3.1.6   Sediment Characteristics

The ROI for sediment characteristics is the ocean floor within the ODMDS study areas. Physical, conventional, chemical and radiological sediment characteristics were examined to determine current baseline conditions in the study region. Measurements included grain size, TOC, nitrogen (ammonia, Total Kjeldahl Nitrogen (TKN), Total Organic Nitrogen (TON), sulfides, solids, trace metals, Acid volatile sulfides Simultaneously Extracted Metals (AVS-SEM), persistent organic pollutants (PAHs, chlorinated pesticides/PCBs, organotins, dioxins/furans) and gross alpha/beta. Results of sediment characteristics tests are described below for the alternative sites and a reference site. Complete details of the study are included in Weston Solutions and TEC (2008b).

3.1.6.1   Physical Analyses

Grain size is the most essential physical characteristic of sediment. Information on sediment grain size is used in determining trends of chemical processes, surface processes related to transportation and deposition, sample permeability/stability, affinities of contaminants and movement of subsurface fluids (Blatt et al. 1972; McCave and Syvitski 1991). Grain size measurements were analyzed in sediments from nine stations in this study and presented in Figure 3-27 and Table 14 of Weston Solutions and TEC (2008b).

North Study Area

Sediment samples collected from Stations 1, 2 and 3 located in the North Study Area were primarily sand with some silt and clay. The dominant sand fraction had an average of 69.82%, with a range of 58.93% at Station 1 to 80.10% at Station 2. The lesser silt fraction averaged 25.17%, with a range of 16.14% at Station 2 to 35.47% at Station 1. The minor clay fraction averaged 5.01%, with a range of 3.76% at Station 2 to 5.68% at Station 3. Results indicate that there was no gravel fraction detected in sediments collected from the North Study Area.

Northwest Study Area

Sediment samples collected from Stations 6, 7 and 8 located in the Northwest Study Area were primarily sand and silt with some clay. The major sand fraction had an average of 52.05%, with a range of 42.57% at Station 8 to 63.44% at Station 6. The minor silt fraction averaged 39.48%, with a range of 30.33% at Station 6 to 47.79% at Station 8. The lesser clay fraction averaged 8.47%, with a range of 6.22% at Station 6 to 9.64% at Station 8. Results indicate that there was no gravel fraction detected in sediments from the Northwest Study Area.

Inshore/Proposed Reference Site

Sediment samples collected from Stations 4 and 9 located inshore of the two alternative areas, including the proposed reference site located at Station 5, were primarily sand with some silt and clay. The dominant sand fraction had an average of 65.11%, with a range of 57.30% at Station 5 to 72.38% at Station 9. The lesser silt fraction averaged 27.73%, with a range of 27.31% at Station 4 to 33.96% at Station 5. The minor clay fraction averaged 7.16%, with a range of 5.69% at Station 9 to 8.75% at Station 5. Results indicate that there was no gravel fraction detected in sediments from the inshore study area including the proposed upstream reference site.
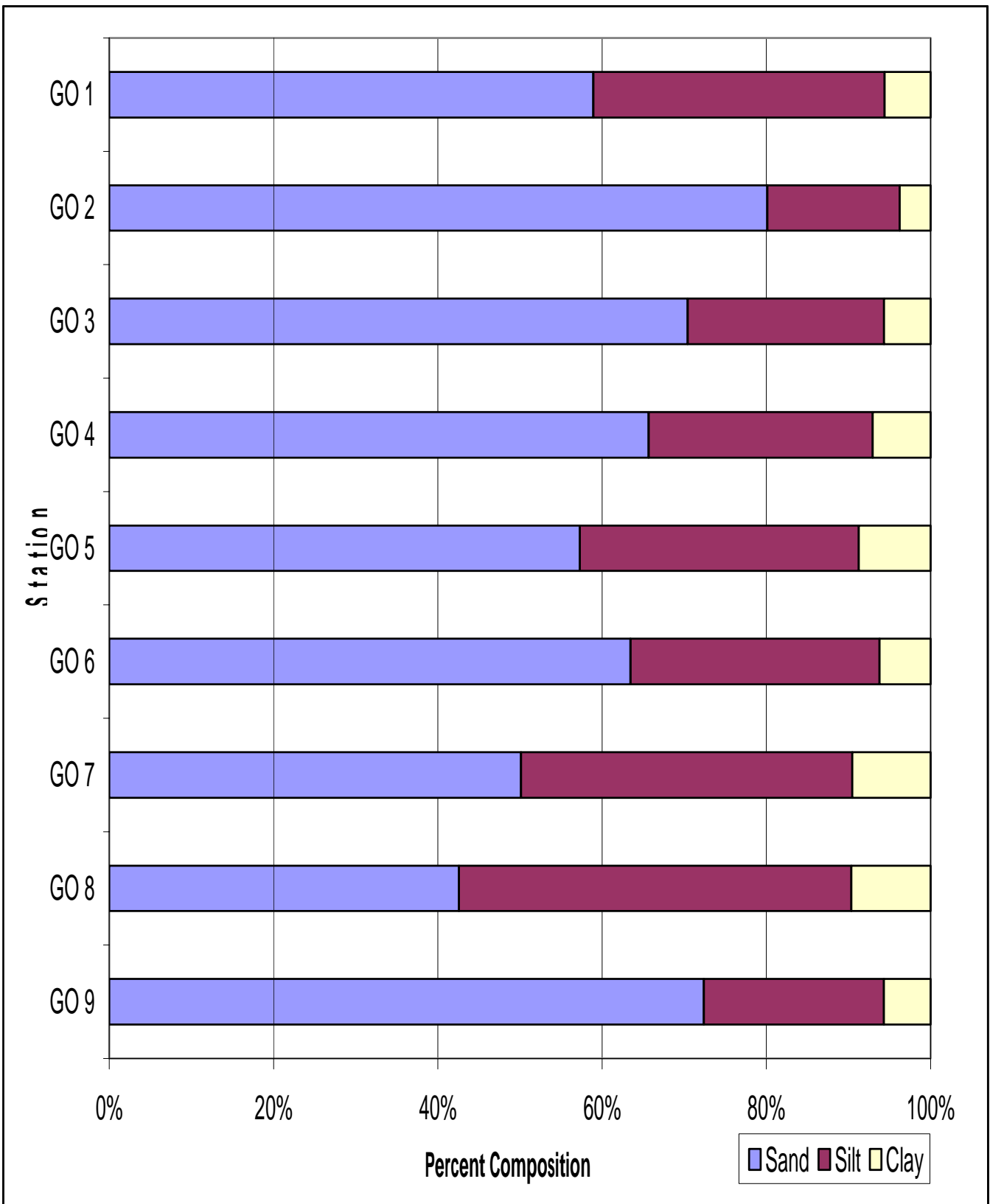
Figure 3-27.
Grain Size Distribution by Size Class (Gravel*, Sand, Silt, Clay) of the Seafloor Sediment Samples Collected in the Guam ODMDS Study Region, April 2008
*Gravel was not present in any of the samples

Source: Weston, 2008

3.1.6.2   Chemical Analyses

<u>Conventional Parameters</u>

Concentrations of carbon (TOC), nitrogen (ammonia, TKN, TON), sulfides and solids were analyzed in sediments from this study and presented in Table 15 of Weston Solutions and TEC (2008b) and Figure 3-28.

North Study Area

Conventional parameters analyzed in sediment samples from Stations 1, 2 and 3 located in the North Study Area were detected in low concentrations. Percent solid content averaged 54.3% with a range of 53.7% at Station 1 to 54.8% at Station 2. TOC averaged 0.22% with a range of 0.17% at Station 3 to 0.29% at Station 1. TON averaged 95.69 mg/dry kg with a range of 76.45 mg/dry kg at Station 2 to 119.64 mg/dry kg at Station 3. Ammonia-N averaged 0.28 mg/dry kg with a range of 0.26 mg/dry kg at Station 3 to 0.32 mg/dry kg at Station 1. These ammonia-N averages were approximately 2 orders of magnitude lower than biologically toxic concentrations (30 ppm) and were supported by toxicity test results conducted on project sediments. TKN averaged 177 mg/wet kg with a range of 140 mg/wet kg at Station 2 to 220 mg/wet kg at Station 3. Total sulfides averaged 0.66 mg/dry kg with a range of 0.50 mg/dry kg at Station 1 to 0.87 mg/dry kg at Station 2. Analysis of conventional parameters using the Dixon's Test established no relative differences in TOC, nitrogen (ammonia, TKN, TON), sulfides and solids content of sediment between stations located in the North Study Area.

Northwest Study Area

Conventional parameters analyzed in sediment samples from Stations 6, 7 and 8 located in the Northwest Study Area were detected in low concentrations. Percent solid content had averaged 52.5% with a range of 51.5% at Station 7 to 53.8% at Station 6. TOC averaged 0.28% with a range of 0.19% at Station 6 to 0.39% at Station 8. TON averaged 89.01 mg/dry kg with a range of 72.79 mg/dry kg at Station 8 to 97.61 mg/dry kg at Station 7. Ammonia-N averaged 0.24 mg/dry kg with a range of 0.20 mg/dry kg at Station 6 to 0.29 mg/dry kg at Station 8. These ammonia-N averages were approximately 2 orders of magnitude lower than biologically toxic concentrations (30 ppm) and were supported by toxicity test results conducted on project sediments. TKN averaged 170 mg/wet kg with a range of 140 mg/wet kg at Station 8 to 190 mg/wet kg at Station 7.

Total sulfides averaged 0.53 mg/dry kg with a range of 0.51 mg/dry kg at Station 6 to 0.56 mg/dry kg at Station 8. Analysis of conventional parameters using the Dixon's Test established no relative difference in TOC, ammonia-N, TKN, sulfides and solids content of sediment in the Northwest Study Area. TON concentration was slightly lower at Station 8 (72.79 mg/dry kg) than Stations 6 (96.64 mg/dry kg) and 7 (97.61 mg/dry kg).
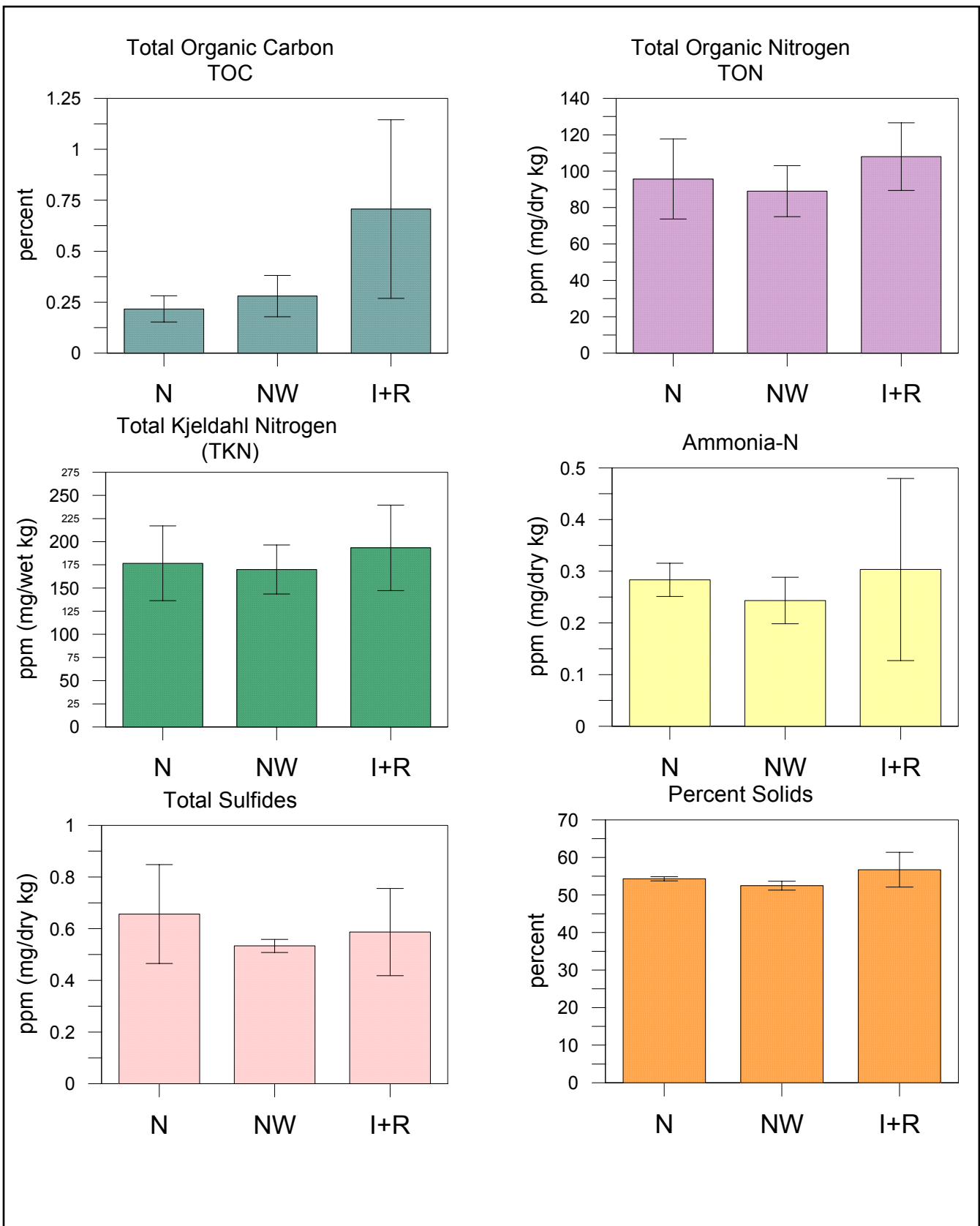
Figure 3-28.
Mean and Standard Deviation of Selected Conventional Chemistry
Constituents Showing Comparison of Study Areas to Each Other and Proposed Reference

Source: Weston, 2008

Inshore/Proposed Reference Site

Conventional parameters analyzed in sediment samples from Stations 4 and 9 located inshore of the two alternative areas, as well as the proposed reference site located at Station 5, were detected in low concentrations. Percent solid content had an average 56.7% with a range of 53.3% at Station 5 to 62.0% at Station 9. TOC content averaged 0.71 % with a range of 0.22% at Station 4 to 1.07% at Station 9. TON averaged 107.98 mg/dry kg with a range of 86.64 mg/dry kg at Station 9 to 120.53 mg/dry kg at Station 4. Ammonia-N averaged 0.30 mg/dry kg with a range of 0.16 mg/dry kg at Station 9 to 0.50 mg/dry kg at Station 5. These ammonia-N averages were approximately 2 orders of magnitude lower than biologically toxic concentrations (30 parts per million) and were supported by toxicity test results conducted on project sediments. TKN averaged 193 mg/wet kg with a range of 140 mg/wet kg at Station 9 to 220 mg/wet kg at Stations 4 and 5. Total sulfides averaged 0.59 mg/dry kg with a range of 0.47 mg/dry kg at Station 9 to 0.78 mg/dry kg at Station 5. Analysis of conventional parameters using the Dixon's Test established no relative difference in TOC, TON, ammonia-N, sulfides and solids content of sediment in the inshore study area including the proposed reference site. TKN concentration was slightly lower at Station 9 (140 mg/wet kg) than Stations 4 (220 mg/wet kg) and 5 (220 mg/dry kg).
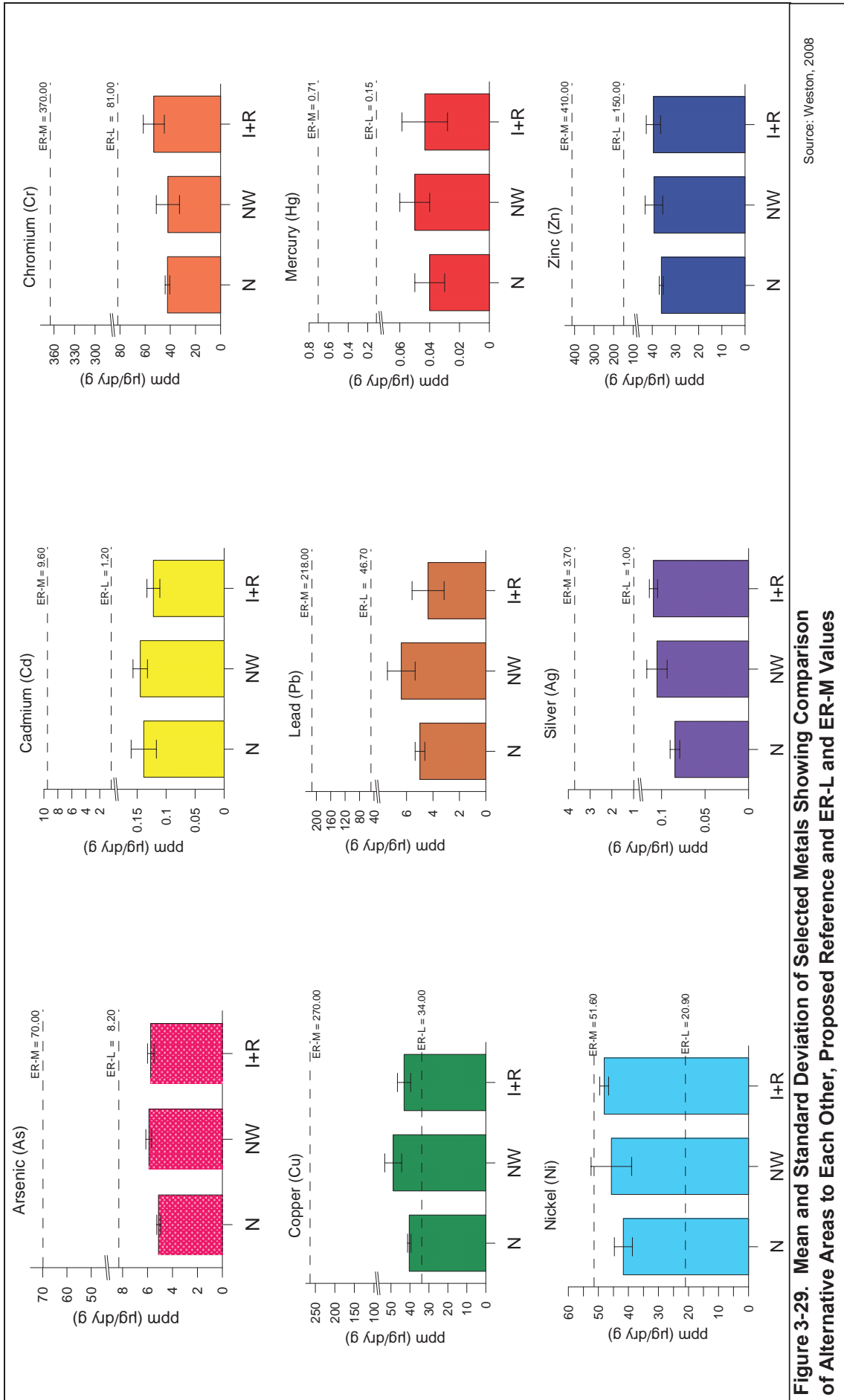
Trace Metals

Although many metals are biologically essential in trace amounts excessive quantities can interfere with fundamental physiological processes in organisms ranging from yeast to humans. Both localized and dispersed metal pollutants such as cadmium, lead, mercury, and silver are not biodegradable, are toxic in solution, and subject to biomagnifications in the tissues of marine organisms causing adverse environmental impacts (Lau et al. 1998). Metals are introduced in marine systems as a result of the weathering of soils and rocks, from volcanic eruptions, and from a variety of human activities involving the mining, processing, or use of metals and/or substances that contain metals. Concentrations in sediments are typically orders of magnitude greater than concentrations in overlying water and constitute an enriched pool of metal (Luoma 1989). A portion of its biologically available form is generally chemically fixed and largely unavailable to organisms without chemical changes in the sediment. Concentrations of 23 metals were analyzed in sediments from this study and presented in Table 15 of Weston Solutions and TEC (2008b) and Figure 3-29. For comparison, available ER-L/ER-M values and data for central Pacific Ocean sediments collected at comparable depths with similar bathymetric features are also presented in Table 15 of Weston Solutions and TEC (2008b).

North Study Area

All 23 metals measured in sediment samples from Stations 1, 2, and 3 located in the North Study Area were detected. Analysis of metals using the Dixon's Test established no relative difference in metal content of sediment between stations located in the North Study Area.

Cadmium, zinc, mercury, arsenic, chromium, lead and silver concentrations in the North Study Area were below ER-L levels. Average copper concentrations slightly exceeded the ER-L (34 µg/dry g) but at concentrations well below the ER-M (270 µg/dry g). Average nickel concentrations were approximately two times the ER-L (20.9 µg/dry g) and slightly less than the ER-M (51.6 µg/dry g).

Figure 3-29. Mean and Standard Deviation of Selected Metals Showing Comparison of Alternative Areas to Each Other, Proposed Reference and ER-L and ER-M Values

Source: Weston, 2008

Sediment metal levels in the North Study Area were below average oceanic crustal abundances available for barium, cobalt, copper, iron, lead, manganese, nickel, strontium, titanium, vanadium and zinc. Average aluminum concentrations were an order of magnitude greater than, while average chromium concentrations were more than double the oceanic crustal abundance values measured in the central Pacific Ocean (Wen et al. 1997).

Northwest Study Area

All 23 metals measured in sediment samples from Station 6, 7 and 8 located in the Northwest Study Area were detected. Analysis of metals using the Dixon's Test established no relative difference in all but two metals between stations located in the Northwest Study Area. Strontium concentrations were lower at Station 8 (1,167 µg/dry g) than Stations 6 (1,437 µg/dry g) and 7 (1,440 µg/dry g). Zinc concentrations were also slightly lower at Station 8 (34.89 µg/dry g) than Stations 6 (41.31 µg/dry g) and 7 (41.58 µg/dry g).

Cadmium, zinc, mercury, arsenic, chromium, lead and silver concentrations in the Northwest Study Area were below ER-L levels. Average copper concentrations slightly exceeded the ER-L (34 µg/dry g) but at concentrations well below the ER-M (270 µg/dry g). Average nickel concentrations were more than 2 times the ER-L (20.9 µg/dry g) and slightly less than the ER-M (51.6 µg/dry g).

Sediment metal levels in the Northwest Study Area were below average oceanic crustal abundance levels available for barium, cobalt, copper, iron, lead, manganese, nickel, titanium, vanadium and zinc. Average aluminum concentrations were an order of magnitude greater than, while average chromium concentrations were more than double the oceanic crustal abundance values. Average strontium only slightly exceeds the oceanic crustal abundance values measured in the central Pacific Ocean (Wen et al. 1997).

Inshore/Proposed Reference Site

All 23 metals measured in sediment samples from Stations 4 and 9 located inshore of the two alternative areas, as well as the proposed reference site located at Station 5, were detected. Analysis of metals using the Dixon's Test established no relative difference in all but three metals between stations in the inshore study area including the proposed reference site. Copper concentrations were lower at Station 5 (30.02 µg/dry g) than Stations 4 (45.22 µg/dry g) and 9 (44.96 µg/dry g). Nickel concentrations were also slightly lower at Station 5 (46.36 µg/dry g) than Stations 4 (48.90 µg/dry g) and 9 (48.94 µg/dry g). In contrast, antimony concentrations were slightly greater at Station 9 (0.190 µg/dry g) than Stations 4 (0.151 µg/dry g) and 5 (0.152 µg/dry g).

Cadmium, zinc, mercury, arsenic, chromium, lead and silver concentrations in the inshore study area including the proposed upstream reference site were below ER-L levels. Average copper concentrations slightly exceeded the ER-L (34 µg/dry g) but at concentrations well below the ER-M (270 µg/dry g). Average nickel concentrations were more than two times the ER-L (20.9 µg/dry g) and slightly lower than the ER-M (51.6 µg/dry g).

Sediment metal levels in the inshore study area including the proposed upstream reference site were below average oceanic crustal abundance values available for barium, cobalt, copper, iron, lead, manganese, nickel, titanium, vanadium and zinc. Average aluminum concentrations were an order of magnitude greater than, while average chromium concentrations were more than double the oceanic crustal abundance values. Average strontium only slightly exceeds the oceanic crustal abundance values measured in the central Pacific Ocean (Wen et al. 1997).

Acid Volatile Sulfides/Simultaneously Extracted Metals (AVS-SEM)

In sediments depleted of oxygen, there is commonly a substantial pool of sulfide in the form of solid Iron Sulfide (FeS), referred to as AVS. The availability of metals such as cadmium, copper, nickel, lead, zinc, and silver is thought to be controlled in part by its precipitation as insoluble sulfides complexes. This property allows the presence of excess AVS to influence the toxicity potential of these metals to benthic organisms by acting as a sink for and immobilizing its biologically available, ionic form (Ankley et al. 1996). AVS is operationally defined as the amount of sulfides that can be changed into a vapor during a cold acid extraction. The AVS-bound metals are extracted at the same time and are referred to as SEM. Laboratory and field experiments have shown that if the ratio of SEM:AVS is less than one, there are likely to be no biologically available metals in solution. This ratio approach can be used to predict the lack of toxicity but not the onset of toxicity (Di Toro et al. 2001). AVS are naturally produced by the bacterial breakdown of organic material and cannot exist in the presence of oxygen, therefore have no utility in oxygenated sediment or terrestrial environments. Table 3-13 presents the SEM results for six metals (cadmium, copper, nickel, lead, zinc, and silver) that are likely to bind to AVS and the concentration of AVS for each sample.

North Study Area

AVS and SEM analyzed in sediment samples collected from Stations 1, 2 and 3 located in the North Study Area were detected in low concentrations. AVS averaged 0.041 µmol/dry g with a range of 0.034 µmol/dry g at Station 3 to 0.046 µmol/dry g at Station 1. Combined SEM averaged 0.111 µmol/dry g with a range of 0.068 µmol/dry g at Station 3 to 0.165 µmol/dry g at Station 1. The calculated $\sum$SEM:AVS ratio averaged 2.66 with a range of 2.01 at Station 3 to 3.63 at Station 1. While this implies the potential for toxicity due to metal bioavailability, studies suggests that a $\sum$SEM:AVS ratio greater than 40 is required for certainty of metal toxicity predictions (Di Toro et al. 2001). Analysis of SEM:AVS using the Dixon's Test established no relative difference in the SEM:AVS ratio of sediment between stations located in the North Study Area.

Northwest Study Area

AVS and SEM analyzed in sediment samples from Stations 6, 7 and 8 located in the Northwest Study Area were detected in low concentrations. AVS averaged 0.039 µmol/dry g with a range of 0.032 µmol/dry g at Station 6 to 0.047 µmol/dry g at Station 8. Combined SEM had an average of 0.154 µmol/dry g with a range of 0.109 µmol/dry g at Station 6 to 0.211 µmol/dry g at Station 8. The calculated $\sum$SEM:AVS ratio averaged 3.93 with a range of 3.40 at Station 6 to 4.45 at Station 8. While this implies the potential for toxicity due to metal bioavailability, studies suggests that a $\sum$SEM:AVS ratio greater than 40 is required for certainty of metal toxicity predictions (Di Toro et al. 2001). Analysis of SEM:AVS using the Dixon's Test established no relative difference in the SEM:AVS ratio of sediments between stations located in the Northwest Study Area.

Table 3-13. Simultaneously Extracted Metals/Acid Volatile Sulfides Results and ∑SEM:AVS for Seafloor Sediment Samples Collected in the Guam ODMDS Study Region, April 2008

Analyte	Units	MDL	RL	Station ID								
				GO 1	GO 2	GO 3	GO 4	GO 5	GO 6	GO 7	GO 8	GO 9
Cadmium (Cd) - SEM	µmol/dry g	0.0018	0.0036	<0.0018	<0.0018	<0.0018	<0.0018	<0.0018	<0.0018	<0.0018	<0.0018	<0.0018
Copper (Cu) - SEM	µmol/dry g	0.0062	0.0124	0.0825	0.0378	0.0217	<0.0062	0.0569	0.0435	0.0745	0.113	0.0416
Lead (Pb) - SEM	µmol/dry g	0.0002	0.0004	0.0007	<0.0002	<0.0002	<0.0002	0.0003J	<0.0002	0.0002J	0.0013	<0.0002
Nickel (Ni) - SEM	µmol/dry g	0.0033	0.0066	0.0106	0.0097	0.0066	0.0049J	0.0126	0.008	0.0077	0.0107	0.0076
Silver (Ag) - SEM	µmol/dry g	0.0047	0.0094	<0.0047	<0.0047	<0.0047	<0.0047	<0.0047	<0.0047	<0.0047	<0.0047	<0.0047
Zinc (Zn) - SEM	µmol/dry g	0.0015	0.003	0.0696	0.0494	0.0379	0.0256	0.0533	0.0557	0.058	0.0841	0.0423
∑SEM[1]	µmol/dry g	-	-	0.165	0.099	0.068	0.036	0.125	0.109	0.142	0.211	0.094
Acid Volatile Sulfides (AVS)	mg/dry kg	0.05	0.1	1.46	1.37	1.09	0.9	2.01	1.03	1.16	1.52	1.01
Acid Volatile Sulfides (AVS)	µmol/dry g	0.002	0.003	0.046	0.043	0.034	0.028	0.063	0.032	0.036	0.047	0.031
∑SEM:AVS	ratio	-	-	3.63	2.32	2.01	1.27	2.00	3.40	3.94	4.45	2.97

J = estimated value above the MDL and below the RL

[1] ∑SEM = sum (Cd + Cu + Pb + Ni + (Ag/2) + Zn): if ND, then 1/2 MDL used

∑SEM:AVS = >1, indicating potential for metal toxicity due to presence of unbound, ionized metal

Inshore/Proposed Reference Site

AVS and SEM analyzed in sediment samples from Stations 4 and 9 located inshore of the two alternative areas, as well as the proposed reference site located at Station 5, were detected in low concentrations. AVS averaged 0.041 µmol/dry g with a range of 0.028 µmol/dry g at Station 4 to 0.063 µmol/dry g at Station 5. Combined SEM averaged 0.085 µmol/dry g with a range of 0.036 µmol/dry g at Station 4 to 0.125 µmol/dry g at Station 5. The calculated ∑SEM:AVS ratio averaged 2.08 with a range of 1.27 at Station 4 to 2.97 at Station 9. While this implies the potential for toxicity due to metal bioavailability, studies suggests that a ∑SEM:AVS ratio are greater than 40 is required for certainty of metal toxicity predictions (Di Toro et al. 2001). Analysis of SEM:AVS content using the Dixon's Test established no relative difference in the SEM:AVS ratio between stations in the inshore study area including the proposed reference site.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are one of the most widespread organic pollutants due to their collective natural and manufactured origins. They are a group of over 100 different chemicals that occur naturally in oil, coal, tar deposits and are formed during the incomplete combustion of petroleum products, garbage, tobacco, and even charbroiled meat. Different types of incinerations yield unique distributions of PAHs in both relative amounts of individual PAHs and in which compounds are produced, making them potentially useful in source identification. PAHs are also manufactured in their pure form and used in medicines or to make dyes and plastics. Because of its chemical affinity for lipids, PAHs in the marine environment are found primarily in carbon rich sediments. A total of 25 individual PAHs were analyzed in sediments from this study and presented in Table 15 of Weston Solutions and TEC (2008b).

North Study Area

PAHs analyzed in sediment samples from Stations 1, 2 and 3 located in the North Study Area were not detected, with the exception of one station. Station 3 had detectable concentrations of two PAHs at estimated results for anthracene (1.6 ng/dry g) and phenanthrene (1.2 ng/dry g).

Northwest Study Area

PAHs analyzed in sediment samples from Stations 6, 7, and 8 located in the Northwest Study Area were not detected.

Inshore/Proposed Reference Site

PAHs analyzed in sediment samples from Stations 4 and 9 located inshore of the two study areas, as well as the proposed reference site located at Station 5, were not detected, with the exception of one station. Station 4 had detectable concentrations of PAHs at estimated results for dibenzothiophene (2.1 ng/dry g).

Organochlorine Pesticides/PCBs

Unlike PAHs, organochlorine pesticides and PCBs are solely human-related in origin. DDT is the first and one of the most renowned chlorinated organic insecticides. In the 1970s and 1980s, applications of DDT were banned in most developed countries although its limited use in disease control continues in certain parts of the world where malaria persists (Larson 2007). While the DDT family is the best known organochlorine pesticide, it is only one of a large number of related compounds used for a variety of pest control needs.

Due to their chemical stability and nonflammable properties, PCBs are valuable as coolants and insulating fluids, stabilizing additives, pesticide extenders, cutting oils, flame retardants, hydraulic fluids, sealants, adhesives, wood finishes, paints, aspirating agents, and in carbonless copy paper. There are theoretically 209 different PCB congeners, although only approximately 130 of these were found in commercial PCB mixtures. Aroclor is the trade name of commercial PCB mixture marketed from the 1930s until its ban in the 1970s. Commercial PCBs are known to be contaminated with levels of other significantly toxic compounds such as dioxins and furans through chemical reactions with oxygen. Concentrations of 31 individual organochlorine pesticides, 53 PCB congeners and 7 unique Aroclor PCB mixtures were analyzed in sediments from this study and presented in Table 15 of Weston Solutions and TEC (2008b).

North Study Area

Chlorinated pesticides and PCBs analyzed in sediment samples from Stations 1, 2, and 3 located in the North Study Area were not detected.

Northwest Study Area

Chlorinated pesticides and PCBs analyzed in sediment samples from Stations 6, 7, and 8 located in the Northwest Study Area were not detected.

Inshore/Proposed Reference Sites

Chlorinated pesticides and PCBs analyzed sediment samples from Stations 4 and 9 located inshore of the two alternative areas, as well as the proposed reference site located at Station 5, were not detected.

Organotins

Organotin compounds or stannanes have no known natural sources and therefore have exclusively human-related origins. These compounds are used in plastics manufacturing, as wood preservatives, slimicides, and disinfectants. Organotins are also potent biocides for cooling systems, power station cooling towers, pulp and paper mills, breweries, leather processing, textile mills and marine antifouling paints. The environmentally toxic biocidal properties of organotins are unique to tributyltin (TBT). The monobutyltins and dibutyltins do not exhibit these properties. Tetrabutyltins are very stable molecules that are also unusable as biocides, but can be metabolized into TBT compounds by microorganisms. Controls on the use of TBT in antifouling paints were introduced in 1986 when the sale of TBT-based paints was banned. In 1987, the use of TBT-based paints on boats under 25 meters and mariculture equipment was also prohibited. These measures have reduced the potential routes of entry into the marine environment and successfully reduced environmental concentrations (Waite et al. 1991). Organotins have low water solubility and a strong tendency to adsorb strongly to suspended materials and sediments (Laughlin et al. 1986). Organotins were analyzed in sediments from this study and presented in Table 15 of Weston Solutions and TEC (2008b).

North Study Area

Organotins analyzed in sediment samples from Stations 1, 2, and 3 located in the North Study Area were not detected.

Northwest Study Area

Organotins analyzed in sediment samples from Stations 6, 7, and 8 located in the Northwest Study Area were not detected.

Inshore/Proposed Reference Site

Organotins analyzed sediment samples from Stations 4 and 9 located inshore of the two alternative areas, as well as the proposed upstream reference site located at Station 5, were not detected.

Dioxins/Furans

The general term 'dioxins' is often used for a family of 210 structurally and chemically related polychlorinated dibenzodioxins, polychlorinated dibenzofurans and even some PCBs. Dioxins and furans are chemical compounds inadvertently generated and released into the environment as by-products of various combustion and chemical processes involving chlorine, including smelting, waste incineration, plastic production, pulp and paper bleaching, and the manufacturing of chemicals and pesticides such as PCBs. They can also result from natural processes such as volcanic eruptions and forest fires. Low levels of dioxins and furans are expected in the environment due to natural sources or the dechlorination of chlorinated pesticides due to biological or abiotic processes (Gaus et al. 2002 and Holt et al. 2008). The most toxic chemical in the group is 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-para-dioxin), it

should be noted that 2,3,7,8-TCDD was detected at concentrations in the sediment samples collected from both alternative ODMDS sites. Because it is the most toxic, 2,3,7,8-TCDD is the standard to which other dioxins are compared. Furans are approximately a tenth as toxic while twelve of the 209 congeners of PCBs are approximately one hundredth as toxic (Eisler 1986). Although formation of dioxins is localized, environmental distribution is global due to its chemical affinity for lipids. The highest levels of dioxins are found in soil, sediment and the fatty tissues of animals, with much lower levels found in plants, water and air. Complex mixtures of 17 family member dioxin and furan compounds were analyzed in sediments from this study and presented in Table 15 of Weston Solutions and TEC (2008b). For each analyte that was not detected, an Estimated Detection Limit (EDL) was calculated. The EDL is a sample specific, laboratory estimate of the minimum analyte concentration required to produce a signal with a peak height of at least 2.5 times the background noise signal level. Because of the toxicological significance of dioxins and furans, the EDL value is reported for non-detected analytes rather than simply reporting the respective Method Detection Limits (MDLs).

North Study Area

Dioxins and furans analyzed in sediment samples from Stations 1, 2, and 3 located in the North Study Area were detected in low concentrations. The sum of all detectable dioxins averaged 19.66 pg/g with a range of 17.51 pg/g at Station 2 to 22.49 pg/g at Station 1. The sum of all detectable furans averaged 2.50 pg/g with a range of 2.00 pg/g at Station 3 to 3.49 pg/g at Station 1. Analysis of dioxins and furans using the Dixon's Test established no relative difference in the dioxin concentration of sediment between Stations located in the North Study Area. Furan concentration was slightly higher at Station 1 (3.49 pg/g) than Stations 2 (2.02 pg/g) and 3 (2.00 pg/g).

Northwest Study Area

Dioxins and furans analyzed in sediment samples from Stations 6, 7, and 8 located in the Northwest Study Area were detected in low concentrations. The sum of all detectable dioxins averaged 18.33 pg/g with a range of 16.19 pg/g at Station 8 to 19.47 pg/g at Station 6. The sum of all detectable furans averaged 2.20 pg/g with a range of 1.17 pg/g at Station 8 to 3.65 pg/g at Station 6. Analysis of dioxins and furans using the Dixon's Test established no relative difference in the furan concentration of sediment between Stations located in the Northwest Study Area. Dioxin concentration was slightly lower at Station 8 (16.19 pg/g) than Stations 6 (19.47 pg/g) and 7 (19.34 pg/g).

Inshore/Proposed Reference Site

Dioxins and furans analyzed in samples from Stations 4 and 9 located inshore of the two alternative areas, as well as the proposed upstream reference site located at Station 5, were detected in low concentrations. The sum of all detectable dioxins averaged 21.12 pg/g with a range of 17.73 pg/g at Station 9 to 26.98 pg/g at Station 5 (Table 3-14). The sum of all detectable furans averaged 3.03 pg/g with a range of 1.47 pg/g at Station 9 to 5.10 pg/g at Station 5. Analysis of dioxins and furans using the Dixon's Test established no relative difference in the dioxin and furan concentration of sediment between stations located in inshore study area including the proposed upstream reference site.

Table 3-14. Calculated Sum Total Dioxins (CDD) and Furans (CDF) for Sediment Samples Collected Offshore of Guam

Analyte	Units	MDL	RL	Station ID								
				GO 1	GO 2	GO 3	GO 4	GO 5	GO 6	GO 7	GO 8	GO 9
Total Tetra CDD	pg/g	-	-	< 0.30 (1)	0.2	< 0.27 (1)	0.34	< 0.33 (1)	< 0.34 (1)	0.3	< 0.12	< 0.092
Total Penta CDD	pg/g	-	-	4.92	2.18	3.46	2.21	2.67	3.25	1.47	2.4	2.56
Total Hexa CDD	pg/g	-	-	0.85	< 2.1 (1)	< 2.0 (1)	< 1.9 (1)	< 2.4 (1)	0.95	0.17	< 1.8 (1)	0.27
Total Hepta CDD	pg/g	-	-	2.62	1.73	2.14	2.3	1.48	2.33	1.6	0.47	1.61
Octa CDD	pg/g	5.00	100	13.8	11.3	11.1	11.9	20.1	12.6	15.8	11.4	13.2
$\sum$CDD[1]	pg/g			22.49	17.51	18.97	18.65	26.98	19.47	19.34	16.19	17.73
Total Tetra CDF	pg/g	-	-	0.34	0.45	0.43	0.52	0.69	0.42	0.52	0.39	0.25
Total Penta CDF	pg/g	-	-	< 0.90 (1)	< 0.23 (1)	< 0.18 (1)	< 0.24 (1)	< 0.41 (1)	< 1.2 (1)	< 0.25 (1)	< 0.11	< 0.14 (1)
Total Hexa CDF	pg/g	-	-	< 0.22	0.2	0.2	< 0.19	0.55	0.68	0.13	< 0.12 (1)	< 0.23 (1)
Total Hepta CDF	pg/g	-	-	0.84	< 0.48 (1)	< 0.54 (1)	< 0.87 (1)	< 1.9 (1)	< 0.71 (1)	< 0.26 (1)	< 0.20 (1)	0.28
Octa CDF	pg/g	5.00	100	1.19 J	0.66 J	0.65 J	0.71 J	1.55 J	0.64 J	0.63 J	0.35 J	0.57 J
$\sum$CDF[2]	pg/g			3.49	2.02	2.00	2.53	5.10	3.65	1.79	1.17	1.47

[1] $\sum$CDD = sum (Total Tetra CDD + Total Penta CDD + Total Hexa CDD + Total Hepta CDD + Octa CDD) if ND, then sample-specific laboratory EDL used

[2] $\sum$CDD = sum (Total Tetra CDF + Total Penta CDF + Total Hexa CDF + Total Hepta CDF + Octa CDF) if ND, then sample-specific laboratory EDL used

J = estimated value above the MDL and below the RL

(1) EMPC / NDR - Peak detected does not meet ratio criteria and has resulted in an elevated detection limit.

Gross Alpha/Beta

Radioactive nuclei can emit several kinds of particles that can be classified into three primary types: alpha particles (α), beta particles (β), and photons that are either x rays or gamma rays (γ). For the purposes of this study, gross alpha- and beta-emitting radionuclides were characterized to screen samples for relative levels of radioactivity.

Several properties distinguish alpha and beta particles from one another. One is electric charge; alpha particles are emitted with a positive charge of two, beta particles are emitted with either one negative charge (electron) or one positive charge (positron). Another important property is penetration of the particles through matter. Alpha particles lose energy rapidly and travel relatively slowly due to their electric charge and large mass. Beta particles can travel several feet in open air but are easily stopped by solid materials. Alpha and beta emitters have anthropogenic sources and occur naturally in the environment, present in varying amounts in nearly all rocks, soils, and water. Gross alpha and gross beta radiation were analyzed in sediments from this study and presented in Table 15 of Weston Solutions and TEC (2008b).

North Study Area

Alpha and beta particle activity analyzed in sediment samples from Stations 1, 2 and 3 located in the North Study Area were detected in low concentrations. Gross alpha averaged 9.70 pCi/g with a range of 7.02 pCi/g at Station 3 to 12.4 pCi/g at Station 1. Gross beta averaged 4.96 pCi/g with a range of 0.90 pCi/g at Station 3 to 6.19 pCi/g at Station 1. Analysis of gross alpha and beta using the Dixon's Test established no relative difference in alpha and beta-particle activity of sediment between Stations located in the North Study Area.

Northwest Study Area

Alpha and beta particle activity analyzed in sediment samples from Stations 6, 7 and 8 located in the Northwest Study Area were detected in low concentrations. Gross alpha averaged 11.5 pCi/g with a range of 10.8 pCi/g at Station 7 to 12.10 pCi/g at Station 6. Gross beta averaged 3.31 pCi/g with a range of 1.61 pCi/g at Station 8 to 5.86 pCi/g at Station 6. Analysis of gross alpha and beta using the Dixon's Test established no relative difference in alpha and beta-particle activity of sediment between Stations located in the Northwest Study Area.

Inshore/Proposed Reference Site

Alpha and beta particle activity analyzed in samples from Stations 4 and 9 located inshore of the two alternative areas, as well as the proposed upstream reference site located at Station 5, were detected in low concentrations. Gross alpha averaged 9.51 pCi/g with a range of 6.45 pCi/g at Station 5 to 12.4 pCi/g at Station 9. Gross beta averaged 2.86 pCi/g with a range of 2.17 pCi/g at Station 5 to 3.67 pCi/g at Station 4. Analysis of gross alpha and beta using the Dixon's Test established no relative difference in alpha and beta-particle activity of sediment between stations located in inshore study area including the proposed upstream reference site.

3.1.6.3   Sediment Characteristics Summary

In general, the physical, conventional, chemical and radiological characteristics of sediments collected from stations located in the North and Northwest Study Areas are similar with the exception of grain size and few trace metals. Sediment samples from Stations 6, 7, and 8 located in the Northwest Study Area were finer than those from Stations 1, 2, and 3 located in the North Study Area. The foremost reason for this difference in grain size can be attributed to the contrast in seafloor location of these study areas. Bathymetry charts show that stations in the Northwest Study Area are located on the southeastern slope of a seamount, whereas stations in the North Study Area are located in a depression between seamounts. Mean concentrations of cadmium, chromium, mercury, nickel and zinc were similar in both alternative

study areas, while slightly higher mean concentrations of silver, arsenic, copper and lead were measured in sediment samples from Stations 6, 7, and 8, located in the Northwest Study Area. Most persistent organic pollutants were not detected.

3.1.7 Mariana Trench Marine National Monument

The Mariana Trench Marine National Monument (the 'Monument') was established in January 2009 by Presidential Proclamation under the authority of the Antiquities Act (16 U.S.C. 431). The Monument consists of approximately 71,897 sq. nm (246,600 sq. km) of submerged lands and waters of the Mariana Archipelago and was designated with the purpose of protecting the submerged volcanic areas of the Mariana Ridge, the coral reef ecosystems of the waters surrounding the islands of Farallon de Pajaros, Maug, and Asuncion in the Commonwealth of the Northern Mariana Islands, and the Mariana Trench. The Monument includes the waters and submerged lands of the three northernmost Mariana Islands (the 'Islands Unit') and only the submerged lands of designated volcanic sites (the 'Volcanic Unit') and the Mariana Trench (the 'Trench Unit') to the extent that the seaward boundaries of the Islands Unit of the Monument extend to the lines of latitude and longitude depicted on Figure 3-30, which lay approximately 50 nm (93 km) from the mean low water line of Farallon de Pajaros (Uracas), Maug, and Asuncion.

The inland boundary of the Islands Unit of the monument is the mean low water line. The boundary of the Trench Unit of the Monument extends from the northern limit of the Exclusive Economic Zone of the United States in the Commonwealth of the Northern Mariana Islands to the southern limit of the Exclusive Economic Zone of the U.S. in Guam approximately following the points of latitude and longitude identified in Figure 3-31. The boundaries of the Volcanic Unit of the Monument include a circle drawn with a 1 nm-radius centered on each of the volcanic features identified in Figure 3-32 and its legend.

The Monument contains objects of scientific interest, including the largest active mud volcanoes on Earth. The Champagne vent, located at the Eifuku submarine volcano, produces almost pure liquid carbon dioxide. This phenomenon has only been observed at one other site in the world. The Sulfur Cauldron, a pool of liquid sulfur, is found at the Daikoku submarine volcano. The only other known location of molten sulfur is on Io, a moon of Jupiter. Unlike other reefs across the Pacific, the northernmost Mariana reefs provide unique volcanic habitats that support marine biological communities requiring basalt. Maug Crater represents one of only a handful of places on Earth where photosynthetic and chemosynthetic communities of life are known to come together.

The waters of the Monument's northern islands are among the most biologically diverse in the Western Pacific and include the greatest diversity of seamount and hydrothermal vent life yet discovered. These volcanic islands are ringed by coral ecosystems with very high numbers of apex predators, including large numbers of sharks. They also contain one of the most diverse collections of stony corals in the Western Pacific. The northern islands and shoals in the Monument have substantially higher large fish biomass, including apex predators, than the southern islands and Guam. The waters of Farallon de Pajaros (also known as Uracas), Maug, and Asuncion support some of the largest biomass of reef fishes in the Mariana Archipelago.

Mariana Trench
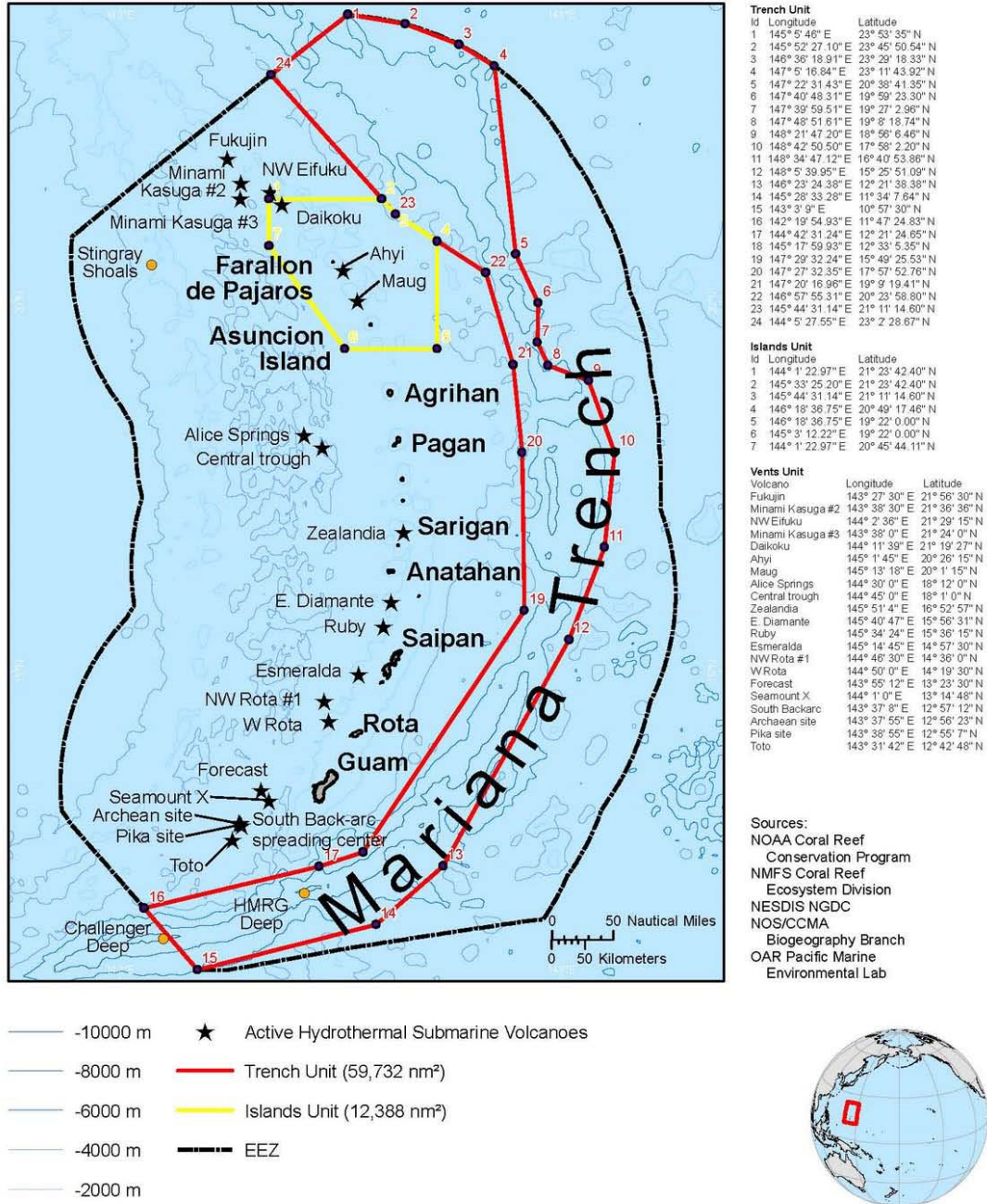# Marine National Monument
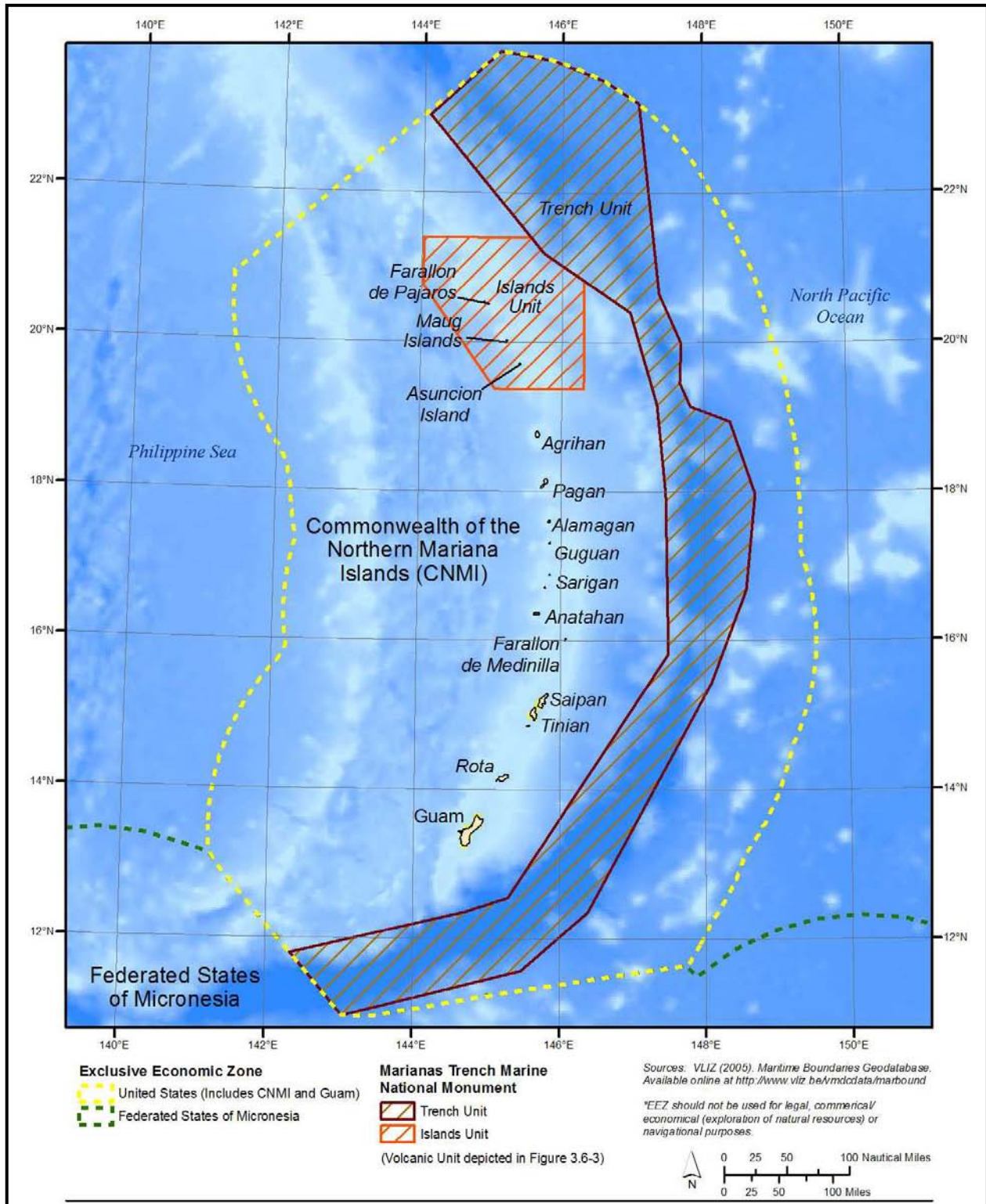

Figure 3-30.
Mariana Trench Marine National Monument

Figure 3-31.
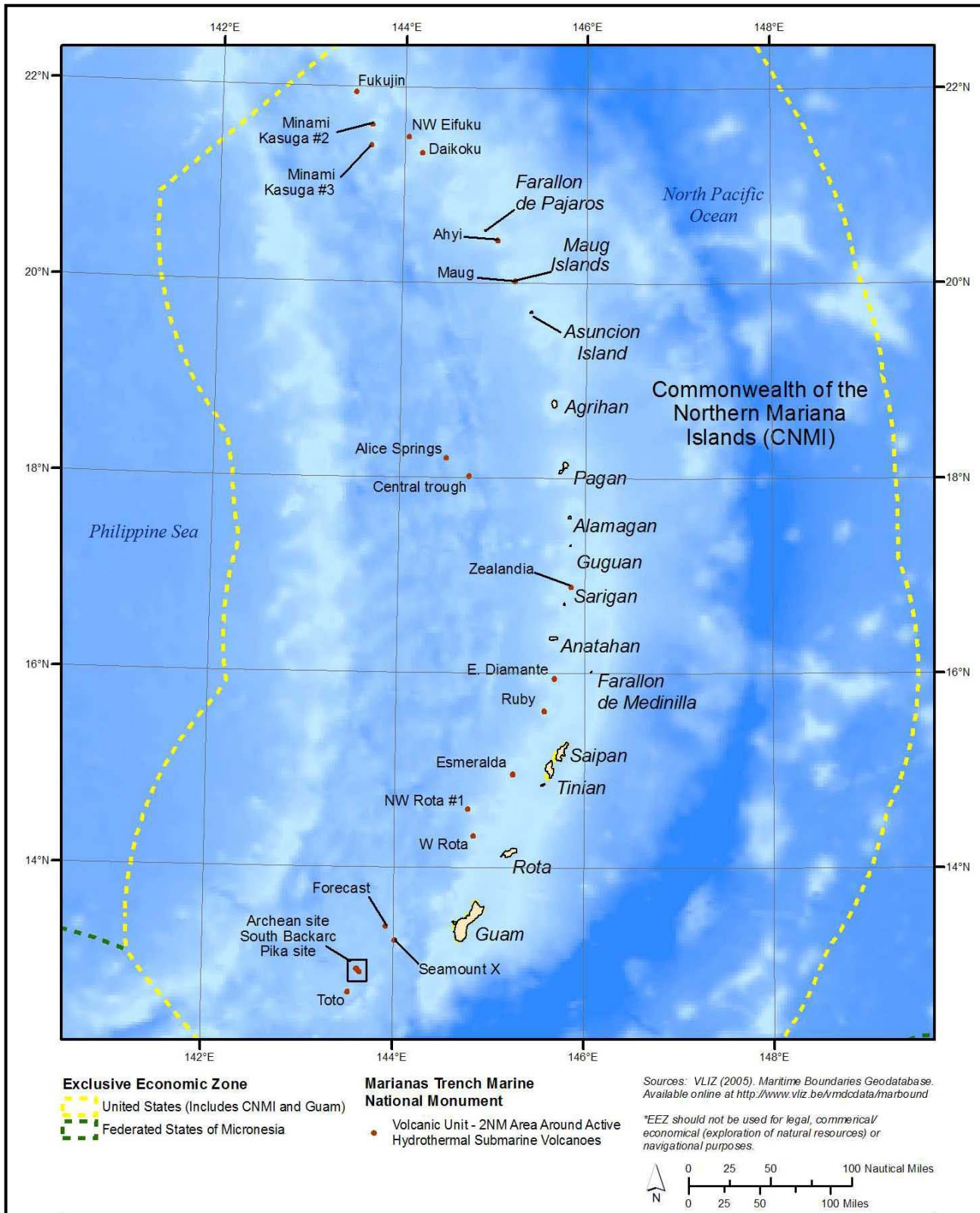**Mariana Trench Marine National Monument Trench and Islands Units**

Figure 3-32.
Mariana Trench Marine National Monument Volcanic Unit