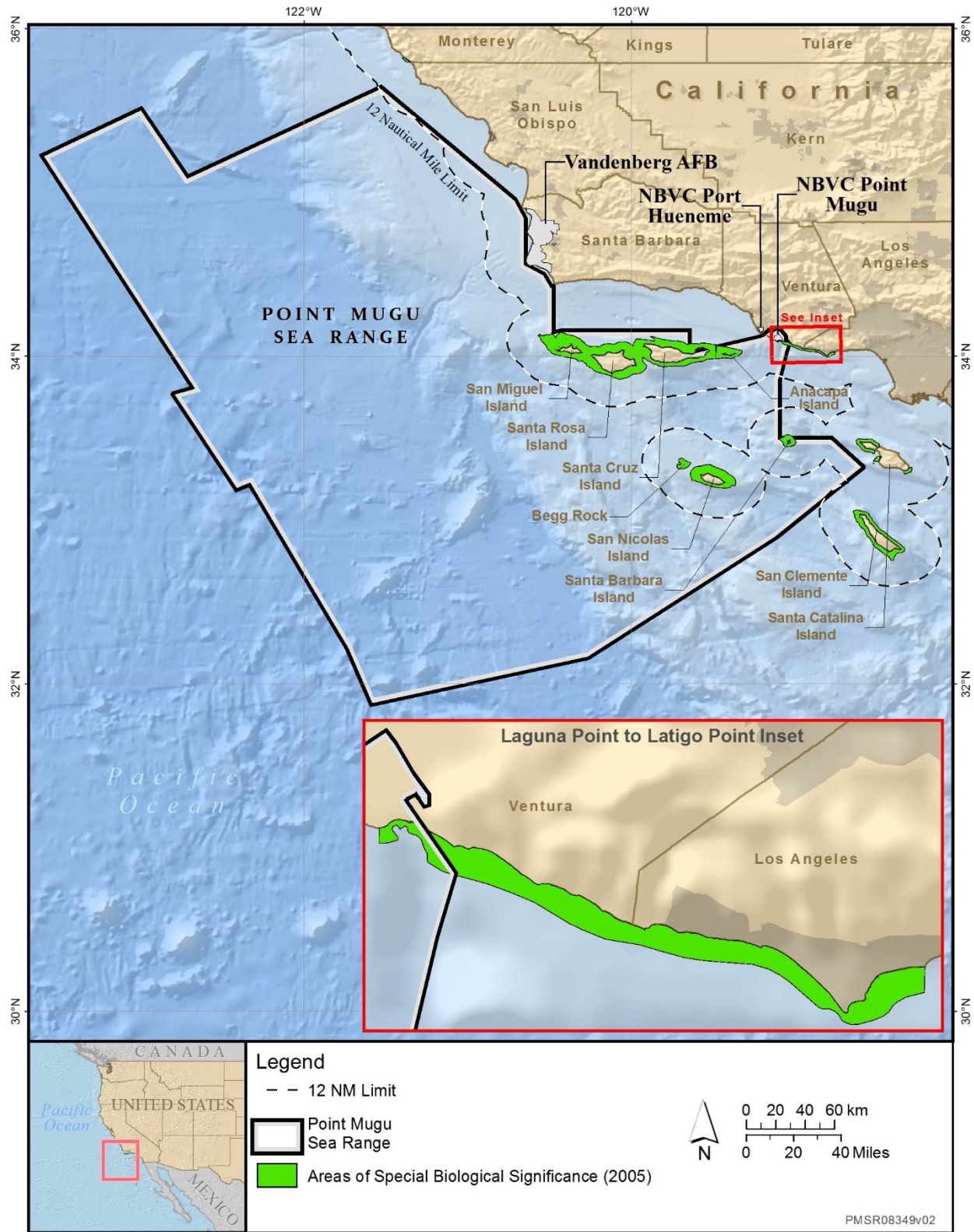


Figure 3.2-7: Areas of Special Biological Significance

### **Anthropogenic Sources**

Within the PMSR, water quality in the nearshore areas is strongly affected by human activities in heavily developed Central and Southern California. Urban runoff is the largest source of contaminants along this portion of the California coast and can transport bacteria, inorganic nutrients, various organic compounds, metals, and debris into downstream or adjacent water bodies. Nonpoint source runoff is substantial in Southern California, because most rivers are highly modified stormwater conveyance systems that are not connected to sewage treatment systems. When storm events occur, runoff plumes can become large oceanographic features that extend for many miles (Center for Ocean Solutions, 2009). Along the Southern California coast, land-based chemical pollution, in particular PCBs and DDT, affects water quality. Another potential source of water pollution offshore comes from the oil and gas development industry and natural crude seeps. As activity increases from offshore oil and gas development, the potential for discharge into the Study Area also increases (U.S. Department of the Navy, 2016). In recent years, the increased frequency and extent of regional beach and shellfish-bed closures, coupled with decreases in local fishing catches, are taken as signs of declining water quality (U.S. Department of Commerce et al., 2008).

Commercial, recreational, and institutional vessels also discharge water pollutants along the Southern California coast. Shipboard waste-handling procedures governing the discharge of nonhazardous waste streams have been established for commercial and Navy vessels. The U.S. Navy's Environmental Readiness Program Manual (Chief of Naval Operations Instruction M-5090.1 applies to U.S. Navy ships and floating drydocks worldwide and, as appropriate, to the boats and other craft carried by these ships (U.S. Department of the Navy, 2007). This manual provides the Navy policy for environmental stewardship and compliance for its vessels operating both within U.S. waters and abroad. The discharge of waste, including blackwater (sewage), graywater (water from deck drains, showers, dishwashers, laundries, etc.), hazardous and medical wastes, plastics and other trash, as well as procedures for oil spill response and ballast water control are described.

PMSR and SNI have current Stormwater Pollution Prevention Plans; Spill Prevention, Control, and Countermeasure Plans; and Oil and Hazardous Substances Facility Response Plans. The Spill Prevention, Control, and Countermeasure Plans and Facility Response Plans are incorporated into the Integrated Oil and Hazardous Material Contingency Plan. Protective measures are in place per the current Stormwater Pollution Prevention Plan; however, these protective measures do not include the range operational areas. Additionally, both Point Mugu and SNI are in compliance with current water and wastewater program requirements.

### **Military Operations**

Available scientific information associated with the impact of military operations and associated munitions and explosives of concern on water quality is limited. There is no direct information available for the PMSR concerning impacts on water quality from military munitions and explosives.

Consequently, the studies mentioned below were used to indirectly correlate the impact of military operations and associated munitions and explosives on water quality at PMSR.

Studies conducted at World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016) and at an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) confirmed that water tested had no detection of munitions constituents. Assessments done at the Potomac River Test Range indicated that munitions expended at Dahlgren have not contributed significant water contamination and that any contributions made, with respect to heavy

metals or common organic hazardous constituents, are orders of magnitude less than concentrations already present in the Potomac River (U.S. Department of the Navy, 2013d). A study conducted by the U.S. Marine Corps sampled sediments and water quality for 26 different constituents, including lead and magnesium, related to munitions at several U.S. Marine Corps water-based training ranges. These areas also were used for bombing practice. No munitions constituents were detected above screening values used at the U.S. Marine Corps water ranges (U.S. Department of the Navy, 2010b).

Additionally, Lotufo et al. (2017) examined concentrations of explosives in the water column at multiple sites, including in Hawaii and Vieques, Puerto Rico, and found that there were no sites at which RDX or HMX concentrations exceeded ecological screening levels. The authors found one site, the Vieques bombing range, where TNT and 2,4-DNT concentrations exceeded at least one of four assessed ecological screening levels. The authors noted that the samples with exceedances were collected 10 cm from a breached munition, and that the TNT concentration was lower than the ecological screening level for a sample collected 1 m from the breached munition. Sampling results from the Vieques bombing range in Puerto Rico showed that munitions constituent concentrations in seawater are expected to decrease significantly as distance from the munition increases (Lotufo, 2018). Refer to Section 3.2.5 (Environmental Consequences) for a more in-depth discussion of these research efforts and marine operations in relation to water quality. Most modern military ordnance contains explosive compositions with blends containing multiple constituents, often with additional binder agents included. When explosives detonate, the solid charge is rapidly converted to gaseous products (U.S. Department of the Army, 1984); 99 percent of constituents are burned upon detonation and do not greatly impact water quality (Hewitt et al., 2003). Failure rates for all of the munitions used in the Proposed Action are not available; however, based on the data that are available, approximately 5 percent of munitions fail to detonate and enter the environment as unexploded ordnance (UXO) (MacDonald & Mendez, 2005). In the form of UXO, explosives are unique environmental contaminants and are subject to slow dissolution in an aqueous medium. Generally, explosives have slower degradation rates and tend to be less mobile than other anthropogenic water contaminants such as oil. Sediment microbial and chemical reduction, as well as mineralization, assist with the natural attenuation of contaminants over time and limit impact on water quality (Johnson et al., 2002). It is important to recognize that munitions and explosives of concern and UXO constituents may not be the only contaminants in the sea range, and that quantification of water quality and its impact on ecological risk requires a complete understanding of all contaminants that may exhibit toxicity and exposure potential (Johnson et al., 2002).

#### **3.2.4.2.2 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, be washed in with storm water, arise from recreational use of coastal areas, or be generated by extreme weather events. Ocean-based 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 (U.S. Environmental Protection Agency, 2010). These materials are concentrated at the near-surface and in the water column.

According to the U.S. Environmental Protection Agency (2010), land-based sources account for about half of marine debris, and ocean/waterway-based sources contribute another 18 percent. Bergmuller et al. (2007) confirmed that the majority of marine debris originates from land. Land-based debris included

items like syringes, condoms, metal beverage cans, motor oil containers, balloons, six-pack rings, straws, tampon applicators, and cotton swabs. Ocean-based debris included gloves, plastic sheets, light bulbs and tubes, oil and gas containers, pipe-thread protectors, nets, traps and pots, fishing line, light sticks, rope, salt bags, fish baskets, cruise line logo items, and floats and buoys. Plastics, generally referring to petroleum-based, manmade materials, make up the vast majority of marine debris (Bergmuller et al., 2007; Law & Thompson, 2014).

Microscopic plastic fragments enter the marine environment from use as scrubbers in hand cleaning and other cosmetic products, abrasive beads for cleaning ships, and deterioration of macroscopic plastics (Teuten et al., 2007). Microplastic beads commonly used in cosmetic products such as facial scrubs and other exfoliants are not broken down in wastewater treatment facilities and are largely not filtered out of the waste stream before they are flushed into the marine environment (Chang, 2015; Napper et al., 2015). These microbeads are found worldwide in marine sediments, persist in the marine environment, and accumulate up the food chain (Cole & Galloway, 2015).

Plastics may serve as vehicles for transport of various pollutants, whether by binding them 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 polychlorinated biphenyls, dichlorodiphenyldichloroethylene (a breakdown product of DDT), and the persistent organic pollutant nonylphenol (a precursor to certain detergents). Polychlorinated biphenyls and dichlorodiphenyldichloroethylene were adsorbed from seawater and accumulated on the surface of plastics. The original source of nonylphenol was less clear; it may have originated from the pellets themselves or may have been adsorbed from the seawater.

Since plastics are man-made polymers, they may contain other organic pollutants such as phthalates, organotins, and phenols (including bisphenol A) (Rios et al., 2010; Teuten et al., 2007). The biodegradation of plastic polymers by bacteria has been shown to introduce bisphenol A into seawater (Artham & Doble, 2009). In addition, analysis of plastic debris collected from coastal California found concentrations of PAHs, PCBs, and DDT (Rios et al., 2010).

Microbeads have also been shown to adsorb hydrophobic chemical contaminants, such as DDT, from seawater, allowing for the accumulation and transport of these often-toxic chemicals to widely dispersed areas of the oceans. While the impacts on the marine ecosystem are largely unknown, some examples illustrating potential widespread impacts have been discussed. For example, it has been suggested that white and blue microplastic beads, common in many exfoliants, resemble plankton and may be mistakenly ingested by plankton-feeding fishes, which rely on visual cues to find prey (Napper et al., 2015; Wright et al., 2013). The long-term effects on the environment from the proliferation of microbeads and other microplastics are still being researched. Since there is no way of effectively removing microplastics from the marine environment, and given that plastics are highly resistant to degradation, it is likely that the quantity of microplastics in the marine environment will only continue to increase, and therefore the likelihood of environmental impacts can only increase (Napper et al., 2015). The only way to reduce long-term impacts is to reduce or eliminate the use of microplastics, a course of action that is gaining recognition (Chang, 2015).

Because of their buoyancy, many types of plastic items float and may travel thousands of miles in the ocean (U.S. Commission on Ocean Policy, 2004). Exceptions include heavy nets and ropes. Although plastics are resistant to degradation, they do gradually break down into smaller particles due to sunlight and mechanical wear (Law et al., 2010). A study by Teuten et al. (2007) indicated that the water-borne

phenanthrene (a type of PAH) adhered preferentially to small pieces of plastic ingested by a bottom-dwelling marine lugworm and incorporated into its tissue. Marine microbes and fungi are known to degrade biologically produced polyesters, such as polyhydroxyalkanoates, a bacterial carbon and energy source (Doi et al., 1992). Marine microbes also degrade other synthetic polymers, although at slower rates (Shah et al., 2008).

Annex V of the International Convention for the Prevention of Pollution from Ships prohibits the discharge of plastic waste from vessels at sea, and the U.S. Act to Prevent Pollution from Ships brought U.S. public vessels in alignment with the international convention. The National Defense Authorization Act of 1996 specifically directed the Navy to install plastic waste processors aboard the surface fleet. The U.S. Navy's plastics waste processors compress and melt shipboard-generated plastic waste into dense, sanitary disks of compressed plastics that can be stored over long at-sea deployments. The plastic wastes items include lightly contaminated food containers as well as clean plastics and other materials that may be combined with, or contain, plastic components that cannot be processed in the normal solid waste stream. The plastic waste disks are offloaded for proper disposal once a ship comes into port. The plastic compression technology enables Navy ships to operate at sea over long time periods without discharging plastics into the oceans.

#### **3.2.4.2.3 Climate Change and Water Quality**

According to the U.S. Global Change Research Program, the rise in ocean temperature over the last century will continue into the reasonably foreseeable future, with continued and perhaps increasing impacts on ocean circulation, marine chemistry, and marine ecosystems. Because the ocean currently absorbs about a quarter of human-produced carbon dioxide emissions, increasing carbon dioxide absorption will increase acidification of ocean waters. This in turn will alter the distribution, abundance, and productivity of many marine species (Melillo et al., 2014).

Below are two of the key findings of the 2014 National Climate Assessment that may pertain to waters off California:

- With the decreases in snowpack and streamflow expected to continually decline, freshwater inputs into California's coastal estuaries will decrease, with subsequent losses of ecosystem services that estuaries provide (e.g., nutrient cycling, filtration).
- Sea level rise is projected to increase, resulting in major damage as wind-driven waves ride upon higher seas and reach farther inland.

#### **3.2.5 Environmental Consequences**

This section evaluates how and to what degree the testing and training activities described in Chapter 2 (Description of Proposed Action and Alternatives) may impact sediments and water quality in the Study Area. Section 2.1.1 (Current and Proposed Activities) presents current and proposed testing and training activities conducted annually for Alternatives 1 and 2. The analysis presented below applies to all of the testing and training scenarios (air-to-air, air-to-surface, surface-to-air, surface-to-surface, and subsurface-to-surface), as described in detail in Section 2.1.3 (Primary Mission Areas). Each water quality stressor is introduced, described in detail, and analyzed by alternative for potential impacts. Potential impacts could result from

- releasing materials into the water that subsequently disperse, react with seawater, or may dissolve over time;

- depositing materials on the ocean bottom and any subsequent interactions with sediments or the accumulation of such materials over time;
- depositing materials or substances on the ocean bottom and any subsequent interaction with the water column; and
- depositing materials on the ocean bottom and any subsequent disturbance of those sediments or their resuspension in the water column.

These potential impacts may result from four stressors: (1) explosives and explosive byproducts; (2) propellants, fuels, and initiators; (3) metals; and (4) other military expended materials (hereinafter referred to as other materials). The term “stressor” is used because materials in these four categories may directly impact sediments and water quality by altering their physical and chemical characteristics.

The area of analysis for sediments and water quality includes estuaries, nearshore areas, and the open ocean (including the seafloor) in the Study Area. The environmental fate of explosives, explosive byproducts, propellants, fuels, initiators, metals, and other materials depends on environmental factors, geochemical conditions, and various mechanisms that transport the constituents in the environment. Some natural transport mechanisms, such as advection by currents, dispersion, dissolution (dissolving), precipitation by chemical reaction, and adsorption (the adhesion of a chemical constituent onto the surface of a particle in the environment [e.g., clay]) reduce concentrations in water and redistribute constituents between the water and sediments. Other processes, such as biodegradation, may change or destroy the explosive compounds but would not affect metals. Source volume is a critical consideration in evaluating risk of operations to water quality and sediments. The ocean’s volume and the dilution caused by the currents, coupled with the procedures of testing and training at PMSR not allowing for accumulation of ordnance containing munitions constituents in a finite area, significantly reduces adverse impacts. For this analysis, potential impacts on sediments and water quality from military expended materials that are deposited in sediments at any given distance from shore are assumed to be similar.

#### **Explosives and Explosive Byproducts**

Explosives may be introduced into the seawater and sediments by the Proposed Action. Activities involving explosives and explosive byproducts occur on the land portions of Point Mugu and SNI, Mugu Lagoon, and between 0 and 3 NM offshore. These activities (0–3 NM) would be subject to State sediment and water quality standards and guidelines while activities conducted more than 3 NM offshore would be subject to federal sediment and water quality standards and guidelines.

Explosives are classified as primary, secondary, or tertiary based on their susceptibility to initiation. Energetic compounds are defined as the active chemical components of explosives. Commonly used military energetic compounds include the explosives 2,4,6- TNT, RDX, and HMX. TNT is one of the most common bulk explosives used in military ordnance; RDX is typically used in mixtures with other explosives; and HMX is used to burst artillery shells and as a component of plastic explosives (Pichtel, 2012). For the purpose of this analysis, impacts from chemical constituents produced in the combustion of propellants, fuels, and initiators are evaluated in Section 3.2.5.2.2 (Propellants, Fuels, and Initiators).

The explosive fillers contained within the munitions used during testing and training activities and their degradation products can enter the environment through high-order detonations (i.e., the munition functions as intended and 99 percent of explosives are consumed (Hewitt et al., 2003)), low-order detonations (i.e., the munition partially functions with only a portion of the explosives consumed), or unexploded munitions (i.e., the munition fails to detonate and explosives remain in the casing). In the

case of a successful detonation, only a small or residual amount of explosives may enter the marine environment (U.S. Environmental Protection Agency, 2012a). A low-order detonation would result in some residual explosives and some unconsumed explosives remaining in the munitions casing entering the water. In the case of unexploded munitions, the explosives contained in the munition would not be consumed and would remain encased within the munition as it enters the marine environment. In some cases, the munitions casing may corrode or rupture over long periods of time and release explosives into the sediments and water column. Even in the cases of low-order detonations and unexploded munitions, the ordnance containing munitions constituents do not accumulate in a small enough area to cause significant concern for adverse impact.

The behavior of explosives and explosive byproducts in marine environments and the extent to which those constituents of explosives have adverse impacts are influenced by a number of processes, including the ease with which the explosive dissolves in a liquid such as water (solubility), the degree to which explosives are attracted to other materials in the water (e.g., clay-sized particles and organic matter, sorption), and the tendency of the explosives to evaporate (volatilization). Dissolution of munitions constituents in marine waters is characterized by the solubility of the material and rate at which it dissolves (Beck et al., 2018). Dissolution rates for explosives (e.g., RDX) occur much more slowly when the munition is buried in sediments (even 1–2 cm of sediments) than for a munition exposed to the water column (Lotufo, 2018; Rosen & Lotufo, 2010). Munitions constituents often become attached to sediment particles through sorption processes (i.e., absorption and adsorption) and ultimately reside where sediments settle. The propensity for sorption varies with the type of explosive material, sediment type, mineral content of sediments, and physical factors, such as temperature (Ariyaratna et al., 2016; Beck et al., 2018). Sorption rates decrease at colder temperatures, which is an important relationship to note, because munitions frequently reside in deep water environments where temperatures are typically only a few degrees above freezing (Pickard & Emery, 1990). Dilution processes redistribute munitions constituents released into the water column according to concentration gradients and natural mixing (e.g., through currents) (Lotufo et al., 2017).

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 & Brannon, 2002). Unlike the physical processes that redistribute munitions constituents within the marine environment, chemical and biological processes change the chemical structures of the munitions constituents through reactions, including oxidation and reduction, photolysis, hydrolysis, and mineralization, resulting in the degradation (or breakdown) of the constituents often into naturally occurring substances (Beck et al., 2019; Tobias, 2019; Voie & Mariussen, 2017). Reduction and oxidation (e.g., oxidation of iron resulting in iron oxide) of munitions and constituents is the most likely process to occur in sediments, whereas photolysis (i.e., breakdown due to the absorption of light) of munitions constituents is most likely to occur in the photic zone of the water column. Mineralization involves degrading organic substances in munitions constituents into inorganic molecules including carbon dioxide, nitrogen, and water. The mineralization of explosives (RDX and HMX are readily mineralized) requires multiple steps, some of which may be biologically driven (Beck et al., 2018). Tobias (2019) used stable isotope tracers to show that over 50 percent of RDX compounds were mineralized into inert inorganic constituents, particularly in sediments with high organic content. The breakdown of TNT compounds resulted in aqueous (i.e., in a water solution) organic constituents, suggesting that TNT constituents remain suspended in the water column. The results are consistent with observations by Montgomery et al. (2011) that showed TNT may degrade at higher rates where turbidity levels in the water column are higher (e.g., at a turbidity front where fresh water from a river encounters brackish water in an estuary).

The solubility of various explosives is provided in Table 3.2-6, where higher values indicate greater solubility. For example, HMX is virtually insoluble in water. Table salt, which dissolves easily in water (highest solubility), is included in the table for comparison.

According to Walker et al. (2006), TNT, RDX, and HMX 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 PAHs. 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, both explosives of concern, by organisms in sediments is dependent on temperature and type of sediment (e.g., finer-grained). Nipper et al. (2002) noted that irreversible binding to sediments and biodegradation of 2, 6-dinitrotoluene, tetryl, and picric acid occurred in fine-grained sediments high in organic carbon, resulting in lower concentrations of the contaminants. Pavlostathis and Jackson (2002) reported that the marine microalgae *Anabaena* spp. was highly efficient at the removal and metabolism of TNT in a continuous flow experiment. 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 speculated that “the ability of marine macroalgae to metabolize TNT is widespread, if not generic.” The studies cited above indicate that TNT and its constituent products can be removed from the environment by naturally occurring biological processes in sediments, reducing sediment toxicity from these chemical contaminants.

**Table 3.2-6: Water Solubility of Common Explosives and Explosive Degradation Products**

<i>Compound</i>	<i>Water Solubility<sup>1</sup> (mg/L at 20 °C)</i>
Table salt (sodium chloride) <sup>2</sup>	357,000
Ammonium perchlorate (O)	249,000
Picric acid (E)	12,820
Nitrobenzene (D)	1,900
Dinitrobenzene (E)	500
Trinitrobenzene (E)	335
Dinitrotoluene (D)	160
TNT (E)	130
Tetryl (E)	51
Pentaerythritoltetranitrate (E)	43
Royal Demolition Explosive (E)	38
High Melting Explosive (E)	7

<sup>1</sup>Units are milligrams per liter at 20 degrees Celsius; <sup>2</sup>Table salt is not an explosive degradation product;

Notes: D = explosive degradation product, E = explosive, O = oxidizer additive, TNT = trinitrotoluene

Source: (U.S. Department of the Navy, 2008a)

Singh et al. (2009) indicated that biodegradation of RDX and HMX 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 HMX and RDX biodegradation are similar, but that HMX degrades more slowly. Singh et al. (2009) noted that RDX and HMX are biodegraded under a variety of anaerobic conditions by specific microbial species and by mixtures of such species. Zhao et al. (2004a); Zhao et al. (2004b) found that biodegradation of RDX and HMX occurs in cold marine sediments.

According to Singh et al. (2009), typical end products of the degradation of RDX 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 RDX and HMX 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).

Multiple investigations since 2007 involving survey and sampling of World War II munition dump sites and other locations have found that (1) chemicals and degradation products from underwater munitions do not pose a risk to human health or to fauna living in direct contact with munitions, (2) metals measured in sediment samples next to World War II munitions are lower than naturally occurring marine levels and do not cause a significant impact on the environment, and (3) sediment is not a significant sink of chemicals released by degradation of the explosive components in munitions (Edwards et al., 2016). Disposal site surveys off Hawaii (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016) and the Mariana Islands (Smith & Marx, 2016) showed no confirmed detection for explosive materials and no bioaccumulation of munitions-related chemicals in the species (Koide et al., 2016). In addition, physical or biological resources showed no signs of being adversely impacted by the testing and training activities (Smith & Marx, 2016). Furthermore, both studies (Hawaii and Mariana Islands) found that the health, abundance, and biomass of fishes, corals, and other marine resources were comparable to or superior to those in similar habitats at other locations nearby, concluding that sediments and water quality conditions were not impacted by testing and training activities.

The concentration of explosive munitions and any associated explosives byproducts at any single location in the PMSR Study Area would be a small fraction of the totals that have accumulated over decades at World War II-era dump sites and military ranges. Based on findings from much more intensively used locations, effects on sediment and water quality from the use of explosive munitions during testing and training activities would be negligible by comparison. As a result, explosive byproducts and unexploded munitions would have no meaningful effect on sediment and water quality.

Most explosive material is consumed in an explosion, so the vast majority of explosive material entering the marine environment would be encased in munitions that failed to detonate. Failure rates for all munitions used in the Proposed Action are not available; however, based on the data that are available, a 5 percent munitions failure rate was applied to estimate failure rates for all munitions used in the Proposed Action. Based on the available data, low-order detonation rates are assumed to be at least an order of magnitude less than failure rates for all munitions and are not considered in the analysis. Table 3.2-7 provides information about the rates of failure and low-order detonations for explosives and other munitions (MacDonald & Mendez, 2005).

**Table 3.2-7: Failure and Low-Order Detonation Rates of Military Munitions**

<i>Munitions</i>	<i>Failure Rate (Percent)</i>	<i>Low-Order Detonation Rate (Percent)</i>
Guns/artillery	4.68	0.16
Hand grenades	1.78	n/a
Explosive munitions	3.37	0.09
Rockets	3.84	n/a
Submunitions	8.23	n/a

Note: n/a = not available

**Propellants, Fuels, and Initiators**

Solid propellants for guns, artillery, and mortars comprise low-explosive materials formulated to burn at a controlled rate and produce gases that propel rockets or accelerate projectiles from guns. The primary component of gun, artillery, and mortar propellant formulations is commonly a nitro-containing organic chemical such as nitrocellulose often combined with other energetic compounds. Additional ingredients include compounds that modify burn rate, binders, or plasticizers (Pichtel, 2012). Table 3.2-8 lists the chemical constituents produced in the combustion of propellants and fuels. It also lists the constituents remaining after the detonations of non-munitions, such as spotting charges and tracers. Not all of the listed chemical constituents in a propellant would be used in combination; some are substitutes that would replace another chemical in the list, depending on the type of propellant used. For example, ammonium perchlorate is the preferred oxidizer in propellant, but ammonium dinitramide could act as the oxidizer in some propellants. These constituents are in addition to the explosives contained in munitions.

Lead azide, titanium compounds, 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 below.

Chemical constituents produced in the combustion of propellants, fuels, and initiators have been previously analyzed in the Hawaii-Southern California Training and Testing Final Environmental Impact Statement/Overseas Environmental Impact Statement (U.S. Department of the Navy, 2018), which found that chemical, physical, or biological changes in sediments or water quality would not be detectable for properly functioning munitions. It is therefore assumed that the impact of such constituents on water and sediment quality at PMSR is negligible.

**Table 3.2-8: Constituents in Propellants, Fuels, and Initiators**

<i>Munitions Component</i>	<i>Constituent</i>
Pyrotechnics and Flares Tracers Spotting Charges	Barium chromate Potassium perchlorate Chlorides Phosphorus Titanium compounds
Oxidizers	Lead (II) oxide
Propellant (rockets and missiles)	Ammonium perchlorate (50–85 percent by weight) Ammonium dinitramide Aluminum powder (5–21 percent by weight) High melting explosive Royal demolition explosive Hydroxyl-terminated polybutadiene Carboxyl-terminated polybutadiene Polybutadiene-acrylic acid-acrylonitrile Triphenyl bismuth Nitrate esters Nitrated plasticizers Polybutadiene-acrylic acid polymer Elastomeric polyesters Polyethers Nitrocellulose plasticized with nitroglycerine 2-nitrodiphenylamine N-methyl-4-nitroaniline Hydrazine
Delay Elements	Barium chromate Potassium perchlorate Lead chromate
Fuses	Potassium perchlorate
Detonators	Fulminate of mercury Potassium perchlorate
Primers	Lead azide

**Metals**

Metals are a natural component of the Earth’s crust; natural processes such as weathering and erosion cause metals to be washed from the land and transported to the oceans. However, increased industrial activity and other anthropogenic sources have been significant contributors to metal concentrations in oceans. Anthropogenic sources of metals include the processing of industrial ores (e.g., iron ore), production of chemicals, fertilizers used in agriculture, the marine industry (e.g., anti-fouling anti-corrosion paints), runoff from urban and suburban sprawl, dredge spoil disposal, exhaust from automotive transportation, atmospheric deposition, and industrial emissions (Haugland et al., 2006). Metals would be introduced into nearshore and offshore marine waters and sediments by the Proposed Action. Because of the physical and chemical reactions that occur with metals in marine systems, many metals will precipitate out of seawater and settle in solid form on the seafloor where they can concentrate in sediments. Thus, metal contaminants in sediments pose a greater environmental concern than metals in the water column. However, the procedures of testing and training at PMSR prevents the

accumulation of ordnance containing munitions constituents in a finite area, which significantly reduces adverse impacts.

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. These metals also occur naturally in sediments and small concentrations are typically found suspended in the water column. 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, 2008c). 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). Testing and training activities using these weapons do not use fixed aim points or permanent targets, so munitions do not accumulate to any significant volume.

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, both the direct exposure of the material to seawater and the rate of corrosion decrease. Dispersal of these materials in the water column is controlled by physical mixing and diffusion, both of which tend to vary with time and location. The analysis of metals in marine systems begins with a review of studies involving metals used in military testing and training activities that may be introduced into the marine environment.

A number of studies focused on the effects of metals from military expended materials (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016; Pait et al., 2010; Smith & Marx, 2016; U.S. Department of the Navy, 2010b; University of Hawaii, 2010) show that the sediment and water quality effects from metals used in munitions, expended materials, target vessels, or other devices resulting from any of the proposed activities would be negligible by comparison and would not adversely affect benthic and water column habitat. Furthermore, both studies (Hawaii and Mariana Islands) found that the health, abundance, and biomass of fishes, corals, and other marine resources were comparable to or superior to those in similar habitats at other locations nearby. A healthy marine environment is one in which sediments and water quality support a rich, healthy, and diverse community of marine resources. The conclusions from these studies would also be true for testing and training activities at PMSR.

#### **Other Materials**

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

depending upon their buoyancy. Marine markers and flares are largely consumed during use. Airborne and seaborne targets are recovered for subsequent use.

PMSR does not use permanently fixed aim points or targets. Therefore, target locations vary and the munitions used on these targets are not accumulated in specific areas. Towed and stationary targets include floating steel drums; towed aerial targets; and inflatable, floating targets. Towed aerial targets are either (1) rectangular pieces of nylon fabric 7.5 ft. by 40 ft. that reflect radar or lasers; or (2) aluminum cylinders with a fiberglass nose cone, aluminum corner reflectors (fins), or a short plastic tail section. This second target is about 10 ft. long and weighs about 75 pounds. These four targets are recovered after use and will not be considered further.

Flares are used to signal, to illuminate surface areas at night for various aggressor and defensive operations, and to assist with search and rescue activities. They range in weight from 5 to 14 kilograms. The major constituents of flares include magnesium granules and sodium nitrate. Containers are constructed of aluminum closed with a felt spacer and end cap. The entire assembly is usually consumed during flight with the exception of the end cap, which falls to the surface. Flares may also contain a primer such as TNT, propellant (ammonium perchlorate), and other explosives. These materials are present in small quantities (e.g.,  $1.0 \times 10^{-4}$  ounces [oz.] of ammonium perchlorate and  $1.0 \times 10^{-7}$  oz. of explosives). Small amounts of metals are used to give flares bright and distinctive colors. Combustion products from flares include magnesium oxide, sodium carbonate, carbon dioxide, and water. Illuminating flares are usually entirely consumed during use; neither is intended to be recovered. Constituents from flare debris that reach water would not accumulate in noticeable quantities because of consumption during use (U.S. Department of the Air Force, 1997). Impacts from end caps would be considered insignificant given the large area of dispersment. Dud flares are rare events and would not cause significant build-up of flare material in ocean sediments or the water column. Flare ash is widely dispersed by wind, reducing the potential for chemical concentrations to reach levels that can affect sediment quality or benthic habitats.

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 consists of small, thin glass fibers coated in aluminum that are light enough to remain in the air anywhere from 10 minutes to 10 hours (Farrell & Siciliano, 2004). Chaff is typically packaged in cylinders that measure approximately 6 inches by 1.5 inches (15.2 cm by 3.8 cm), weigh about 5 oz. (140 g), and contain a few million fibers. Chaff may be deployed from an aircraft or may be launched from a surface vessel. The chaff fibers are approximately the thickness of a human hair (generally 25.4 microns in diameter) and range in length from 0.8 to 5.1 cm. The major components of the chaff glass fibers and the aluminum coating are provided in Table 3.2-9.

Factors influencing chaff dispersion include the altitude and location where it is released, prevailing winds, and meteorological conditions (Spargo, 2008; U.S. Department of the Navy, 1999b). 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, U.S. Department of the Navy (1999b) calculated that an area 8 kilometers (km) by 12 km (96 square km) would be affected by deployment of a single cartridge containing 150 g of chaff. The resulting chaff concentration would be about 5.4 g per square nautical mile. This corresponds to less than 0.005 fiber per square meter, assuming that each canister contains 5 million fibers.

**Table 3.2-9: Major Components of Chaff**

<i>Component</i>	<i>Percent by Weight</i>
<b><i>Glass Fiber</i></b>	
Silicon dioxide	52–56
Aluminum	12–16
Calcium oxide, magnesium oxide	16–25
Boron oxide	8–13
Sodium oxide, potassium oxide	1–4
Iron oxide	≤ 1
<b><i>Aluminum Coating</i></b>	
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

Chaff fibers are dispensed in cartridges or projectiles; thus, some chaff debris is also released during deployment. This debris typically consists of paper, cardboard, plastic end caps, pistons, and miscellaneous parts (Farrell & Siciliano, 2004). The two plastic end caps are 1-inch long, 1/8-inch thick, and weigh approximately 0.042 oz. individually. These materials land in the water and become part of the floating debris on the water’s surface or sink. Chaff debris that reaches water from deployment would not accumulate in noticeable quantities. Decomposition of chaff debris would have no adverse impacts on sediments and water quality.

Chaff is generally resistant to chemical weathering and likely remains in the environment for long periods. However, all the components of chaff’s aluminum coating are present in seawater in trace amounts, except magnesium, which is present at 0.1 percent (Nozaki, 1997). Farrell and Siciliano (2004) discussed that 25 years of chaff operations at Chesapeake Bay, Maryland, did not result in a significant increase in aluminum concentrations in sediments or water collected from directly under the chaff release area and compared to samples collected 3.7 km upwind of the release area. Aluminum is the most common metal in the Earth’s crust and also occurs naturally in trace amounts in the aquatic environment. Aluminum oxide and silicon dioxide are the two most common minerals in the earth’s crust, and ocean waters are constantly exposed to both minerals, so the addition of small amounts of chaff would not affect water quality or sediment composition (U.S. Department of the Navy, 1999b).

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

**3.2.5.1 No Action Alternative**

Under the No Action Alternative, proposed testing and training activities would not occur within the PMSR. Other military activities not associated with this Proposed Action would continue to occur.

Therefore, existing environmental conditions would either remain unchanged or would improve slightly after cessation of ongoing testing and training activities.

Discontinuing the testing and training activities would result in fewer impacts on sediments and water quality where testing and training activities have historically been conducted. Therefore, discontinuing testing and training activities under the No Action Alternative would lessen the potential for impacts on sediments and water quality.

### **3.2.5.2 Alternative 1 (Preferred Alternative)**

A comparison of operational tempo proposed for each alternative, and proposed types and level of activities, are provided in Section 2.1.1 (Current and Proposed Activities).

#### **3.2.5.2.1 Explosives and Explosive Byproducts**

For the purpose of this analysis, the distribution of explosives used in testing and training activities is uniform throughout the PMSR Study Area with the exception of RATO bottles (previously referred to as jet assisted takeoff bottles), which are specific to Mugu Lagoon and SNI. Under Alternative 1, the quantity of explosives and explosive byproduct materials entering the marine environment associated with testing and training activities would increase compared to baseline conditions (see Table 3.0-7).

The highest concentrations of munition residues result from detonation failure (i.e., low-order detonations or unexploded ordnance). As a general rule, between 10,000 and 100,000 high-order detonations deposit the same mass of explosive residue as one low-order detonation of the same munition (U.S. Environmental Protection Agency, 2012a). Over 98 percent of explosives byproducts introduced into the environment result from low-order detonations or unexploded ordnance; when a munition successfully detonates, over 99 percent of constituents are burned and little to no explosive material remains in the environment (Hewitt et al., 2003). Therefore, an estimate of the amount of explosives material and byproducts from an explosion that would be introduced into the environment is based solely on the failure rate for each type of munition, discounting the negligible contribution from munitions that successfully detonate. The military does not track failure rates for all munitions. The available data typically report failure rates ranging from less than 2 percent up to 10 percent. For the purpose of estimating the amount of explosives and explosive byproducts entering the marine environment, a 5 percent failure rate is applied to all types of munitions used. The amount of explosive materials is estimated by multiplying the failure rate by the number of explosive munitions and the net explosive weight of each munition used during testing and training activities.

The majority of explosive material would result from munitions used at least 3 NM from shore and often more than 12 NM from shore, which diminishes any potential impact on nearshore sediments and water quality. Additionally, an important consideration for offshore areas is the massive volume of water in the PMSR Study Area, which is constantly mixed by currents moving throughout the water column. Since there are no fixed aim points or permanent targets, munitions would be widely distributed in the PMSR Study Area and would not accumulate in particular areas. As such, the ocean's volume and the dilution caused by the currents would reduce long-term adverse impacts. Explosive material entering the environment due to failed detonations would result in short-term minor adverse impacts on water quality and sediment immediately adjacent to the point of release. As the concentrations dissipate due to mixing and dilution, the effects would be reduced to negligible as concentrations would fall below detection levels beyond the point of release and over the long-term from degradation (Briggs et al., 2016; U.S. Department of the Navy, 2010a, 2010b, 2013d).

RATO bottles and their associated targets are launched from the Naval Base Ventura County Point Mugu Building 55 Launch Complex and from two launch areas on SNI. The bottle falls off soon after launch and typically lands 700–1,400 ft. in front of the launch site. RATO bottles would be of more concern at Naval Base Ventura County Point Mugu due to the bottles landing near Mugu Lagoon; however, RATO bottles are recovered whenever practical and resources are available. Residual perchlorate is present in surface water concentrations at Mugu Lagoon but is below the current DoD level of concern for managing perchlorate (24 ppb). Mugu Lagoon’s surface water concentrations are also several orders of magnitude below the 9,300 ppb ecological marine surface water screening value developed by the DoD Range and Munitions Use Subcommittee (U.S. Department of Defense, 2009). Therefore, potential impacts on sediments and water quality associated with the use of RATO bottles would be less than significant.

Although there is a substantial increase in explosive usage under Alternative 1 (see Table 3.0-7), studies conducted at several Navy ranges where explosives have been used more frequently and for longer periods of time indicate that explosives constituents are released into the aquatic environment over long periods of time and do not result in water or sediment toxicity (Briggs et al., 2016; U.S. Department of the Navy, 2010a, 2010b, 2013d). The fate and transport of munitions constituents in underwater environments is affected by numerous physical, chemical, and biological processes that typically combine to attenuate the concentrations of munitions constituents and their degradation products at a given site. Based on these and other analyses conducted for similar activities (U.S. Department of the Navy, 2018), there would be minor short-term and negligible long-term impacts on sediments and water quality from explosives and explosive byproducts, but overall potential impacts are expected to be less than significant.

#### **3.2.5.2.2 Propellants, Fuels, and Initiators**

The distribution of munitions that use propellants, fuels, and initiators is uniform throughout the PMSR Study Area. Under Alternative 1, propellants, fuels, and initiators would be associated with several types of munitions used during testing and training activities, specifically missiles and rockets. The largest quantities of chemicals would be expended from the use of propellants and fuels. Rocket motors are over 99 percent efficient at burning propellant; therefore, no measurable amounts of propellant or combustion products would enter the water column. The propellant used by rockets and missiles is typically consumed prior to impact at the water’s surface, even if the munition fails to detonate upon impact, leaving little residual propellant to enter the water.

For properly functioning munitions, chemical, physical, or biological changes in sediments or water quality would not be detectable. Impacts would be negligible for the following reasons: (1) the size of the area in which expended materials would be distributed is several square miles; (2) most propellant combustion byproducts are benign, while those of concern would be diluted to below detectable levels within a short time; (3) 98 percent of propellants are consumed during normal operations; (4) the failure rate of munitions using propellants and other combustible materials is less than 5 percent; and (5) most of the constituents of concern are biodegradable by various marine organisms or by physical and chemical processes common in marine ecosystems. Therefore, potential impacts of propellants, fuels, and initiators on sediments and water quality from testing and training activities would be less than significant.

#### **3.2.5.2.3 Metals**

Many activities included in the Proposed Action would involve the expenditure of munitions and other military expended materials with metal components. Refer to Chapter 2 (Description of Proposed Action

and Alternatives) for a detailed description of munitions and other military expended materials that would be used during testing and training activities under Alternative 1.

The distribution of non-explosive munitions and other expended materials composed of or containing metals that are used in testing and training activities is uniform throughout the PMSR Study Area. Non-explosive munitions are the largest portion of expended objects composed of metal or containing metal components.

Metals from munitions and other expended materials would sink to the seafloor, where they would most likely be buried or partially buried in sediments, depending on the type of seafloor substrate. In the PMSR Study Area, the offshore substrate is predominately composed of soft sediments; thus, the likelihood of complete or partial burial of expended materials, including munitions, is high. Metals exposed to the seawater would slowly corrode over years or decades, releasing small amounts of water-soluble metal compounds into the water column and corrosion products into adjacent sediments. The low, near-freezing water temperatures and low oxygen levels in sediments only a few inches below the water column-seafloor interface that characterize deepwater (greater than 250 m), benthic habitats would inhibit corrosion of metals and any dispersion of metals and corrosion products beyond isolated areas adjacent to the munition.

As described previously, studies from munitions disposal sites (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016; University of Hawaii, 2010) and heavily used Navy ranges show that metals did not impact sediment quality despite longtime use and high concentrations of military munitions composed primarily of metal components. The concentration of munitions and other expended materials containing metals in any one location in the PMSR Study Area would be a small fraction of that found in a munitions disposal site (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016; University of Hawaii, 2010), a target island used for 45 years (Smith & Marx, 2016), or a water range in a river used for almost 100 years (U.S. Department of the Navy, 2013d). Chemical, physical, or biological changes to sediments or water quality in the Study Area would not be detectable and would be similar to nearby areas without munitions or other expended materials containing metals. This conclusion, which has been supported by research studies in similar locations with similar testing and training activities, is based on the following assumptions: (1) most of the metals are benign, and those of potential concern make up a small percentage of expended munitions and other metal objects; (2) metals released through corrosion would be diluted by currents or bound up and sequestered in adjacent sediment; (3) elevated concentrations of metals in sediments would be limited to the immediate area around the expended material; and (4) the areas over which munitions and other metal components would be distributed are large.

Based on findings from these and other intensively used locations, the sediment and water quality effects from metals used in munitions or other expended materials resulting from any of the proposed activities would be negligible by comparison. Therefore, potential impacts of metals on sediments and water quality from testing and training activities would be less than significant.

#### **3.2.5.2.4 Other Materials**

The distribution of other expended materials used in testing and training activities would be uniform throughout the PMSR Study Area. These other expended materials include flares, chaff, expendable towed and stationary targets, wires and cables, and miscellaneous components. Under Alternative 1, chaff and flare usage would decrease compared to baseline conditions.

Constituents in flares are consumed during combustion and byproducts are expended into the air. The failure rate of flares is low (5 percent), and the remaining amounts are small and subject to additional chemical reactions and subsequent dilution in the ocean. The analysis and conclusions presented previously in the Metals discussion within Section 3.2.5 (Environmental Consequences) would apply to metals in flares as well, and the analysis concludes that sediment and water quality effects from metals would be negligible. The small amounts of explosives used in flares, specifically TNT and RDX, released into the sediments would not impact marine sediments for the same reasons presented previously in the Explosives and Explosive Byproducts discussion within Section 3.2.5 (Environmental Consequences). Based on the results of studies conducted at multiple marine and freshwater ranges where explosives have been used extensively over decades, no impacts on sediments and water quality from explosives in unconsumed flares would be expected.

Chaff concentrations would be expected to be low due to the large size of the Study Area. As discussed previously, all the components of chaff's aluminum coating are present in seawater in trace amounts; however, aluminum is the most common metal in the Earth's crust, occurs naturally in the aquatic environment, and is typically found in trace amounts within the water column from natural sources. Chaff fibers are dispersed by waves and currents, and chemicals leached by chaff would be diluted by the surrounding seawater. Due to the dilution, dispersion, and naturally occurring aluminum concentrations in the water, the addition of small amounts of chaff would not impact sediments and water quality.

Plastics and other floating expended materials (e.g., rubber components) would either degrade over time in the water column or on the seafloor or wash ashore. Materials that sink to the seafloor would be widely distributed over the PMSR Study Area. As described in Section 3.2.4.1.2 (Marine Debris in Nearshore and Offshore Areas of the Point Mugu Sea Range Study Area), the worldwide use and disposal of plastics is rapidly increasing the amount of plastic accumulating in large areas of the world's oceans. Small pieces of plastic associated with the use of chaff, flares, and targets would likely persist in the marine environment as floating debris in the water column or on the seafloor. Plastic floating near the surface and exposed to the sun and mechanical wear and tear would break down over time. Plastic that sinks in the water column below the photic zone or to the seafloor would degrade more slowly or not at all. Only small pieces of plastics would be expended—larger pieces from targets are recovered—and dispersed over a large area. Therefore, potential impacts from military expended material, such as chaff and flares, on sediments or water quality would be less than significant.

### **3.2.5.3 Alternative 2**

A comparison of operational tempo proposed for each alternative, and proposed types and level of activities, are provided in Section 2.1.1 (Current and Proposed Activities).

#### **3.2.5.3.1 Explosives and Explosive Byproducts**

Under Alternative 2, there would be a decrease in the amount of explosive material from UXO entering the environment compared to Alternative 1 and an increase compared to baseline conditions. The potential impact on sediments and water quality would be less than under Alternative 1 because of the decrease in use of explosives. As discussed previously, studies conducted at several Navy ranges where explosives have been used more frequently and for longer periods of time indicate that explosives constituents are released into the aquatic environment over long periods of time and do not result in water or sediment toxicity (Briggs et al., 2016; U.S. Department of the Navy, 2010a, 2010b, 2013d). The fate and transport of munitions constituents in underwater environments is affected by numerous

physical, chemical, and biological processes that typically combine to attenuate the concentrations of munitions constituents and their degradation products at a given site. Based on these and other analyses conducted for similar activities (U.S. Department of the Navy, 2018), and how over 99 percent of constituents are burned upon detonation (Hewitt et al., 2003), there would be minor short-term and negligible long-term impacts on sediments and water quality from explosives and explosive byproducts, but overall potential impacts would be less than significant.

#### **3.2.5.3.2 Propellants, Fuels, and Initiators**

Under Alternative 2, the number of missiles and rockets used annually would increase compared to baseline conditions and decrease compared to Alternative 1 (Table 3.0-12). Because rocket motors are over 99 percent efficient at burning propellant, no measurable amounts of propellant or combustion products would be expected to enter the water column. Therefore, potential impacts on sediments and water quality from the release of chemicals derived from propellants and fuels would be less than Alternative 1, and still less than significant.

#### **3.2.5.3.3 Metals**

Under Alternative 2, the number of munitions and other expended materials containing metals used during testing and training activities would increase compared to baseline conditions, but decrease compared to Alternative 1. Because of the large size of this Study Area (thousands of square nautical miles), no measurable amounts of metals from munitions and other expended materials would be expected to enter the water column; therefore, the impacts on sediments and water quality from metals used in munitions and other expended materials from proposed testing and training activities would be less than those described for Alternative 1, and less than significant.

#### **3.2.5.3.4 Other Materials**

Under Alternative 2, the number flares, chaff, expendable towed and stationary targets, wires and cables, and miscellaneous components would decrease compared to Alternative 1 and baseline conditions. Potential impacts on sediments and water quality from other materials would be the same as described above for Alternative 1 and would be less than significant.

#### **3.2.5.4 Indirect Effects**

Indirect effects are those effects that are caused by another action or actions that have an established relationship or connection to a proposed action. As described above, neither State nor federal standards or guidelines for sediments or water quality would be violated under Alternative 1 or Alternative 2. Therefore, no indirect effects are anticipated as a result of proposed testing and training activities under any of the action alternatives.

## REFERENCES

- Agency for Toxic Substances and Disease Registry. (1999). *Toxicological Profile for Mercury*. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
- Agency for Toxic Substances and Disease Registry. (2007). *Toxicological Profile for Lead*. Atlanta, GA: U.S. Department of Health and Human Services.
- Ariyaratna, T., P. Vlahos, C. Tobias, and R. W. Smith. (2016). Sorption Kinetics of TNT and RDX in Anaerobic Freshwater and Marine Sediments: Batch Studies. *Environmental Toxicology and Chemistry*, 35, 47–55. DOI:10.1002/etc.3149
- Artham, T. and M. Doble. (2009). Fouling and Degradation of Polycarbonate in Seawater: Field and Lab Studies. *Journal of Polymers and the Environment*, 17, 170–180. DOI:10.1007/s10924-009-0135-x
- Bearzi, M. (2003). *Behavioral Ecology of the Marine Mammals of Santa Monica Bay, California*. (Ph.D. dissertation). University of California at Los Angeles.
- Beck, A. J., M. Gledhill, C. Schlosser, B. Stamer, C. Böttcher, J. Sternheim, J. Greinert, and E. P. Achterberg. (2018). Spread, behavior, and ecosystem consequences of conventional munitions compounds in coastal marine waters. *Frontiers in Marine Science*, 5.
- Beck, A. J., E. M. van der Lee, A. Eggert, B. Stamer, M. Gledhill, C. Schlosser, and E. P. Achterberg. (2019). In Situ Measurements of Explosive Compound Dissolution Fluxes from Exposed Munition Material in the Baltic Sea. *Environmental Science & Technology*, 53(10), 5652–5660.
- Bergmuller, R., R. A. Johnstone, A. F. Russell, and R. Bshary. (2007). Integrating cooperative breeding into theoretical concepts of cooperation. *Behavioural Processes*, 2, 67–72.
- Blott, S. J. and K. Pye. (2012). Particle size scales and classification of sediment types based on particle size distributions: Review and recommended procedures. *Sedimentology*, 59(7), 2071–2096. DOI:10.1111/j.1365-3091.2012.01335.x
- Boudreau, B. P. (1998). Mean mixed depth of sediments: The wherefore and the why. *Limnology and Oceanography*, 43(3), 524–526.
- Breitbarth, E., E. P. Achterberg, M. V. Ardelan, A. R. Baker, E. Bucciarelli, F. Chever, P. L. Croot, S. Duggen, M. Gledhill, M. Hasselov, C. Hassler, L. J. Hoffmann, K. A. Hunter, D. A. Hutchins, J. Ingri, T. Jickells, M. C. Lohan, M. C. Nielsdottir, G. Sarthou, V. Schoemann, J. M. Trapp, D. R. Turner, and Y. Ye. (2010). Iron biogeochemistry across marine systems—progress from the past decade. *Biogeosciences*, 7, 1075–1097.
- Briggs, C., S. M. Shjegstad, J. A. K. Silva, and M. H. Edwards. (2016). Distribution of chemical warfare agent, energetics, and metals in sediments at a deep-water discarded military munitions site. *Deep Sea Research Part II: Topical Studies in Oceanography*, 128, 63–69.
- Bruland, K. W. (1992). Complexation of cadmium by natural organic ligands in the Central North Pacific. *ASLO Limnology and Oceanography*, 37(5), 1008–1017.
- Burtenshaw, J. C., E. M. Oleson, J. A. Hildebrand, M. A. McDonald, R. K. Andrew, B. M. Howe, and J. A. Mercer. (2004). Acoustic and satellite remote sensing of blue whale seasonality and habitat in the Northeast Pacific. *Deep-Sea Research II*, 51, 967–986.
- Byrne, R. H. (1996). Specific problems in the measurement and interpretation of complexation phenomena in seawater. *Pure and Applied Chemistry*, 68(8), 1639–1656.

- California Ocean Protection Council and National Oceanic and Atmospheric Administration Marine Debris Program. (2018). *California Ocean Litter Prevention Strategy: Addressing Marine Debris from Source to Sea*. Sacramento, CA: California Ocean Protection Council.
- Carmody, D. J., J. B. Pearce, and W. E. Yasso. (1973). Trace metals in sediments of New York Bight. *Marine Pollution Bulletin*, 4, 132–135.
- Carr, R. S. and M. Nipper. (2003). *Assessment of Environmental Effects of Ordnance Compounds and their Transformation Products in Coastal Ecosystems*. Port Hueneme, CA: Naval Facilities Engineering Service Center.
- Center for Ocean Solutions. (2009). *Pacific Ocean Synthesis: Scientific Literature Review of Coastal and Ocean Threats, Impacts, and Solutions*. San Jose, CA: Stanford University.
- Chang, M. (2015). Reducing microplastics from facial exfoliating cleansers in wastewater through treatment versus consumer product decisions. *Marine Pollution Bulletin*, 101, 330–333. DOI:10.1016/j.marpolbul.2015.10.074
- Chapman, P. M., F. Wang, C. R. Janssen, R. R. Goulet, and C. N. Kamunde. (2003). Conducting ecological risk assessments of inorganic metals and metalloids: Current status. *Human and Ecological Risk Assessment*, 9(4), 641–697.
- Chen, C.-T. A., A. G. Andreev, K.-R. Kim, and M. Yamamoto. (2004). Roles of Continental Shelves and Marginal Seas in the Biogeochemical Cycles of the North Pacific Ocean. *Journal of Oceanography*, 60, 17–44.
- Chester, R. (2003). *Marine Geochemistry* (2nd ed.). Malden, MA: Blackwell Publishing Company.
- Cole, M. and T. S. Galloway. (2015). Ingestion of nanoplastics and microplastics by Pacific oyster larvae. *Environmental Science & Technology*, 49(24), 14625–14632. DOI:10.1021/acs.est.5b04099
- Coleman, J. M. and D. B. Prior. (1988). Mass wasting on continental margins. *Annual Review of Earth Planet Science*, 16, 101–119.
- Crocker, F. H., K. J. Indest, and H. L. Fredrickson. (2006). Biodegradation of the cyclic nitramine explosives RDX, HMX, and CL-20. *Applied Microbiology and Biotechnology*, 73, 274–290. DOI:10.1007/s00253-006-0588-y
- Cruz-Uribe, O., D. P. Cheney, and G. L. Rorrer. (2007). Comparison of TNT removal from seawater by three marine macroalgae. *Chemosphere*, 67, 1469–1476. DOI:10.1016/j.chemosphere.2007.01.001
- Dailey, M. D., D. J. Reish, and J. W. Anderson. (1993). *Ecology of the Southern California Bight: A Synthesis and Interpretation*. Los Angeles, CA: University of California Press.
- Demina, L. L. and S. V. Galkin. (2009). Geochemical features of heavy metal bioaccumulation in the Guaymas Basin of the Gulf of California. *Oceanology*, 49(5), 697–706. DOI:10.1134/s0001437009050117
- Dodder, N., K. Schiff, A. Latker, and C. L. Tang (2016). *Southern California Bight 2013 Regional Monitoring Program: Volume IV. Sediment Chemistry* (Technical Report 922). Costa Mesa, CA: Southern California Coastal Water Research Project Authority.
- Doi, Y., Y. Kanesawa, N. Tanahashi, and Y. Kumagai. (1992). Biodegradation of microbial polyesters in the marine environment. *Polymer Degradation and Stability*, 36, 173–177.

- Edwards, K. P., J. A. Hare, F. E. Werner, and B. O. Blanton. (2006). Lagrangian circulation on the Southeast U.S. Continental Shelf: Implications for larval dispersal and retention. *Continental Shelf Research*, 26(12–13), 1375–1394. DOI:10.1016/j.csr.2006.01.020
- Edwards, M. H., S. M. Shjegstad, R. Wilkens, J. C. King, G. Carton, D. Bala, B. Bingham, M. C. Bissonnette, C. Briggs, N. S. Bruso, R. Camilli, M. Cremer, R. B. Davis, E. H. DeCarlo, C. DuVal, D. J. Fornari, I. Kaneakua-Pia, C. D. Kelley, S. Koide, C. L. Mah, T. Kerby, G. J. Kurras, M. R. Rognstad, L. Sheild, J. Silva, B. Wellington, and M. V. Woerkom. (2016). The Hawaii undersea military munitions assessment. *Deep Sea Research Part II: Topical Studies in Oceanography*, 128, 4–13. DOI:10.1016/j.dsr2.2016.04.011
- Eggleton, J. and K. V. Thomas. (2004). A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. *Environment International*, 30(7), 973–980. DOI:10.1016/j.envint.2004.03.001
- Farrell, R. E. and S. D. Siciliano. (2004). *Environmental Effects of Radio Frequency Chaff Released During Military Training Exercises: A Review of the Literature*. Saskatoon, Canada: Goose Bay Office of the Department of National Defense.
- Fitzgerald, W. F., C. H. Lamborg, and C. R. Hammerschmidt. (2007). Marine biogeochemical cycling of mercury. *Chemical Reviews*, 107, 641–662.
- Hameedi, M., A. Pait, and R. Warner. (2002). *Environmental Contaminant Monitoring in the Gulf of Maine*. Presented at the Northeast Coastal Monitoring Summit. Durham, NH.
- Hatzinger, P. B., G. Harvey, W. A. Jackson, J. K. Bohlke, N. C. Sturchio, B. Gu, D. Grantz, K. Burkey, and M. McGrath. (2017). *Final Report: Phase II: Identification and Characterization of Natural Sources of Perchlorate*. Alexandria, VA: Strategic Environmental Research and Development Program.
- Haugland, M., J. C. Holst, M. Holm, and L. P. Hansen. (2006). Feeding of Atlantic salmon (*Salmo salar* L.) post-smolts in the Northeast Atlantic. *ICES Journal of Marine Science*, 63, 1488–1500.
- Hayward, T. L. (2000). El Niño 1997–98 in the coastal waters of southern California: A timeline of events. *CalCOFI Reports*, 41, 98–116.
- Hayward, T. L., R. Durazo, T. Murphree, T. R. Baumgartner, G. Gaxiola-Castro, F. B. Schwing, M. J. Tegner, D. M. Checkley, K. D. Hyrenbach, A. W. Mantyla, M. M. Mullin, and P. E. Smith. (1999). The state of the California Current in 1998–1999: Transition to cool-water conditions. *CalCOFI Report*, 40, 29–62.
- Hedges, J. I. and J. M. Oades. (1997). Review Paper: Comparative organic geochemistries of soils and marine sediments. *Organic Geochemistry*, 27(7–8), 319–361. DOI:S0146-6380(97)00056-9
- Hewitt, A., T. Jenkins, T. Ranney, J. Stark, M. Walsh, S. Taylor, M. Walsh, D. Lambert, N. Perron, N. Collins, and R. Karn. (2003). *Estimates for Explosives Residue from the Detonation of Army Munitions*. Hanover, NH: U.S. Army Engineer Research and Development Center: Cold Region Research and Engineering Laboratory.
- Ho, T.-Y., L.-S. Wen, C.-F. You, and D.-C. Lee. (2007). The trace-metal composition of size-fractionated plankton in the South China Sea: Biotic versus abiotic sources. *Limnology and Oceanography*, 52(5), 1776–1788. DOI:10.4319/lo.2007.52.5.1776
- Johnson, C., B. Sugiyama, B. Wild, and S. Lin. (2002). *Environmental Effects of Underwater Ordnance*. Port Huenuma, CA: Naval Facilities Engineering Service Center.

- Juhasz, A. L. and R. Naidu. (2007). Explosives: Fate, dynamics, and ecological impact in terrestrial and marine environments. *Reviews of Environmental Contamination and Toxicology*, 191, 163–215.
- Keller, A. A., E. L. Fruh, M. M. Johnson, V. Simon, and C. McGourty. (2010). Distribution and abundance of anthropogenic marine debris along the shelf and slope of the U.S. West Coast. *Marine Pollution Bulletin*, 60(5), 692–700. DOI:10.1016/j.marpolbul.2009.12.006
- Kelley, C., G. Carton, M. Tomlinson, and A. Gleason. (2016). Analysis of towed camera images to determine the effects of disposed mustard-filled bombs on the deep water benthic community off south Oahu. *Deep Sea Research Part II: Topical Studies in Oceanography*, 128, 34–42. DOI:10.1016/j.dsr2.2015.01.016
- Kennett, J. P. (1982). *Marine Geology*. New York, NY: Prentice-Hall.
- Koide, S., J. A. K. Silva, V. Dupra, and M. Edwards. (2016). Bioaccumulation of chemical warfare agents, energetic materials, and metals in deep-sea shrimp from discarded military munitions sites off Pearl Harbor. *Deep Sea Research Part II: Topical Studies in Oceanography*, 128, 53–62. DOI:10.1016/j.dsr2.2015.03.002
- Kszos, L. A., J. J. Beauchamp, and A. J. Stewart. (2003). Toxicity of lithium to three freshwater organisms and the antagonistic effect of sodium. *Ecotoxicology*, 12(5), 427–437.
- Kudela, R., G. Pitcher, T. Probyn, F. Figueiras, T. Moita, and V. Trainer. (2005). Harmful algal blooms in coastal upwelling systems. *Oceanography*, 18(2), 184–197.
- Law, K. L., S. Moret-Ferguson, N. A. Maximenko, G. Proskurowski, E. E. Peacock, J. Hafner, and C. M. Reddy. (2010). Plastic accumulation in the North Atlantic Subtropical Gyre. *Scienceexpress*, 329, 1–8. DOI:10.1126/science.1192321
- Law, K. L. and R. C. Thompson. (2014). Microplastics in the Sea. *Science*, 345(6193), 144–145. DOI:10.1002/2014EF000240/
- Legaard, K. R. and A. C. Thomas. (2006). Spatial patterns in seasonal and interannual variability of chlorophyll and sea surface temperature in the California Current. *Journal of Geophysical Research*, 111(C06032), 1–21.
- Li, J., J. Ren, J. Zhang, and S. Liu. (2008). The distribution of dissolved aluminum in the Yellow and East China Seas. *Journal of Ocean University of China*, 7(1), 48–54. DOI:10.1007/s11802-008-0048-7
- Libes, S. M. (2009). *Introduction to Marine Biogeochemistry* (2nd ed.). Burlington, MA, San Diego, CA, and London, United Kingdom: Academic Press.
- Long, E. R., D. D. MacDonald, S. L. Smith, and F. D. Calder. (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management*, 19(1), 81–97.
- Lotufo, G. (2018). Overview of munitions constituents in Water, Sediment and Biota, Toxicity to Aquatic Biota and Derivation of Protection Levels. Presentation to SERDP/ESTCP on May 21.
- Lotufo, G. R., M. A. Chappell, C. L. Price, M. L. Ballentine, A. A. Fuentes, T. S. Bridges, R. D. George, E. J. Glisch, and G. Carton. (2017). *Review and Synthesis of Evidence Regarding Environmental Risks Posed by Munitions Constituents (MC) in Aquatic Systems*. Washington, DC: U.S. Army Corps of Engineers, Engineer Research and Development Center.
- MacDonald, J. and C. Mendez. (2005). *Unexploded ordnance cleanup costs: Implications of alternative protocols*. Santa Monica, CA: Rand Corporation.

- Mann, K. H. and J. R. N. Lazier. (1996). *Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans* (2nd ed.). Boston, MA: Blackwell Scientific Publications.
- Maruya, K. A. and K. Schiff. (2009). The extent and magnitude of sediment contamination in the Southern California Bight. *The Geological Society of America, Special Paper 454*, 399–412.
- Mato, Y., T. Isobe, H. Takada, H. Kanehiro, C. Ohtake, and T. Kaminuma. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental Science Technology*, 35, 318–324.
- Melillo, J. M., T. Richmond, and G. W. Yohe. (2014). *Climate Change Impacts in the United States: The Third National Climate Assessment*. Washington, DC: U.S. Global Change Research Program.
- Missile Technology Control Regime. (1996). *Missile Technology Control Regime*. Retrieved from <http://mtcr.info>.
- Mitchell, C. P. J. and C. C. Gilmour. (2008). Methylmercury production in a Chesapeake Bay salt marsh. *Journal of Geophysical Research*, 113(G2), G00C04. DOI:10.1029/2008jg000765
- Mitsch, W. J. and J. G. Gosselink. (2007). *Wetlands* (Fourth ed.). Hoboken, NJ: John Wiley & Sons, Inc.
- Mitsch, W. J., J. G. Gosselink, C. J. Anderson, and L. Zhang. (2009). *Wetland Ecosystems*. Hoboken, NJ: John Wiley & Sons, Inc.
- Montgomery, M. T., T. J. Boyd, J. P. Smith, S. E. Walker, and C. L. Osburn. (2011). 2,4,6-Trinitrotoluene Mineralization and Incorporation by Natural Bacterial Assemblages in Coastal Ecosystems *Environmental Chemistry of Explosives and Propellant Compounds in Soils and Marine Systems: Distributed Source Characterization and Remedial Technologies* (Vol. 1069, pp. 171–184).
- Moore, S., M. Sutula, T. Von Bitner, G. Lattin, and K. Schiff. (2016). *Southern California Bight 2013 Regional Monitoring Program: Volume III. Trash and Marine Debris*. Costa Mesa, CA: Southern California Coastal Water Research Project.
- Morel, F. M. M. and N. M. Price. (2003). The biogeochemical cycles of trace metals in the oceans. *Science*, 300(5621), 944–947. DOI:10.1126/science.1083545
- Morgan, L., S. Maxwell, F. Tsao, T. A. C. Wilkinson, and P. Etnoyer. (2005). *Marine Priority Conservation Areas: Baja California to the Bering Sea*. Montreal, Canada: Commission for Environmental Cooperation of North America and the Marine Conservation Biology Institute.
- Napper, I. E., A. Bakir, S. J. Rowland, and R. C. Thompson. (2015). Characterisation, quantity and sorptive properties of microplastics extracted from cosmetics. *Marine Pollution Bulletin*, 99(1–2), 178–185. DOI:10.1016/j.marpolbul.2015.07.029
- Neira, C., F. Delgadillo-Hinojosa, A. Zirino, G. Mendoza, L. A. Levin, M. Porrachia, and D. D. Deheyn. (2009). Spatial distribution of copper in relation to recreational boating in a California shallow-water basin. *Chemistry and Ecology*, 25(6), 417–433.
- Nipper, M., R. S. Carr, J. M. Biedenbach, R. L. Hooten, and K. Miller. (2002). Toxicological and chemical assessment of ordnance compounds in marine sediments and porewaters. *Marine Pollution Bulletin*, 44, 789–806.
- Nozaki, Y. (1997). *Supplementary Materials to "A Fresh Look at Element Distribution in the North Pacific"*. Retrieved February 16, 2011, from <http://www.agu.org/pubs/eos-news/supplements/1995-2003/97026e.shtml>.

- Pait, A. S., A. L. Mason, D. R. Whitall, J. D. Christensen, and S. I. Hartwell. (2010). Chapter 5: Assessment of Chemical Contaminants in Sediments and Corals in Vieques. In L. J. Bauer & M. S. Kendall (Eds.), *An Ecological Characterization of the Marine Resources of Vieques, Puerto Rico* (pp. 101–150). Silver Spring, MD: National Oceanic and Atmospheric Administration.
- Pavlostathis, S. G. and G. H. Jackson. (2002). Biotransformation of 2, 4, 6-trinitrotoluene in a continuous-flow *Anabaena* sp. system. *Water Research*, 36, 1699–1706.
- Pennington, J. C. and J. M. Brannon. (2002). Environmental fate of explosives. *Thermochimica Acta*, 384(1–2), 163–172.
- Pichtel, J. (2012). Distribution and fate of military explosives and propellants in soil: A review. *Applied and Environmental Soil Science*, 2012, 1–33. DOI:10.1155/2012/617236
- Pickard, G. L. and W. J. Emery. (1990). *Descriptive Physical Oceanography: An Introduction* (5th ed.). Oxford, United Kingdom: Pergamon Press.
- Rabalais, N. N., R. E. Turner, and W. J. Wiseman, Jr. (2002). Gulf of Mexico hypoxia, a.k.a. "The Dead Zone." *Annual Review of Ecology and Systematics*, 33, 235–263.
- Rios, L. M., P. R. Jones, C. Moore, and U. V. Narayan. (2010). Quantification of persistent organic pollutants adsorbed on plastic debris from the Northern Pacific Gyre's eastern garbage patch. *Journal of Environmental Monitoring*, 12, 2226–2236.
- Rosen, G. and G. R. Lotufo. (2010). Fate and effects of composition B in multispecies marine exposures. *Environmental Toxicology and Chemistry*, 29(6), 1330–1337. DOI:10.1002/etc.153
- Schneider, N., E. Di Lorenzo, and P. P. Niiler. (2005). Salinity Variations in the Southern California Current. *American Meteorological Society*, 35, 1421–1436.
- Schwing, F. B., C. S. Moore, S. Ralston, and K. M. Sakuma. (1999). Record coastal upwelling in the California Current in 1999. *CalCOFI Report*, 41, 148–160.
- Shah, A. A., F. Hasan, A. Hameed, and S. Ahmed. (2008). Biological degradation of plastics: A comprehensive review. *Biotechnology Advances*, 26(3), 246–265. DOI:10.1016/j.biotechadv.2007.12.005
- Sheavly, S. B. (2007). *National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary*. Washington, DC: U.S. Environmental Protection Agency.
- Singh, R., P. Soni, P. Kumar, S. Purohit, and A. Singh. (2009). Biodegradation of high explosive production effluent containing RDX and HMX by denitrifying bacteria. *World Journal of Microbiology and Biotechnology*, 25, 269–275.
- Smith, S. H. and D. E. Marx, Jr. (2016). De-facto marine protection from a Navy bombing range: Farallon de Medinilla, Mariana Archipelago, 1997 to 2012. *Marine Pollution Bulletin*, 102(1), 187–198. DOI:10.1016/j.marpolbul.2015.07.023
- Southern California Coastal Water Research Project. (2018). *2018 Southern California Bight Regional Marine Monitoring Survey (Bight '18)*. Costa Mesa, CA: Bight '18 Trash Committee.
- Spargo, B. J. (2008, September 22). Personal communication via email between Barry Spargo, (U.S. Department of the Navy, Naval Research Laboratory) and Mark Collins (Parsons) regarding chaff end cap and piston buoyancy.
- State of California. (2009). *California Ocean Plan: Water Quality Control Plan for the Ocean Water of California*. Sacramento, CA: California Environmental Protection Agency.

- State Water Resources Control Board. (2015). *Water Quality Control Plan: Ocean Waters of California*. Sacramento, CA: State Water Resources Control Board.
- Stillman, J. H. and A. W. Paganini. (2015). Biochemical adaptation to ocean acidification. *The Journal of Experimental Biology*, 218(Pt 12), 1946–1955. DOI:10.1242/jeb.115584
- Teuten, E. L., S. J. Rowland, T. S. Galloway, and R. C. Thompson. (2007). Potential for plastics to transport hydrophobic contaminants. *Environmental Science and Technology*, 41(22), 7759–7764. DOI:10.1021/es071737s
- Tobias, C. (2019). *Tracking the Uptake, Translocation, Cycling, and Metabolism of Munitions Compounds in Coastal Marine Ecosystems Using Stable Isotopic Tracer: Final Report* (SERDP Project ER-2122). Storrs, CT: University of Connecticut.
- Turner, R. E. and N. N. Rabalais. (2003). Linking landscape and water quality in the Mississippi River basin for 200 years. *BioScience*, 53(6), 563–572.
- U.S. Commission on Ocean Policy. (2004). *An Ocean Blueprint for the 21st Century (Final Report)*. Washington, DC: U.S. Commission on Ocean Policy.
- U.S. Department of Agriculture. (1993). Soil Survey Manual. In Soil Conservation Service (Ed.), *U.S. Department of Agriculture Handbook 18* (3rd ed.). Washington, DC: U.S. Department of Agriculture.
- U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and National Marine Sanctuary Program. (2008). *Channel Islands National Marine Sanctuary Final Management Plan/Final Environmental Impact Statement*. Silver Spring, MD: National Oceanic and Atmospheric Administration, National Ocean Service, National Marine Sanctuary Program.
- U.S. Department of Defense. (2009). *Perchlorate Release Management Policy*. Washington, DC: Department of Defense, Office of the Under Secretary of Defense.
- U.S. Department of the Air Force. (1997). *Environmental Effects of Self-Protection Chaff and Flares*. Langley Air Force Base, VA: U.S. Air Force, Headquarters Air Combat Command.
- U.S. Department of the Army. (1984). *Military Explosives*. Washington, DC: U.S. Department of the Army.
- U.S. Department of the Navy. (1999a). *Environmental Assessment for the Plasma Sound Source (PSS) Ocean Test Science & Technology Risk Reduction Phase*. San Diego, CA: Space and Naval Warfare Systems Command.
- U.S. Department of the Navy. (1999b). *Environmental Effects of RF Chaff: A Select Panel Report to the Undersecretary of Defense for Environmental Security*. Washington, DC: U.S. Department of the Navy, Naval Research Laboratory.
- U.S. Department of the Navy. (2002). *Final Environmental Impact Statement/Overseas Environmental Impact Statement Point Mugu Sea Range*. Point Mugu, CA: Naval Air Systems Command, Naval Air Warfare Center Weapons Division.
- U.S. Department of the Navy. (2007). *Environmental Readiness Program Manual OPNAV Instruction 5090.1C*. Washington, DC: Office of the Chief of Naval Operations.
- U.S. Department of the Navy. (2008a). *Final Atlantic Fleet Active Sonar Training Environmental Impact Statement/Overseas Environmental Impact Statement* (Chapter 4: Environmental Consequences). Norfolk, VA: Naval Facilities Engineering Command, Atlantic.

- U.S. Department of the Navy. (2008b). Range Sustainability Environmental Program Assessment Process. Washington, DC: U.S. Department of the Navy, Chief of Naval Operations, Environmental Readiness Division.
- U.S. Department of the Navy. (2008c). *Southern California Range Complex Environmental Impact Statement/Overseas Environmental Impact Statement*. San Diego, CA: Naval Facilities Engineering Command Southwest.
- U.S. Department of the Navy. (2010a). *Water Range Assessment for the Jacksonville Range Complex*. Norfolk, VA: Parsons.
- U.S. Department of the Navy. (2010b). *Water Range Assessment for the VACAPES Range Complex (Final Report)*. Norfolk, VA: Naval Facilities Engineering Command, Atlantic Division.
- U.S. Department of the Navy. (2013a). *Comprehensive Exercise and Marine Species Monitoring Report for the U.S. Navy's Southern California Range Complex*. San Diego, CA: U.S. Navy Pacific Fleet.
- U.S. Department of the Navy. (2013b). *Final Integrated Natural Resources Management Plan for Naval Base Ventura County Point Mugu and Special Areas*. San Diego, CA: Naval Facilities Engineering Command Southwest.
- U.S. Department of the Navy. (2013c). *San Diego Bay Integrated Natural Resources Management Plan*. San Diego, CA: Unified Port of San Diego.
- U.S. Department of the Navy. (2013d). *Water Range Sustainability Environmental Program Assessment: Potomac River Test Range*. Dahlgren, VA: Naval Surface Warfare Center.
- U.S. Department of the Navy. (2015). *Integrated Natural Resources Management Plan for Naval Base Ventura County San Nicolas Island, California*. San Diego, CA: Naval Facilities Engineering Command Southwest.
- U.S. Department of the Navy. (2016). *Environmental Assessment/Overseas Environmental Assessment for Fiber Optic Communications Undersea System (FOCUS) Replacement NAVAIR Sea Range, Point Mugu, California*. Point Mugu, CA: Naval Air Warfare Center Weapons Division.
- U.S. Department of the Navy. (2018). *Hawaii-Southern California Training and Testing Final Environmental Impact Statement/Overseas Environmental Impact Statement*. Pearl Harbor, HI: Naval Facilities Engineering Command, Pacific.
- U.S. Environmental Protection Agency. (2008a). *Interim Drinking Water Health Advisory For Perchlorate*. Washington, DC: Health and Ecological Criteria Division.
- U.S. Environmental Protection Agency. (2008b). *National Coastal Condition Report III*. Washington, DC: Office of Research and Development/Office of Water.
- U.S. Environmental Protection Agency. (2010). *National Marine Debris Monitoring Program: Lessons Learned*. Virginia Beach, VA: U.S. Environmental Protection Agency.
- U.S. Environmental Protection Agency. (2012a). *EPA Federal Facilities Forum Fact Sheet*. Washington, DC: Solid Waste and Emergency Response.
- U.S. Environmental Protection Agency. (2012b). *National Coastal Condition Report IV*. Washington, DC: Office of Research and Development/Office of Water.
- U.S. Environmental Protection Agency. (2014). *Technical Fact Sheet - Perchlorate*. Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response.

- U.S. Environmental Protection Agency. (2017, December 11). *The Clean Water Act and Trash-Free Waters*. Retrieved July 26, 2019, from <https://www.epa.gov/trash-free-waters/clean-water-act-and-trash-free-waters>.
- University of Hawaii. (2010). *Hawaii Undersea Military Munitions Assessment, Final Investigation Report HI-05, South of Pearl Harbor, Oahu, HI*. Honolulu, HI: University of Hawaii at Manoa.
- University of Hawaii. (2014). *Final Environmental Study: Ordnance Reef (HI-06), Wai'anae, O'ahu, Hawai'i* (Contract No. N00024-08-D-6323). Honolulu, HI: University of Hawaii.
- Valette-Silver, N. J. (1993). The use of sediment cores to reconstruct historical trends in contamination of estuarine and coastal sediments. *Estuaries*, 16(3, Part B: Dedicated Issue: Historical Trends in Contamination of Estuarine and Coastal Sediments: Symposium Papers from the Eleventh Biennial International Estuarine Research Conference), 577–588.
- Voie, Ø. A. and E. Mariussen. (2017). Risk Assessment of Sea Dumped Conventional Munitions. *Propellants, Explosives, Pyrotechnics*, 42(1), 98-105. DOI:10.1002/prop.201600163
- Walker, S. W., C. L. Osburn, T. J. Boyd, L. J. Hamdan, R. B. Coffin, M. T. Montgomery, J. P. Smith, Q. X. Li, C. Hennessee, F. Monteil, and J. Hawari. (2006). *Mineralization of 2, 4, 6-Trinitrotoluene (TNT) in Coastal Waters and Sediments*. Washington, DC: U.S. Department of the Navy, Naval Research Laboratory.
- Wallace, G. T., Jr., G. L. Hoffman, and R. A. Duce. (1977). The influence of organic matter and atmospheric deposition on the particulate trace metal concentration of northwest Atlantic surface seawater. *Marine Chemistry*, 5, 143–170.
- Watters, D. L., M. M. Yoklavich, M. S. Love, and D. M. Schroeder. (2010). Assessing marine debris in deep seafloor habitats off California. *Marine Pollution Bulletin*, 60, 131–138. DOI:10.1016/j.marpolbul.2009.08.019
- White, C., J. A. Sayer, and G. M. Gadd. (1997). Microbial solubilization and immobilization of toxic metals: Key biogeochemical processes for treatment of contamination. *FEMS Microbiology Reviews*, 20, 503–516.
- Wiseman, W. J., Jr. and R. W. Garvine. (1995). Plumes and coastal currents near large river mouths. *Estuaries*, 18(3), 509–517.
- Wren, P. A. and L. A. Leonard. (2005). Sediment transport on the mid-continental shelf in Onslow Bay, North Carolina during Hurricane Isabel. *Estuarine, Coastal and Shelf Science*, 63(1–2), 43–56. DOI:10.1016/j.ecss.2004.10.018
- Wright, S. L., R. C. Thompson, and T. S. Galloway. (2013). The physical impacts of microplastics on marine organisms: A review. *Environmental Pollution*, 178, 483–492. DOI:<http://dx.doi.org/10.1016/j.envpol.2013.02.031>
- Wu, J. and E. Boyle. (1997). Lead in the western North Atlantic Ocean: Completed response to leaded gasoline phaseout. *Geochimica et Cosmochimica Acta*, 61(15), 3279–3283. DOI:0016-7037/97
- Zhao, J. S., C. W. Greer, S. Thiboutot, G. Ampleman, and J. Hawari. (2004a). Biodegradation of the nitramine explosives hexahydro-1,3,5-triazine and octahydro-1,3,5,7-tetrazocine in cold marine sediment under anaerobic and oligotrophic conditions. *Canadian Journal of Microbiology*, 50, 91–96. DOI:10.1139/W03-112
- Zhao, J. S., J. Spain, S. Thiboutot, G. Ampleman, C. Greer, and J. Hawari. (2004b). Phylogeny of cyclic nitramine-degrading psychrophilic bacteria in marine sediment and their potential role in the

natural attenuation of explosives. *FEMS Microbiology Ecology*, 49(3), 349–357.  
DOI:10.1016/j.femsec.2004.04.008