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Zone of Siting Feasibility Study
Ocean Dredged Material Disposal Site
Apra Harbor, Guam
Final Report

Prepared For:

Department of the Navy
Naval Facilities Engineering Command Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, Hawaii 96860-3134

September 2006

WESTON SOLUTIONS

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258 Makalapa Drive, Suite 100
Pearl Harbor, Hawaii 96860-3134

Prepared By:

Weston Solutions, Inc.
2433 Impala Drive
Carlsbad, California 92008

In Association With:
Belt Collins Hawaii Ltd.
2153 North King Street, Suite 200
Honolulu, Hawaii 96819

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ACRONYMS AND ABBREVIATIONS

CDF	Confined Disposal Facility
CFR	Code of Federal Regulations
COMNAVMARIANAS	Commander, U.S. Naval Forces Marianas
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Program
DMMP	Dredged Material Management Plan
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
ERA	Ecological Reserve Area
ESA	Endangered Species Act
FAD	Fish Aggregation Device
FWCA	Fish and Wildlife Coordination Act
FY	Fiscal Year
GEPA	Guam Environmental Protection Agency
GovGuam	Government of Guam
HHFP	Helber, Hastert & Fee, Planners
MLLW	Mean Lower Low Water
MPA	Marine Protected Area
MPRSA	Marine Protection, Research and Sanctuaries Act
NAVFAC/PAC	Naval Facilities Engineering Command, Pacific
NCTS	Naval Computer and Telecommunications Station
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NRC	National Research Council
ODMDS	Ocean Dredged Material Disposal Site
PAG	Port Authority of Guam
PWC	Public Works Center
RHA	Rivers and Harbors Act
RNA	Regulated Navigation Area
SRF	Ship Repair Facility
USACE	U.S. Army Corps of Engineers
USDOC	U.S. Department of Commerce
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WAPA	War in the Pacific National Historic Park
WRDA	Water Resources Development Act
WTP	Wastewater Treatment Plant
ZSF	Zone of Siting Feasibility

UNITS of MEASURE

a	acres
cm	centimeters
cy	cubic yards
ft	feet
ft^2	square feet
ha	hectares
in	inches
km	kilometers
km^2	square kilometers
kph	kilometers per hour
m	meters
m^2	square meters
m^3	cubic meters
mi	miles
mph	miles per hour
nm	nautical miles
sq. mi	square miles
yd	yards

1.0 INTRODUCTION

1.1 Purpose and Need

Both the Navy and the Port Authority of Guam (PAG) have plans to expand their operations in Apra Harbor, Guam. Expansion of the Apra Harbor Naval Complex and Commercial Port is necessary to accommodate increases in vessel and cargo traffic, newer classes of vessels and dockside maintenance and support operations. Expansion plans would require construction dredging activities to increase water depths for the safe navigation of military and commercial vessels.

At present, the Navy has planned a total of four separate construction dredging projects at various locations within Inner Apra Harbor (P-431, P-502, P-436 and P-518). Approximately 695,500 cubic yards (cy; 531,366 cubic meters [m^3]) of dredged material is anticipated to be generated as a result of these projects (MEC-Weston 2005). An additional 5,000,000 cy (3,822,774 m^3) of dredged material may be generated as a result of proposed future construction dredging activities (Sato [Naval Facilities Engineering Command, Pacific (NAVFAC/PAC)] 2005). By the year 2036, up to 1,113,000 cy (850,000 m^3) of sediment will likely need to be dredged as part of maintenance dredging projects within Apra Harbor in support of Navy operations. Also, construction and maintenance dredging by the PAG may be initiated in the future at Commercial Port as part of planned port expansion and at Agana Boat Basin, Agat Marina and Tumon Bay (for recreational swimming purposes) generating an unknown volume of dredged material for disposal (GEPA, 2000).

An ocean dredged material disposal site (ODMDS) would provide the Navy and PAG with an alternative to upland disposal or beneficial use of clean dredged materials. Currently, the Navy has two dewatering facilities (Orote Point and the Ship Repair Facility [SRF]) and is considering the possible construction of up to three additional dewatering facilities at Commercial Port and two open fields (Field 3 and Field 5) in the southwest portion of the base. Combined, approximately 1,468,400 cy (1,122,672 m^3) of dredged material can be managed at these three proposed sites. These existing and proposed dewatering facilities do not have sufficient capacity for the anticipated volume of dredged material to be generated over the next 30 years.

The purpose of this study is to evaluate the feasibility of designating an ODMDS near Apra Harbor, Guam. This evaluation will identify the regulatory, technical, logistical, economic and environmental issues, including social and cultural resource concerns, which will need to be addressed when designating an ODMDS. Further, this report will document existing data which may be used for development of the site designation documentation (environmental documentation, site management plan and site monitoring plan) and field sampling efforts required to fill data gaps. A preliminary schedule and potential costs associated with data collection and development of the necessary site documentation will also be presented.

1.2 Background

An interim ODMDS was designated in 1977 offshore of the Territory of Guam (Title 40 Code of Federal Regulations [CFR] Part 228 Section 14). The interim-designation was approved for the disposal of dredged material from Apra Harbor, Guam. The interim-designated site was located at 13° 29’ 30’’ North, 144° 34’ 30’’ East (Figure 1-1). It was centered 5.3 mi (8.6 km) northwest of the entrance to Outer Apra Harbor and had a 1,000 yd (914.4 m) radius. Although the area was listed as an interim-designated ODMDS, disposal of dredged material at this site has never occurred.

In 1992, the Water Resources Development Act (WRDA) amended the Marine Protection, Research and Sanctuaries Act (MPRSA). Section 506 of WRDA promulgated the following rules (USEPA/USACE 1996):

- After January 1, 1995, no site shall receive a final designation unless a management plan has been developed.
- For sites that received a final designation prior to January 1, 1995, management plans shall be developed as expeditiously as practicable, but no later than January 1, 1997, giving priority to sites with the greatest potential impact on the environment.
- Beginning on January 1, 1997, no permit or authorization for dumping shall be issued for a site unless it has received a final designation or it is an alternate site selected by the U.S. Army Corps of Engineers (USACE) under MPRSA Section 103(b).

Pursuant to this legislation, in September 1997, the USACE offered the Commander, U.S. Naval Forces Marianas (COMNAVMARIANAS) the opportunity to request their services as well as those of the U.S. Environmental Protection Agency (USEPA) to complete the documentation necessary to change the status of the disposal site to final-designation. The condition of this request was that the Navy would be required to provide the majority of funding for the completion of studies and environmental documentation. At that time, it was determined that final designation was not critical to support the Navy’s operations in Apra Harbor, Guam. Consequently, final designation of the interim-designated ODMDS was never completed.

1.3 Regulatory Framework

There are numerous federal laws and regulations that guide or restrict the disposal of dredged material into the waters of the United States and its Territories. These laws are designed to protect the environment, coastal resources and commerce. In addition, several Acts have been adopted to protect archaeological and historical resources. Designation of an ODMDS needs to address the potential impacts to these resources. The following laws and regulations are relevant to the ocean disposal of dredged material offshore of the Territory of Guam.

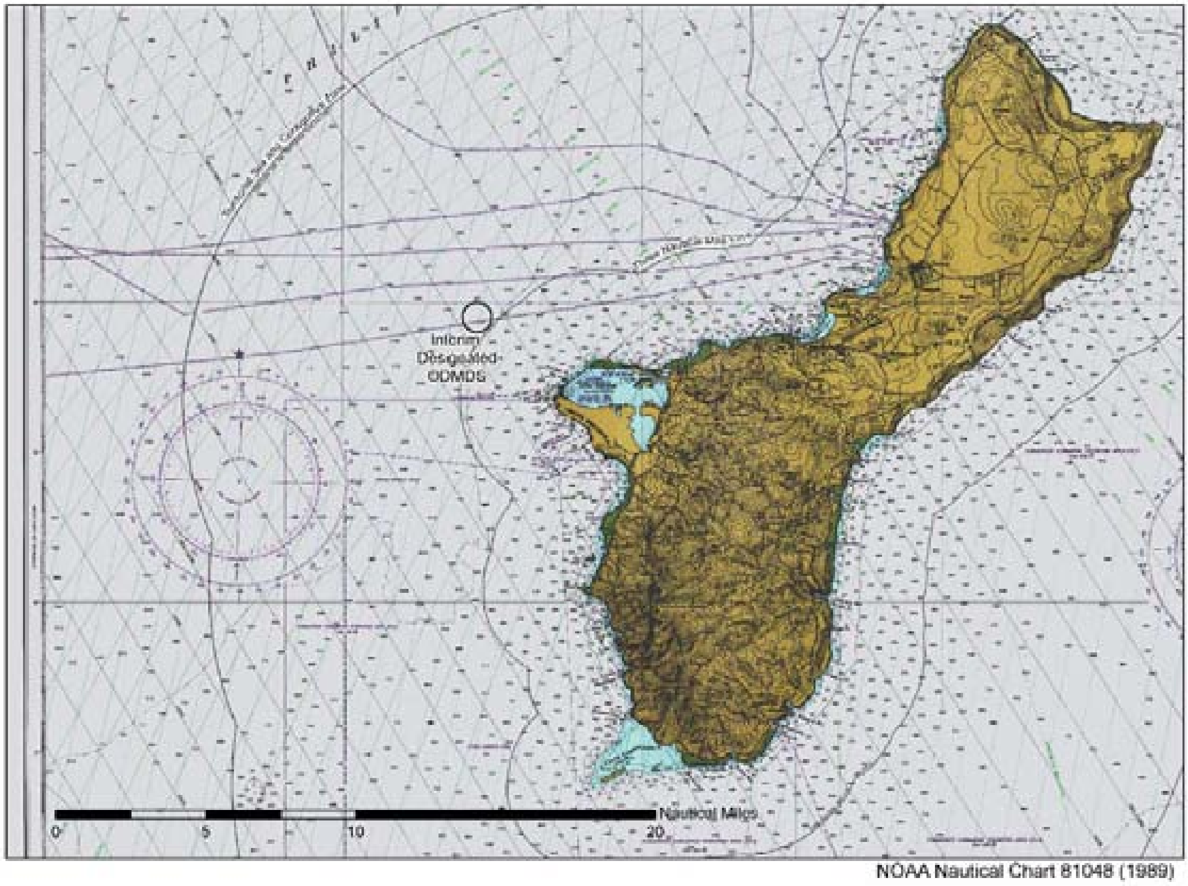

Figure 1-1. Location of Interim-Designated ODMDS, Offshore of Apra Harbor, Guam.

1.3.1 London Convention

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, also known as The London Convention (1972), established provisions that participating nations would follow to control ocean dumping of waste material. The United States abides by the London Convention through the regulations mandated in the MPRSA (1972) and Ocean Dumping Regulations (1977) promulgated by the USEPA (Title 40 CFR Part 220).

1.3.2 Federal Laws and Regulations

1.3.2.1 Marine Protection, Research and Sanctuaries Act, 1972

The MPRSA, also known as the Ocean Dumping Act, regulates the dumping of waste materials, both dredged and non-dredged, into the ocean. The MPRSA prohibits the dumping of material into the ocean that would adversely affect the human health, marine environment or other resources and specifically states that high-level radioactive waste and radiological, chemical and biological warfare agents may never be permitted to be disposed of at sea. Section 102 of the MPRSA authorizes the USEPA to designate acceptable locations for ODMDS. Section 103 of the MPRSA empowers the USACE to issue permits for the ocean dumping of dredged material, provided that the dredged material and disposal activities meet the ocean discharge criteria as established by the USEPA. As mentioned previously, the WRDA of 1992 amended the MPRSA to ensure that after January 1, 1997, no dumping can be permitted or authorized at a site unless it has received final designation or is an alternate site selected by the USACE, and a management plan has been developed for the disposal site.

Section 103 of the MPRSA also indicates that the dredged material must be compared to criteria established to evaluate the potential effects of the disposal activity. The Ocean Testing Manual (i.e., Green Book), developed by the USEPA and USACE (1991) provides guidance for determining the suitability of dredged material for ocean disposal.

1.3.2.2 Ocean Dumping Regulations, 1977

Title 40 CFR Subchapter H (Ocean Dumping) Parts 220-238 is the USEPA promulgated criteria that defines administration of permit applications and the designation and management of ODMDS. These regulations identify five general and 11 specific criteria that are used during the evaluation of an ODMDS designation. The five general criteria are (40 CFR 228.5):

- "The dumping of materials into the ocean will be permitted only at sites or in areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of heavy commercial or recreational navigation."
- "Locations and boundaries of disposal sites will be so chosen that temporary perturbations in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere within the site can be expected to be reduced to normal ambient seawater levels or to undetectable contaminant concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery."
- "If, at any time during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on an interim basis for ocean dumping do not meet the criteria for site selection set forth in 40 CFR 228.5 through 228.6, the use of such sites will be terminated as soon as suitable alternate disposal sites can be designated."
- "The sizes of ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts and permit the implementation of effective monitoring and surveillance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as a part of the disposal site evaluation or designation study."
- "USEPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used."

The following 11 specific criteria shall also be considered (40 CFR 228.6):

- "Geographical position, depth of water, bottom topography and distance from coast."
- "Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases."
- "Location in relation to beaches and other amenity areas."
- "Types and quantities of wastes proposed to be disposed of, and proposed methods of release, including methods of packing the waste, if any."
- "Feasibility of surveillance and monitoring."
- "Dispersal, horizontal transport and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any."
- "Existence and effects of current and previous discharges and dumping in the area (including cumulative effects)."
- "Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance and other legitimate uses of the ocean."
- "The existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys."
- "Potentiality for the development or recruitment of nuisance species in the disposal site."
- "Existence at or in close proximity to the site of any significant natural or cultural features of historical importance."

1.3.2.3 Clean Water Act or Federal Water Pollution Control Act, 1972

The Clean Water Act (CWA) established the basic structure for regulating discharges of pollutants into waters of the United States. Section 404 of the CWA authorizes the Secretary of Army to issue permits for the discharge of dredged or fill material into waters of the United States. The USACE and USEPA are responsible for regulating the discharge of dredged or fill material and to ensure such discharges do not adversely affect waters of the United States. The USACE is responsible for evaluating potential alternatives to discharge activities. The USEPA is responsible for environmental oversight of any USACE proposed disposal decision. Section 401 of the CWA indicates that activities resulting in discharge to waters of a state or territory must comply with all applicable state or territorial water quality standards. Guam's water quality standards were recently revised and approved in 2001 (Guam Environmental Protection Agency [GEPA] 2001). In the case of ocean disposal of dredged materials offshore of Guam, the CWA does not apply as long as the monitoring activities demonstrate that water quality of territorial waters is not impacted by the transport of dredged material through territorial waters.

1.3.2.4 National Environmental Policy Act, 1969

The National Environmental Policy Act (NEPA) is a national policy for the protection of the environment. It is designed to prevent or eliminate damage to the environment and support the health and welfare of the individual. It is intended to develop the understanding of the ecological systems and natural resources important to the nation. It also established a process of environmental review and public notification for federal planning and decision making. The

NEPA requires federal agencies to develop an environmental impact statement (EIS) that considers potential environmental impacts, unavoidable, adverse environmental effects and project alternatives before a decision is made to implement a federal project. Although NEPA does not require the completion of an environmental impact statement for the designation of an ODMDS, the USEPA has established a policy to develop this documentation as part of the site designation process (Federal Register 1998).

1.3.2.5 Endangered Species Act, 1973

The Endangered Species Act (ESA) provides for the conservation of ecosystems that support threatened and endangered plant and animal species. The ESA allows for the determination and development of threatened and endangered species lists. The ESA protects threatened and endangered species by prohibiting federal agencies from authorizing, funding, or carrying out any action that would jeopardize such species or destroy or modify its critical habitat. The U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) administer provisions under this Act.

1.3.2.6 Fish and Wildlife Coordination Act, 1958

The Fish and Wildlife Coordination Act (FWCA) provides that whenever the waters or channel of a body of water are modified by a federal agency, the agency must first consult with the USFWS, NMFS and state or territorial agencies representing local fish and wildlife resources. The review agencies determine any potential adverse impacts to wildlife resources and propose measures that would eliminate or reduce any possible damages or losses to those resources.

1.3.2.7 Magnuson-Stevens Fisheries Conservation and Management Act, 1996

This Act was established to provide for the management of fish and other species within the Exclusive Economic Zone (EEZ) through Regional Fishery Management Councils. The Act requires national fishery conservation and management for the sustained participation of fishery dependent communities and minimizes economic impacts to such communities, identifies over fished species and rebuilds those stocks, and identifies and protects essential fish habitat that may potentially be impacted by activities conducted under federal permits, licenses or other such authorities.

1.3.2.8 Rivers and Harbors Act, 1899

Section 10 of the Rivers and Harbors Act (RHA) prohibits the building of wharves, piers, jetties, and other structures without approval from the USACE. Dredging activities (excavation) or dredged material placement activities (fill) within navigable waters also requires the approval of the USACE.

1.3.2.9 Coastal Zone Management Act, 1972

The Coastal Zone Management Act (CZMA) was established to preserve, protect, develop and where possible, restore and enhance the Nation's coastal resources. States and territories are encouraged to develop coastal zone management programs (CZMPs) to manage economic growth in conjunction with the protection of natural resources, diminution of coastal hazards, improvement of water quality and sustainable coastal development. The Act required that federal activities adhere to the policies established under each state's CZMP (U.S. Department of

Commerce [USDOC] 2000). Since the ODMDS will be located beyond the 3-nm limit, CZMA does not directly preside over designation and subsequent disposal activities. However, CZMA would apply if disposal activities are shown to ultimately impact Guam's coastal zone via oceanographic currents.

1.3.2.10 National Historic Preservation Act, 1966

The National Historic Preservation Act (NHPA) provides for a National Register of Historic Places to include districts, sites, buildings, structures and objects significant in American history, architecture, archaeology and culture. Section 106 of the NHPA requires Federal agencies to consider potential impacts on historic properties resulting from federal activities and provides the Advisory Council on Historic Preservation a reasonable opportunity to comment on such activities. Goals of the NHPA are to seek ways to avoid, minimize or mitigate any adverse effects on historic properties.

1.4 Site Designation Process

There are seven major components that define the selection and designation process of ODMDS (Pequegnat, et al. 1990). These components are:

- Evaluation of need for designation of a new site,
- Identification of suitable areas for site designation,
- Gauging site requirements in relation to dredged material characteristics,
- Selection of candidate sites,
- Estimation of the short and long-term fate and potential effects of dredged material disposal at candidate sites,
- Evaluation of alternative candidate sites, and
- Final selection of the new ODMDS.

1.4.1 Zone of Siting Feasibility

The location of potential ODMDSs is determined by a process known as the Zone of Siting Feasibility (ZSF; Mathis and Payne 1984). The ZSF identifies the maximum area for which designation of an ODMDS is economically and operationally feasible. The ZSF is based on several considerations, including:

- Cost of transporting dredged material to the disposal site,
- Type of disposal plant,
- Navigation restrictions,
- Political and other jurisdictional boundaries, and
- Distance to the edge of the continental shelf.

The maximum extent of the ZSF should be equal to the maximum transport distance that is economically feasible. For Apra Harbor, the ZSF would be an area inside an arc originating from the Apra Harbor entrance and radiating offshore to a distance equal to the maximum transport distance. The maximum transport distance will be dependent on a number of factors, including the type and size of dredging equipment used, production rate of the dredge equipment and acceptable production downtime.

Mechanical dredging has been recommended during Phase I of the Dredged Material Management Plan (MEC-Weston 2005). Additionally, mechanical dredging is the method currently utilized by the Navy during maintenance dredging. For the purposes of establishing the ZSF in the process of designating an ODMDS for Apra Harbor, it would be appropriate to assume mechanical dredging would continue to be the method of choice. In this case, considerations of the size of the dredge bucket and scows, and number of scows available will determine the maximum transport distance. If a hydraulic (hopper) dredging plant is determined to be more suitable to successively complete future dredging operations in Apra Harbor, the ZSF would need to be evaluated accordingly, based on items such as the rate of production, capacity and speed of the dredge plant.

As stated, the maximum transport distance is predicated on the method of dredging chosen. The differences mechanical and hydraulic (hopper) dredge plants have on the maximum transport distance are summarized below and provided in detail in Sections 4 and 5. Mechanical dredge transport distances can be much greater than if a hopper dredge is used, but hopper dredging can be more cost effective for projects having shorter transport distances. Mechanical dredging and hopper dredging involves placing material in a scow or the hopper, respectively, which can be transported over long distances, much like cargo. In a mechanical, or clamshell, dredging system, the dredge and transport scows are separate plants allowing dredging and transport to take place simultaneously if more than one scow is used. Conversely, a hopper dredge is one self-contained plant, which must excavate and transport the material, forcing stoppage in production during the haul phase of the hopper dredge cycle. Hopper dredge transport distance is limited by decreasing production rates with longer transport distances. As transport distances increase to the point where they constitute a large majority of the cycle time, the cost per cubic yard becomes impractically high. However, for shorter transport distances, hopper dredging is more cost effective because loading times are faster and total plant charges can be lower. Mechanical dredging has slower production rates, but is more cost effective as transport distances increase, as long as adequate barges are available.

The ZSF should take into consideration the offshore dredged material disposal needs for other private and government entities in Guam, besides the immediate needs of the Navy for development and maintenance of Apra Harbor.

The ZSF process will identify the areas, or alternatives, suitable for placement of an ODMDS. Typically, this process utilizes a geographic information system that systematically “layers” each constraint or resource (e.g., navigation hazards, jurisdictional boundaries, sensitive environmental resources) to identify areas that are not suitable for the placement of an ODMDS. Areas not excluded are then considered for the siting of an ODMDS. Once identified, each alternative is evaluated based on the five general criteria and 11 specific criteria as described in 40 CFR Part 228.5 and 40 CFR Part 228.6, respectively. A preferred alternative is subsequently selected based on the results of the evaluation.

2.0 REGIONAL OFFSHORE DISPOSAL REQUIREMENTS

2.1 Regional Dredging History

The following section provides insight into the historical dredging needs of the Navy and PAG. In many cases, detailed documentation of the dredged volumes and disposal location is not available. Based on reasonable assumptions, this study relies on estimated dredged volumes for which detailed documentation is not available.

2.1.1 U.S. Navy

Apra Harbor, Guam, has been extensively developed following World War II into a strategic, forward deployed base for the U.S. Armed Forces. Centrally located on Guam's west coast, Apra Harbor is home to COMNAVMARIANAS. The Apra Harbor Naval Complex provides a base for the Military Sealift Command Maritime Prepositioning Ship Squadron 3, Submarine Squadron 15, and NAVFAC Marianas. The majority of the Apra Harbor Naval Complex's wharves and mission support facilities are located around Apra Harbor. Apra Harbor also provides a base for the 14th U.S. Coast Guard District.

An integral part of the Navy's mission and operational preparedness is to support forces transiting through and based in Apra Harbor, Guam. In order to accommodate new classes of vessels that are anticipated to begin using Apra Harbor, maintenance and construction dredging will be required (Helber Hastert & Fee, Planners [HHFP] 2003). Without adequate dredging, the ability of the Navy to support its mission may be compromised. Consequently, management of Apra Harbor dredged material, in a manner consistent with the Navy's mission, is a high priority.

Historical construction dredging occurred in Inner Apra Harbor in the late 1940's and between 1962 and 1964. Initial deepening of Inner Apra Harbor and development of the Apra Harbor Naval Complex was conducted between 1946 and 1950 with design depths of -32 feet (ft; -9.8 meters [m]) mean lower low water (MLLW). Between 1962 and 1964, a construction dredging project increased water depths of the northern half of Inner Apra Harbor to -35 ft (-10.7 m) MLLW (Navy No Date). Although adequate documentation of the dredge volumes of this construction project is unavailable, an estimated dredge volume can be calculated. The calculation assumes the following:

- The shallowest water depths in the northern half of Inner Apra Harbor were -32 ft (-9.8 m) at project initiation.
- Areas deeper than -35 ft (-10.7 m) were not dredged - based on a 2003 bathymetry survey (it is assumed that due to sedimentation, water depths would only become shallower over time, therefore areas with water depths greater than -35 ft [-10.7 m] in 2003 would likely have been deeper in 1964).
- Maintenance dredging activities likely occurred nearest the wharves on the northwestern side of Inner Apra Harbor. Shallow areas along the northeastern shore of Inner Apra Harbor, which are due to sediment deposition from the Atantano River, were likely not dredged.

Based on these assumptions, approximately 64,600 cy (49,390 m^3) of sediment was likely dredged and placed upland between 1962 and 1964 (Table 2-1).

Historical maintenance dredging occurred in Inner Apra Harbor in 1978 and 2003. One maintenance dredging project was conducted in Outer Apra Harbor between 1997 and 1998. Maintenance dredging in Inner Apra Harbor was conducted in 1978 to maintain water depths of -35 ft (-10.7 m) MLLW in the northern half of Inner Apra Harbor and -32 ft (-9.8 m) MLLW in the southern half of the harbor (Navy No Date). Documentation of the dredged volumes is unavailable; however an estimate of the dredged volumes can be calculated. The calculation assumes the following:

- A sedimentation rate of approximately 1.0 inches (in; 2.5 centimeter [cm]) per year occurred evenly throughout Inner Apra Harbor between 1964 and 1978[1]. The sedimentation rate is based on calculations of shoaling between 1978 and 2000 and hindcast, after an adjustment, for the period between 1964 and 1978.

- Areas deeper than -35 ft (-10.7 m) in the northern half of Inner Apra Harbor and deeper than -32 ft (-9.8 m) in the southern half of Inner Apra Harbor were not dredged - based on a 2003 bathymetry survey (it is assumed that due to sedimentation, water depths would only become shallower over time; therefore, areas with water depths greater than design depths in 2003 would likely have been deeper in 1964).

- Maintenance dredging activities likely occurred nearest the wharves on the western side of Inner Apra Harbor and along X-Ray Wharf on the southeast side of Inner Apra Harbor. Shallow areas along the northeastern and southernmost shores of Inner Apra Harbor, which are due to sediment deposition from the Atantano and Aplacho Rivers, respectively, were likely not dredged.

Based on these assumptions, approximately 39,000 cy (29,818 m^3) of sediment was likely dredged and placed upland in 1978. However, this volume estimate represents dredged material that is derived primarily from areas adjacent to wharves on the western side of Inner Apra Harbor. As stated in the assumptions, shoaling was likely higher in these depositional areas; therefore, this volume estimate is likely low. Using the same dredge footprint, but a higher sedimentation (shoaling rate) of 2.7 in (6.9 cm) per year increases the volume of sediment likely dredged in 1978 to 104,900 cy (80,202 m^3; Table 2-1). The volume estimate of 104,900 cy (80,202 m^3) is consistent with maintenance dredging needs for the period between 1978 and 2003.

Between 1997 and 1998, approximately 11,000 cy (8,410 m^3) of sediment was dredged along Echo Wharf in Outer Apra Harbor (Navy No Date). In 2003, maintenance dredging of Inner

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[1] For the period between 1978 and 2000, a sedimentation rate of 2.7 in (6.9 cm) per year was calculated based on a hydrographic survey conducted in 2000 which showed a decrease in water depths of approximately 5 ft (1.5 m) since 1978 (Schroeder *et al*, 2001). The decrease in water depths of approximately 5 ft (1.5 m) was noted as "a loss…in berthing depth". Shoaling in berthing areas is likely exasperated by ship traffic transiting to and from the wharves. Therefore, the calculated sedimentation rate of 2.7 in (6.9 cm) per year is likely not reflective of conditions throughout the harbor. Since the sedimentation rates in other parts of the harbor are likely much lower, we assumed a rate of 1.0 in (2.5 cm) as more typical of sedimentation throughout the harbor.

Apra Harbor was conducted after a 25 year hiatus. Approximately 160,000 cy (122,329 m^3) of sediment was removed from Inner Apra Harbor and placed in upland confined disposal facilities (CDFs; Navy 2003).

Table 2-1. U.S. Navy Historical Dredging Volume Estimate, Apra Harbor, Guam

Type	Year	Dredged Volume (cy)	Average Yearly Dredged Volume 1976 – 2006 (cy)
Construction	1964	64,600	
	Subtotal	**64,600**	**0[1]**
Maintenance	1978	104,900	
	1998	11,000	
	2003	160,000	
	Subtotal	**275,900**	**9,200**
Construction and Maintenance	**Total**	**340,500**	**9,200[1]**

[1] Estimated volume of sediment dredged in 1964 was not used in calculating the 30-year average yearly historical dredging needs.

2.1.2 Port Authority of Guam

The PAG administers the Commercial Port, Agana Boat Basin and Agat Marina. Aquaworld Marina and the Harbor of Refuge are run by private companies in agreement with the Port Authority. All of these marinas and ports, with the exception of Agat Marina, were constructed prior to 1976. According to the PAG, there have been no dredging projects, either construction or maintenance related, undertaken by the PAG over the past 30 years, since it has been under the purview of the Government of Guam (GovGuam; Harris 2006).

Commercial Port is the largest U.S. deepwater port in the Western Pacific. Located in the northeast corner of Outer Apra Harbor, the Commercial Port handles about 2 million tons of cargo a year. Currently, a master plan is being developed for the expansion of the Commercial Port facilities to include new deepwater cargo piers, upgraded fisheries facilities, expanded container lay-down areas, an industrial park and cruise ship facilities.

Agana Boat Basin, located in Agana on the west side of Guam, currently has slips for approximately 40 vessels. The current Agana Boat Basin was created post-World War II with capital improvements undertaken in the 1970's to enlarge the harbor (GEPA 2000). Historical dredging at Agana Boat Basin includes the capital improvement project conducted in the mid-1970's. Dredged material generated from the expansion of the harbor was beneficially used to create an artificial island for construction of the Agana Sewage Treatment Plant (GEPA 2000).

Agat Marina, located on the west side of Guam just south of the village Agat, was constructed in 1992 and has slips for over 160 recreational and commercial vessels. Storm damage has reduced the number of available slips to about 130. Historical dredging at Agat Marina, conducted by the USACE, includes the capital improvement project of construction of the marina. Documentation of the dredged volumes is unavailable; however the dredged volume is estimated at approximately 50,000 cy (15,291 m^3; Table 2-2).

Aquaworld Marina and Harbor of Refuge are privately administered through an agreement with the Port Authority. Both the marina and refuge are located in the northeast corner of Apra Harbor, east of the Cabras Island Channel. The Harbor or Refuge is intended for use of private and small commercial vessels for shelter during adverse weather conditions or for the permitted anchorage of these vessels when the owner or operator is off-island (GovGuam 2004).

Table 2-2. Port Authority of Guam Historical Dredging Volume Estimate, Guam

Type	Year	Dredged Volume (cy)	Average Yearly Dredged Volume 1976 – 2006 (cy)
Construction	1992	~50,000	
	Subtotal	**~50,000**	**1,700**
Maintenance	No Maintenance Dredging Conducted by PAG		
	Subtotal	**0**	**0**
Construction and Maintenance	**Total**	**~50,000**	**1,700**

2.2 Regional Dredging Future Expectations

2.2.1 U.S. Navy

Currently, four construction dredging projects have been identified by the Navy in order to accommodate future operational needs. These include P-431, P-502, P-436 and P-518. The first project (P-431) is expected to begin fiscal year 2006 (FY06) and will dredge approximately 370,000 cy (282,885 m^3) of sediment at the entrance to Inner Apra Harbor and adjacent to Alpha and Bravo Wharves (Table 2-3). The second project (P-502) is scheduled for FY08 and will dredge approximately 165,000 cy (126,152 m^3) of sediment in the vicinity of Kilo Wharf. Approximately 160,000 cy (122,329 m^3) of this amount is characterized as fossilized reef platform (Weston 2005) and, for the purposes of this report, is considered unsuitable for ocean disposal due to the likelihood the dredging process would remove this material in large fragments; however, if the material is dredged in such a manner to reduce its grain size to a consistent grain size as sediments within an ODMDS, it may be deemed acceptable for ocean disposal. The third project (P-436) is scheduled for FY09 and will dredge approximately 225,000 cy (172,407 m^3) of sediment between November and Tango Wharves (MEC-Weston 2005). The fourth project (P-518) is expected to begin FY07 and will dredge approximately 100,000 cy (76,455 m^3) of sediment near X-Ray Wharf. An additional 5,000,000 cy (3,822,774 m^3) of dredged material may be generated as a result of proposed future construction dredging activities (Sato [NAVFAC/PAC] 2005).

Future maintenance dredging needs for Inner Apra Harbor over the next 30 years can be estimated based on the following assumptions:

- Maintenance dredging is not required during the next four years while construction projects P-431, P-518 and P-436 are conducted, i.e. water depths in 2010 are equal or deeper than project design depths.

- A sedimentation rate of approximately 1.0 in (2.54 cm) per year occurred evenly throughout Inner Apra Harbor between 2010 and 2036[2]. Shoaling will likely be higher in depositional areas (near wharf junctions) and lower in high traffic areas.
- Areas deeper than project design depths will not be dredged - based on a 2003 bathymetry survey and the above stated sedimentation rate. The dredge footprint was determined by applying the sedimentation rate for a 26 year period (beginning 2010) and delineating those areas shallower than project design depth.
- Maintenance dredging activities will likely occur nearest the wharves on the western side and along X-Ray Wharf on the southeast side of Inner Apra Harbor. Shallow areas along the northeastern and southernmost shores of Inner Apra Harbor, which are due to sediment deposition from the Atantano and Aplacho Rivers, respectively, will likely not be dredged.

Based on these assumptions, approximately 427,000 cy (326,465 m^3) will likely need to be dredged as part of maintenance dredging operations within Inner Apra Harbor through 2036. The Navy may require the northeastern and southernmost portions of Inner Apra Harbor to be dredged for continued safe operations. It appears these areas have not been historically maintained. Maintenance dredging of these areas would increase maintenance dredging needs of the Navy in Inner Apra Harbor to approximately 2,827,000 cy (2,161,397 m^3) over the next 30 years.

Maintenance dredging at Echo Wharf was conducted between 1997 and 1998 with approximately 11,000 cy (8,410 m^3) of sediment removed. Assuming no other maintenance dredging was conducted at Echo Wharf during the 50 year period between its construction (assumed to be late-1940's) and the late-1990's, an estimate of future dredging needs can be made for the next 25 years. Approximately 5,500 cy (4,205 m^3) of sediment may need to be dredged at Echo Wharf as part of maintenance dredging operations.

Assuming all of these scheduled and proposed future dredging projects occur as anticipated, as much as 8,692,500 cy (6,645,893 m^3) of material will be dredged from Apra Harbor. Of this amount, approximately 160,000 cy (122,329 m^3) of material has been identified as fossilized reef platform and may consequently be unsuitable for ocean disposal. Therefore, the Navy expects to generate approximately 8,532,500 cy (6,523,564 m^3) of dredged material which may be suitable for ocean disposal within the next 30 years.

[2] See Footnote 1

Table 2-3. U.S. Navy Estimated Future Dredging Needs, Apra Harbor, Guam

Type	Year (Project)	Dredged Volume (cy)	Average Yearly Dredged Volume 2006 – 2036 (cy)
Construction	2006 (P-431)	370,000	
	2008 (P-502)	165,000	
	2009 (P-436)	225,000	
	2009 (P-518)	100,000	
	Unscheduled (Unplanned)	5,000,000	
	Subtotal	**5,700,000**[1]	**190,000**
Maintenance	Unscheduled (Apra Harbor)	427,000 – 2,827,000	
	Unscheduled (Echo Wharf)	5,500	
	Subtotal	**432,500 – 2,832,500**	**14,400 – 94,400**
Construction and Maintenance	**Total**	**6,132,500 – 8,532,500**[1]	**204,400 – 284,400**

[1] 160,000 cy of dredged material identified as not suitable for ocean disposal from P-502 is not included in these totals.

2.2.2 Port Authority of Guam

Only one construction dredging project has been identified outside of Apra Harbor by the PAG. Potential development of a public harbor on the south side of Guam, near Merizo, was considered in the 1980's. If plans for construction proceed at a later date, between 34,500 cy (26,377 m^3) and 77,200 cy (59,024 m^3) of sediment would be required to be dredged within the Mamaon Channel at Talona (GEPA 2000; Table 2-4). The Merizo area public harbor would likely have a berthing area dredged to -6 ft (-1.8 m) MLLW for recreational and small commercial boat use. Although no plans have been developed by the PAG for maintenance dredging at any of the small boat marinas, this report conservatively assumes approximately 25,000 cy (19,114 m^3) of sediment will be dredged as part of maintenance dredging operations within the next 30 years. This estimate suggests dredged material volumes generated as part of PAG sponsored operations are minor relative to dredging activities planned by the Navy.

Within Apra Harbor, the PAG has identified an area adjacent to F-7 Wharf that may require construction dredging. However, formal plans for development do not currently exist. Where no plans have been formalized by the PAG for construction or maintenance dredging at Commercial Port, this report conservatively assumes approximately 125,000 cy (95,569 m^3) of sediment will be dredged as part of both construction and maintenance dredging operations at Commercial Port within the next 30 years. This estimate suggests dredged material volumes generated as part of PAG sponsored operations are minor relative to dredging activities planned by the Navy.

Table 2-4. Port Authority of Guam Estimated Future Dredging Needs, Guam

Type	Year	Dredged Volume (cy)	Average Yearly Dredged Volume 2006 – 2036 (cy)
Construction	Unscheduled (Merizo)	77,200	
	Unscheduled (CommPort)	125,000	
	Subtotal	**202,200**	**6,700**
Maintenance	Unscheduled (Marinas)	25,000	
	Unscheduled (CommPort)	125,000	
	Subtotal	**150,000**	**5,000**
Construction and Maintenance	**Total**	**352,200**	**11,700**

2.3 Need for Ocean Disposal

The volume of dredged material expected to be generated around Guam over the next 30 years by the Navy and PAG far exceeds the ability of each entity to stockpile or beneficially use the material. Several confined disposal facilities have been constructed or are planned to be constructed for the placement of dredged materials generated in 2003 from maintenance dredging projects and for dredged materials to be generated between FY06 and FY09 from construction dredging projects. Numerous projects have been identified that would be available for the beneficial use of dredged material. However, considering these placement options, an ODMDS is still required to meet the needs of the Navy and PAG. Table 2-5 summarizes the future dredging needs on Guam and potential management options.

The two CDFs constructed in 2003 are located at the Ship Repair Facility (SRF) and Orote Airfield. The SRF CDF was constructed to manage 10,600 cy (8,104 m^3) of dredged material and the Orote Airfield CDF was constructed to manage 71,900 cy (54,971 m^3) of dredged material. Three separate locations were recommended for placement of additional CDFs to manage dredged material generated from construction dredging between FY06 and FY09, including two vacant fields within the Apra Harbor Naval Complex identified as Field 3 and Field 5 in the Phase I Dredged Material Management Plan (DMMP) as well as vacant fields located near Commercial Port (MEC 2005). For simplicity, this study assumes Field 5 is the preferred and only alternative. Field 5 would be constructed to manage approximately 765,000 cy (584,884 m^3) of dredged material. Combined, SRF, Orote Airfield and Field 5 CDFs would manage approximately 847,500 cy (647,960 m^3) of dredged material at any one time. Assuming an average drying time of approximately 5 years for each CDF and 100% of the dewatered material is reclaimed for beneficial use at the end of each drying cycle, approximately 5,085,000 cy (3,887,761 m^3) can potentially be managed in the existing and planned CDFs during the 30-year projected time frame.

Beneficial use projects identified in the Phase I DMMP include construction of ordnance magazines at Ordnance Annex and Orote Peninsula, daily cover at the Public Works Center (PWC) Landfill, structural fill for the expansion of Commercial Port and Bravo Wharf. Beneficial use of dredged material as structural fill at the Commercial Port would utilize the most dredged material. As part of the PAG’s proposed expansion of the Commercial Port, the

Port Authority anticipates the need for approximately 1,500,000 cy (1,146,832 m^3) of dredge material fill. Approximately 1,000,000 cy (764,555 m^3) of this material is required for structural fill in the construction of deep water wharves and 500,000 cy (382,277 m^3) is required for structural fill behind proposed revetments. Approximately 367,200 cy (273,099 m^3) of dredged material may be used as daily cover at PWC Landfill (20,400 cy [15,597 m^3]/year for the next 18 years). Approximately 149,800 cy (114,530 m^3) of dredged material may be beneficially used in the construction of ordnance magazines and 10,700 cy (8,181 m^3) of dredged material may be beneficially used as structural fill at Bravo Wharf.

The three CDFs may be converted to either upland habitat or recreational park as additional beneficial use projects at the end of the 30 year planning period. Conversion of these CDFs to upland habitat or recreational projects would provide an additional capacity of 847,500 cy (647,960 m^3) for the management of dewatered dredged material.

Assuming all of these projects are online for the placement of dewatered material and the dewatered material meets all applicable water quality standards, soil quality standards and geotechnical properties, beneficial use projects could account for the placement of approximately 2,875,200 cy (2,198,248 m^3) of dewatered material (see discussion below). Beneficial use projects alone do not provide enough capacity for the management of dewatered material. Of the 5,085,000 cy (3,887,761 m^3) of dewatered dredged material managed in CDFs, only 2,875,200 cy (2,198,248 m^3) could be placed in beneficial use projects, leaving an estimated 2,209,800 cy (1,689,513 m^3) of dewatered material that would need to be stockpiled.

The placement of dredged material into existing and proposed CDFs in conjunction with beneficial use options does not satisfy the purpose and need of the Navy or PAG. As much as an estimated 8,884,700 cy (6,792,841 m^3) of material will be dredged as part of construction and maintenance dredging projects from Apra Harbor and Guam's small boat marinas over the next 30 years. Of this quantity, approximately 10% or 888,500 cy (679,307 m^3) may be considered unsuitable for ocean disposal due to elevated levels of contaminants (National Research Council [NRC] 1997). Utilizing dewatered dredged material in beneficial use projects will only account for a maximum of 2,875,200 cy (2,198,248 m^3) of material. Therefore, as much as an estimated 5,121,000 cy (3,915,285 m^3) of dredged material, suitable for ocean disposal, still needs to be managed. Final designation of an ODMDS is the most feasible disposal option for the dredged material remaining to be managed.

Table 2-5. Summary of Future Dredging Needs and Management Options

Type	Source (+) / Sink (-)	Dredged Volume (cy)	Average Yearly Dredged Volume 2006 – 2036 (cy)
Dredged Material Sources (+)			
Construction	Navy	5,700,000	
	PAG	202,200	
Maintenance	Navy	432,500 - 2,832,500	
	PAG	150,000	
	Subtotal	**6,484,700 - 8,884,700**	**216,200 - 296,200**
Estimated Volume (10%) Unsuitable for Ocean Disposal		648,500 – 888,500	
	Subtotal	**5,836,200 – 7,996,200**	**194,500 – 266,500**
Potential Dredged Material Management Options (-)			
Beneficial Use	Various Sites	-2,027,700	
CDF Conversion	SRF, Orote Airfield, Field 5	-847,500	
	Subtotal	**-2,875,200**	**-95,800**
Remaining Dredged Material Requiring Management and Suitable for Ocean Disposal			
	Total	**+ 2,961,000 to +5,121,000**	**+98,700 to +170,700**

3.0 AREAS EXCLUDED FROM OCEAN DREDGED MATERIAL DISPOSAL SITE DESIGNATION

Apra Harbor, Agana Boat Basin and Agat Marina are located on the western side of Guam. There are no deep draft or small boat harbors located on the eastern side of Guam. It is reasonable to assume that the future dredging needs of Navy and PAG will be located on the western side of the island. This study will present areas to be excluded for all of Guam, but will focus on those areas located on the western side of the island, where the potential siting of an ODMDS is most likely.

3.1 Navigation Lanes and Hazards

There are numerous navigational restrictions in Apra Harbor with a few extending beyond Apra Harbor into the Philippine Sea. These include a regulated navigation area (RNA), safety zone, danger area and submerged submarine operating area. Due to the extreme water depths immediately outside Outer Apra Harbor (e.g. >600 ft [>183 m]), there are no anchorages designated in the Philippine Sea for vessels in the vicinity of Guam.

RNAs are defined zones for which established regulations apply to the navigation of vessels within that zone. The regulations are designed to preserve the safety of waterfront infrastructure, guarantee safe transit of vessels and protect the marine environment. In Apra Harbor, two RNAs have been established (33 CFR 165.1402 and 33 CFR 165.1405) for the entire harbor and extend offshore from the entrance to Outer Apra Harbor approximately 2 nautical miles (nm; 3.7 km). Alpha Hotel Pilot Station (13 26’ 52”N, 144 35’16”E) is located approximately 2 mi (3.2 km) west of Orote Point (Figure 3-1). Vessels greater than 300 gross tons and all vessels entering the Apra Harbor for the first time and/or after daylight hours are required to approach Alpha Hotel Pilot Station and acquire a certified pilot (GovGuam 2004).

A safety zone is a water and/or shore area where access is limited to authorized persons, vehicles or vessels for safety or environmental purposes (33 CFR 165.20). Several safety zones have been established in Outer Apra Harbor, but only one safety zone extends into the Philippine Sea. Safety Zone A has a radius of 2175 ft (663 m) originating from Wharf H (13 27' 47"N, 144 39' 01.9"E; Figure 3-1).

A danger area is a water area used for target practice, bombing, rocket firing or other hazardous operations typically conducted by the armed forces (33 CRF 334.2). Along the southwest shore of Orote Peninsula, an intermittently used small arms firing range (danger zone) has been established for Navy operations (Figure 3-1) and extends approximately 1.9 mi (3.1 km) offshore (33 CFR 334.1420). A second firing danger area is identified on the National Oceanographic & Atmospheric Administration [NOAA] Nautical Chart 81048 (2003) and encompasses a large area offshore of the southwest portion of Guam (Figure 3-1).

A submerged submarine operating area is located offshore of Guam. Within this area, submarines may be submerged and surface vessels should proceed with caution. Nearly the entire island of Guam is encompassed by submerged submarine operating area (SS-2) (Figure 3-1). The area is bounded between the shoreline and a line beginning at Orote Point, extending west approximately 8.6 nm (15.9 km), continuing south for 16.6 nm (30.7 km), then easterly for 31.4 nm (58.1 km), turning north for 30.0 nm (55.6 km) and finally west for 8.3 nm (15.4 km) before turning south for 0.8 nm (1.5 km) to end at Ritidian Point (NOAA 2003).

Five surface ship safety lanes (shipping lanes) have been identified for commercial ship traffic approaching Guam (Figure 3-1). One lane approaches from the southwest and another approaches Apra Harbor directly from the west. Three lanes approach from the north, one each from the northwest, north and northeast.

3.2 Government of Guam Jurisdictional Areas

The Submerged Lands Act enacted in 1953 gave coastal states jurisdiction over coastal waters to a distance of 3 nm (5.6 km) from 0 MLLW along the coast. Ensuing legislation also granted several Territories of the United States, including Guam, jurisdiction to 3 nm (5.6 km) (Figure 3-2).

The GEPA developed water quality standards regulating activities within territorial waters that may negatively impact water quality for the protection of human health and the environment and for domestic, agricultural, commercial, industrial, recreational and other uses. Further, the policy states that it is Guam's goal to eliminate the discharge of pollutants into Guam's waters (GEPA 2001). Section 5103 Part A (1) (b) specifies that all waters shall be free from substances and conditions resulting from anthropogenic discharges that may produce visible turbidity, settle to form deposits or otherwise adversely affect aquatic life.

All territorial waters around Guam have been designated either Category M1 or M2 status (Figure 3-2). Category M1 waters are defined to "remain substantially free from pollution attributed to domestic, commercial and industrial discharges, shipping and boating, or mariculture, construction and other activities which can reduce the waters' quality. Category M2 waters "must be of sufficient quality to allow for the propagation and survival of marine organisms, particularly shellfish and other similarly harvested aquatic organisms, corals and other reef-related resources, and whole body contact recreation. Important and intended uses include mariculture activities, aesthetic enjoyment and related activities" (GEPA 2001).

3.3 Marine Protected Areas

Marine Protected Areas (MPAs) consist of any marine environment that has been reserved by Federal, State, territorial, tribal or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein (Federal Register 2000). In Guam, there are numerous ecological reserve areas (ERAs), marine preserves and a territorial seashore park that need to be eliminated from consideration in the ZSF.

3.3.1 Ecological Reserve Areas

ERAs are regions in which current natural conditions, such as unique biological and physical features, are preserved. In 1984, two ERAs were established by the Navy as a mitigation measure for the construction of Kilo Wharf. These were the Orote Peninsula ERA and the Haputo ERA.

The Orote Peninsula ERA is located along the southwestern shore of Orote Peninsula, extending from Orote Point to Agat Bay. The Orote Peninsula ERA includes terrestrial lands from the 0 MLLW line to the upper edge of the cliffs and aquatic lands from the shoreline to a depth of -120 ft (-36.5 m) MLLW offshore (Figure 3-3). The submerged portion of the Orote Peninsula ERA contains pristine coral communities (NAVFAC/PAC 1986).

The Haputo ERA is located along the northwestern shore of Guam on the Naval Computer and Telecommunications Station (NCTS) property, from Haputo Beach north to and including Double Reef (Pugua Patch Reef). The Haputo ERA includes terrestrial lands from the 0 MLLW line to the upper edge of the cliffs and aquatic lands from the shoreline to a depth of -120 ft (-36.5m) MLLW offshore (Figure 3-3). Double Reef supports highly diversified coral and cryptofauna communities (Amesbury et al. No Date).

3.3.2 Marine Preserves

Marine preserves are areas in which activities such as fishing or other taking of aquatic animals and habitat are restricted or prohibited altogether in order to restore the reef fish community. In 1997, five marine preserves were designated in Guam. These include Pati Point, Tumon Bay, Piti Bomb Holes, Sasa Bay and Achang Reef Flat (Division of Aquatic and Wildlife Resources [DAWR] 2006). All of the preserves extend offshore to a depth of -600 ft (-183 m) MLLW and inshore 33 ft (10 m) from the mean high tide mark or along the nearest public right-of-way, whichever comes first.

Pati Point Marine Preserve contains approximately 4,900 a (1,980 ha) of reef environment. It is located on the northeastern tip of Guam, extending from Mergagan Point in the north to Anao Point in the south (Figure 3-3). Pati Point Marine Preserve has narrow reef flats and steep fore reef slopes containing a diverse coral community and the beaches in the preserve are vital green sea turtle habitat (DAWR 2005).

Tumon Bay Marine Preserve is centrally located on the western side of Guam and comprises 1,117 a (450 ha). It extends from Amantes Point (Two Lovers Point) in the north to Ypao Point (Hospital Point) in the south (Figure 3-3). Tumon Bay Marine Preserve consists of a broad reef flat, gently sloping fore reef and a broad bank/shelf habitat (DAWR 2005).

Piti Bomb Holes Marine Preserve is also centrally located on the western side of Guam, approximately 6 mi (9 km) south of Tumon Bay Marine Preserve (Figure 3-3). Extending from Asan Point to the outlet channel from the Cabras power plant, Piti Bomb Holes Marine Preserve comprises 896 a (363 ha) of broad reef flat and fore reef slope. Within the reef flat, "bomb holes", or sinkholes, extend up to 32 ft (10 m) deep MLLW and are populated with hard and soft corals and unique fish and invertebrate communities (DAWR 2005).

Sasa Bay Marine Preserve is located inside Outer Apra Harbor, on the eastern side between Dry Dock Island to the north and Polaris Point to the south (Figure 3-3). Sasa Bay Marine Preserve comprises 770 a (312 ha) and includes the largest mangrove stand in the Marianas. Although the coral habitat is degraded due to elevated sedimentation loads from Sasa and Aguada Rivers, the preserve provides foraging habitat for green and hawksbill sea turtles (DAWR 2005).

Achang Reef Flat Marine Preserve is located at the southern tip of the Guam and contains approximately 1,200 a (485 ha) of mangrove, seagrass, coral, sand and channel habitat. Achang Reef Flat Marine Preserve extends from Ajayan Channel in the east to Achang Bay to the west (Figure 3-3). The seagrass beds provide foraging habitat for green sea turtles (DAWR 2005).

3.3.3 Territorial Seashore Reserve

In 1974, the GovGuam established the Guam Territorial Seashore Protection Act. This Act established the Guam Territorial Seashore Reserve in order to promote public safety, health and welfare and to protect public and private property, wildlife, marine life, other ocean resources and the natural environment (GovGuam 2003). The Guam Territorial Seashore Reserve includes all land and waters of Guam extending seaward to the -60 ft (-18 m) MLLW contour and inshore 33 ft (10 m) from the mean high tide mark or along the nearest public right-of-way, whichever comes first. Cabras Island and villages constructed along the shoreline prior to the establishment of the Act are excluded.

3.4 Parks

The War in the Pacific National Historic Park (WAPA) was established in 1978 as a memorial to those participating in the World War II Pacific theater campaigns. The WAPA is centrally located on the west side of Guam consisting of seven separate sites significant to the 1944 invasion and recapture of Guam. Of these seven sites, two sites, Asan Beach and Agat Beach include waters of the Philippine Sea (Figure 3-4). The Asan Beach site extends along the shoreline from just west of Asan Point east to Adelup Point. The Agat Beach site extends along the shoreline from Apaca Point in the north to just south of Agat Village. The WAPA boundaries extend approximately 0.5 mi (0.8 km) offshore to water depths of approximately 60 ft (18 m; National Park Service 2004).

3.5 Ocean Outfalls

Several wastewater treatment plants (WTPs) provide secondary treatment of wastewater, which is discharged to either the Philippine Sea or Pacific Ocean. These WTPs include the Agat-Santa Rita WTP, Apra Harbor WTP, Agana Bay WTP and the Northern District WTP.

Effluent from the Agat-Santa Rita WTP and Apra Harbor WTP is discharged through the Tipalao outfall to Tipalao Bay in the Philippine Sea. The terminus of the outfall is located at 13 24' 48"N, 144 38' 30"E. Effluent from the Agana Bay WTP is discharged from an outfall located offshore of Marine Drive, Agana, Guam. Its terminus is located at 13 29' 3.3"N, 144 44' 37.1". Effluent from the Northern District WTP is discharged through an outfall located offshore of Dededo, Guam, having a terminus at 13 33' 7.36"N, 144 48' 24.03"E (Figure 3-5).

The Umatak-Merizon WTP and Yona Baza Gardens WTP discharge to inland waters that ultimately discharge to the Philippine Sea or Pacific Ocean. The outfall location for the Umatak-Merizon WTP and Yona Baza Gardens WTP would not constrain the selection of a potential ODMDS.

Unitek Environmental – Guam discharges treated effluent from an portable oily water and ship bilge wastewater treatment unit through three separate outfalls. Each outfall discharges to receiving waters within Apra Harbor. The outfall locations for Unitek Environmental – Guam would not constrain the selection of a potential ODMDS.

The University of Guam Marine Laboratory discharges aquaria circulation water effluent from its seawater system to Pago Bay, tributary to the Pacific Ocean.

3.6 Oil and Mineral Extraction Installations

There are no oil or other mineral extraction platforms and pipelines offshore of Guam.

3.7 Fishing Areas

There are three distinct types of fisheries offshore of Guam: pelagic, reef fish and bottomfish. The pelagic fishery occurs throughout surface waters around Guam and reef fish fishery occurs across many of the reefs and shoreline of Guam. The bottomfish fishery is divided into shallow water and deep water zones. The shallow water zone occurs between -100 to -500 ft (-30 to -154 m) MLLW. The deep water zone occurs between -500 to -700 ft (-154 to -213 m) MLLW. The -700 ft (-213m) depth contour typically occurs within 1 nm (1.9 km) of shore. Recreational and small-scale commercial fishermen predominantly fish the shallow water bottomfish community (NOAA 2006) and in the vicinity of fish aggregation devices (FADs; Figure 3-6) located mostly between two and six miles offshore (Hall 2006). Fish distributions of shallow (0-50 m) schooling fish and intermediate (50-100 m) and deep (100-500 m) scattered fish have been documented to increase as far as 0.2 nm (0.4 km), 0.4 nm (0.7 km) and 0.8 nm (1.5 km), respectively, from FADs (Josse et al. 2000). The FADs illustrated in Figure 3-6 represent an area having a radius of approximately 0.8 nm (1.5 km).

3.7.1 Commercial Fishing

Large-scale commercial fishing by water purse seiners and longliners is conducted beyond Guam's EEZ. There is a longline fishing prohibited area around Guam (50 CFR 660.26).

3.7.2 Recreational Fishing

Recreational deep sea fishing, including charters, around Guam occurs year round. Charter boats are typically bound by a half-day range (approximately 4 hours) that enables their clients to fish shoals between Guam and Rota, known as the Rota Bank (Figure 3-6; Watson 2006). In this area, water depths decrease to approximately 120 ft (37 m). Much of the local fishing community is surface trolling, but there is some bottom fishing. Most of these local fishermen stay within 10 mi (16.1 km) of shore, primarily on the western side of the Guam. The Galvez Bank (Figure 3-6) and Santa Rosa Reef are approximately 14 nm (26 km) and 30 nm (55.6 km) southwest of the southern tip of Guam, respectively. Local fishermen also frequent these southern banks (Watson 2006).

3.8 Visual Resources

Another consideration for placement of a potential ODMDS are negative impacts to the visual resources. Although not defined by a specific boundary, consideration should be give to those areas having the least impact to visual resources. The primary concern of impacts to visual resources is from tourists enjoying the beaches and attractions around Tumon Bay. Tumon Bay is the main tourist destination in Guam, lined with white sand beaches and major resort hotels. Just north of Tumon Bay, Two Lovers Point is the one of the most popular tourist attractions on Guam. Viewpoints at Two Lovers Point are approximately 400 ft (122 m) above the Philippine Sea.

Line of sight to the horizon calculations were developed for the average person standing at the water's edge in Tumon Bay and for an individual standing at Two Lovers Point. Persons standing at the waters edge can see a 20 ft (6 m) high tug and dump scow approximately 7.9 nm (14.6 km) away. Figure 3-7 illustrates the line of sight from Tumon Bay, with the greatest impact to visual resources closer to shore and decreasing with increased distance from shore. Persons standing at Two Lovers Point can see a 20 ft (6 m) high tug and dump scow approximately 28.6 nm (53.0 km) away. Although the higher elevation affords the casual observer with an increased viewing distance, impacts should not be any different than those from normal shipping traffic already occurring through this area.

3.9 Continental Shelf Considerations

The oceanic island of Guam is volcanic in origin and is not a part of any continental land mass. As such, Guam does not have a continental shelf. However, for the purposes of this study, the general definition of a continental shelf will be applied to Guam. In the absence of a shelf break, this area includes all submerged land between the shoreline and a depth of 656 ft (200 m). On Guam, this depth typically occurs within 1 nm (1.9 km) of shore. Water depths over the outer slope increase rapidly offshore of Guam; depths reach 6,000 ft (1,829 m) within 3 nm (5.6 km) of the entrance to Outer Apra Harbor.

3.10 Zone of Siting Feasibility

Figure 3-8 illustrates all the eliminated areas due to navigational lanes and hazards, GovGuam jurisdictional boundaries, marine protected areas, parks, ocean outfalls, fishing areas, visual resources and continental shelf considerations. The remaining areas are considered for placement of an ODMDS. Due to the rapidly increasing project depths, many of the eliminated areas are contained within the GovGuam jurisdictional boundary. For example, the marine preserves extend to a depth of -600 ft (-183 m) MLLW, which occurs within 1 nm (1.9 km) of shore and within the GovGuam jurisdictional boundary. The following Sections will further constrain the available area due to operational and economic factors.

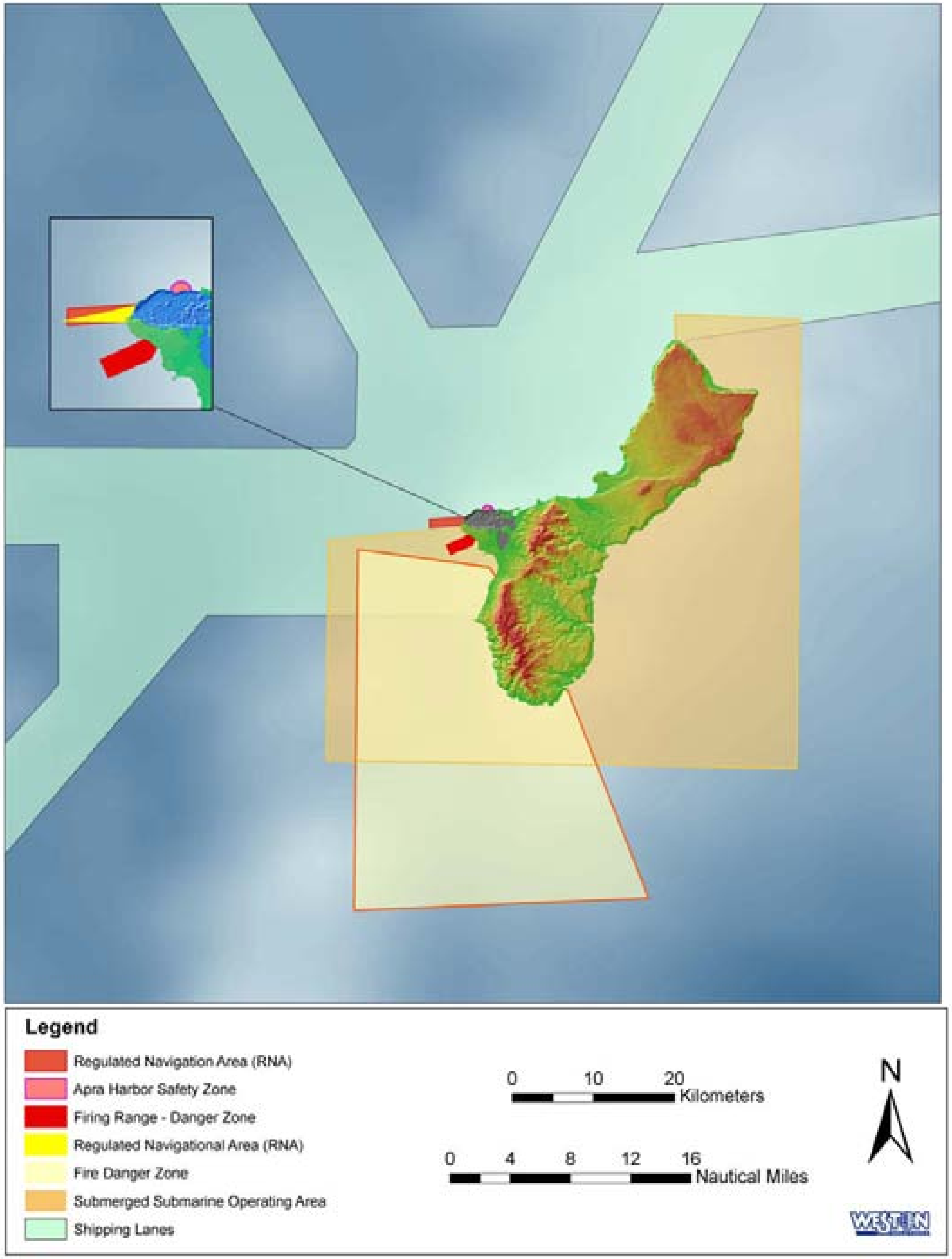

Figure 3-1. ZSF Eliminated Area - Navigational Lanes and Hazards

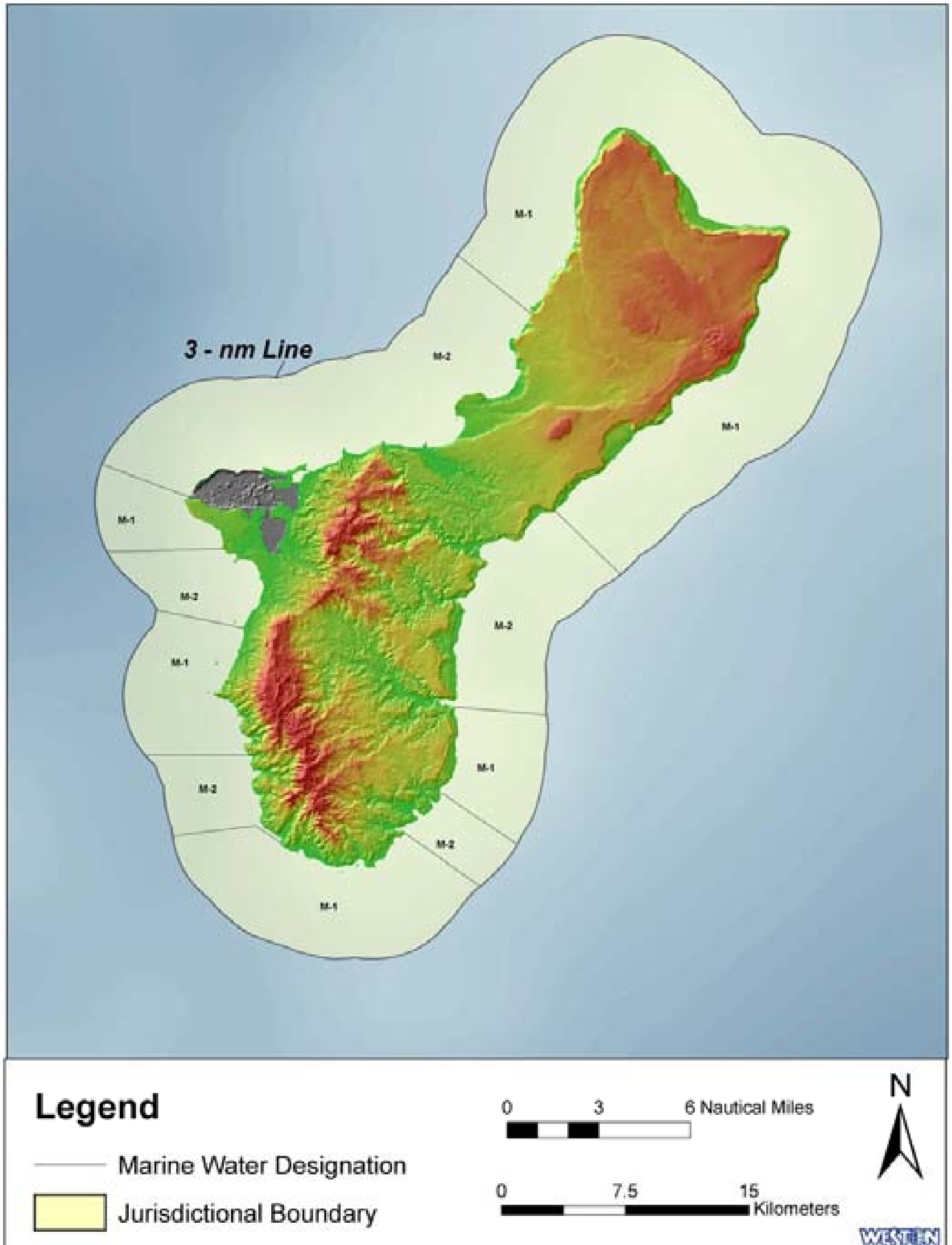

Figure 3-2. ZSF Eliminated Area - Government of Guam Jurisdictional Areas

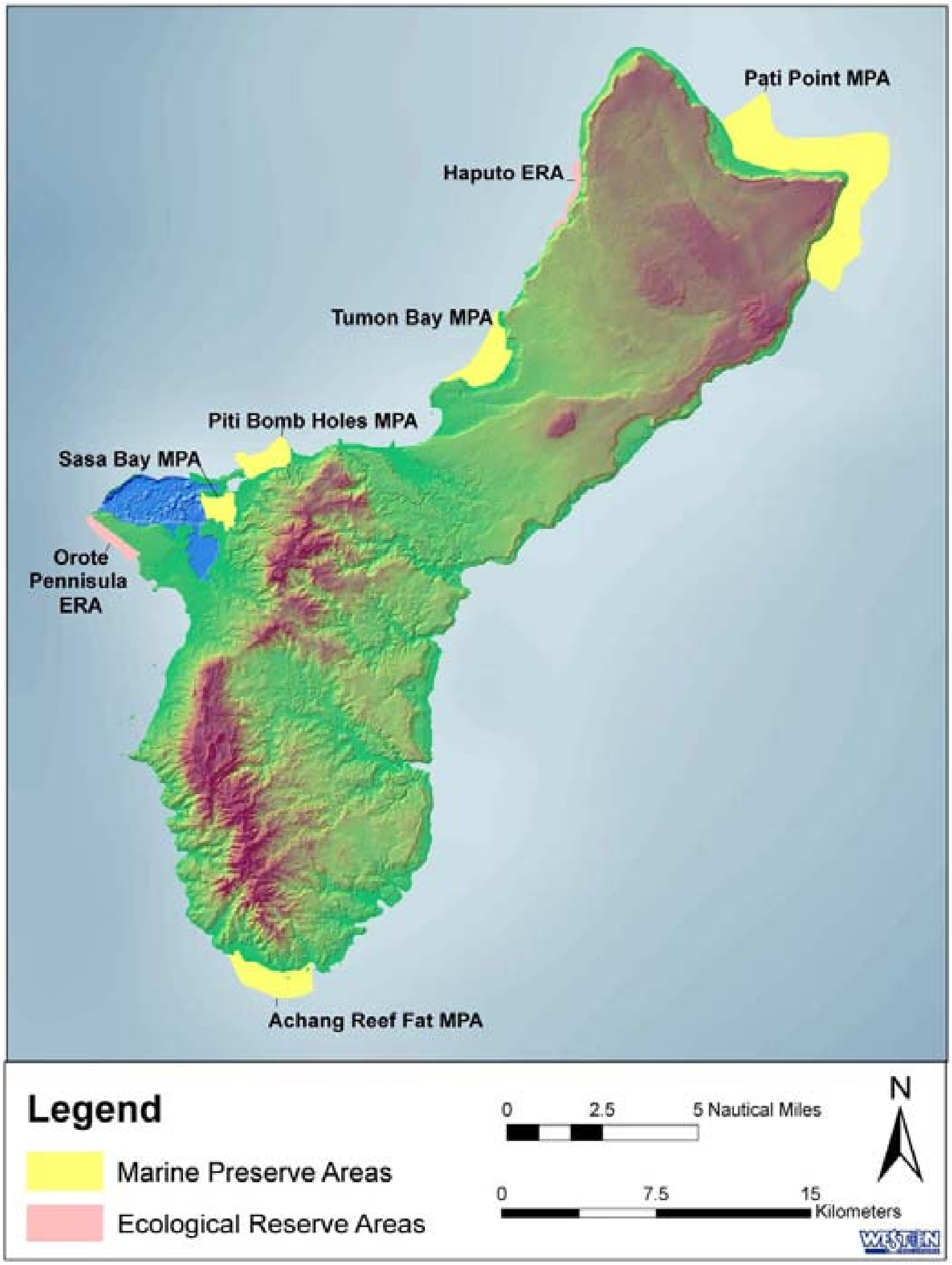

Figure 3-3. ZSF Eliminated Area - Marine Protected Areas

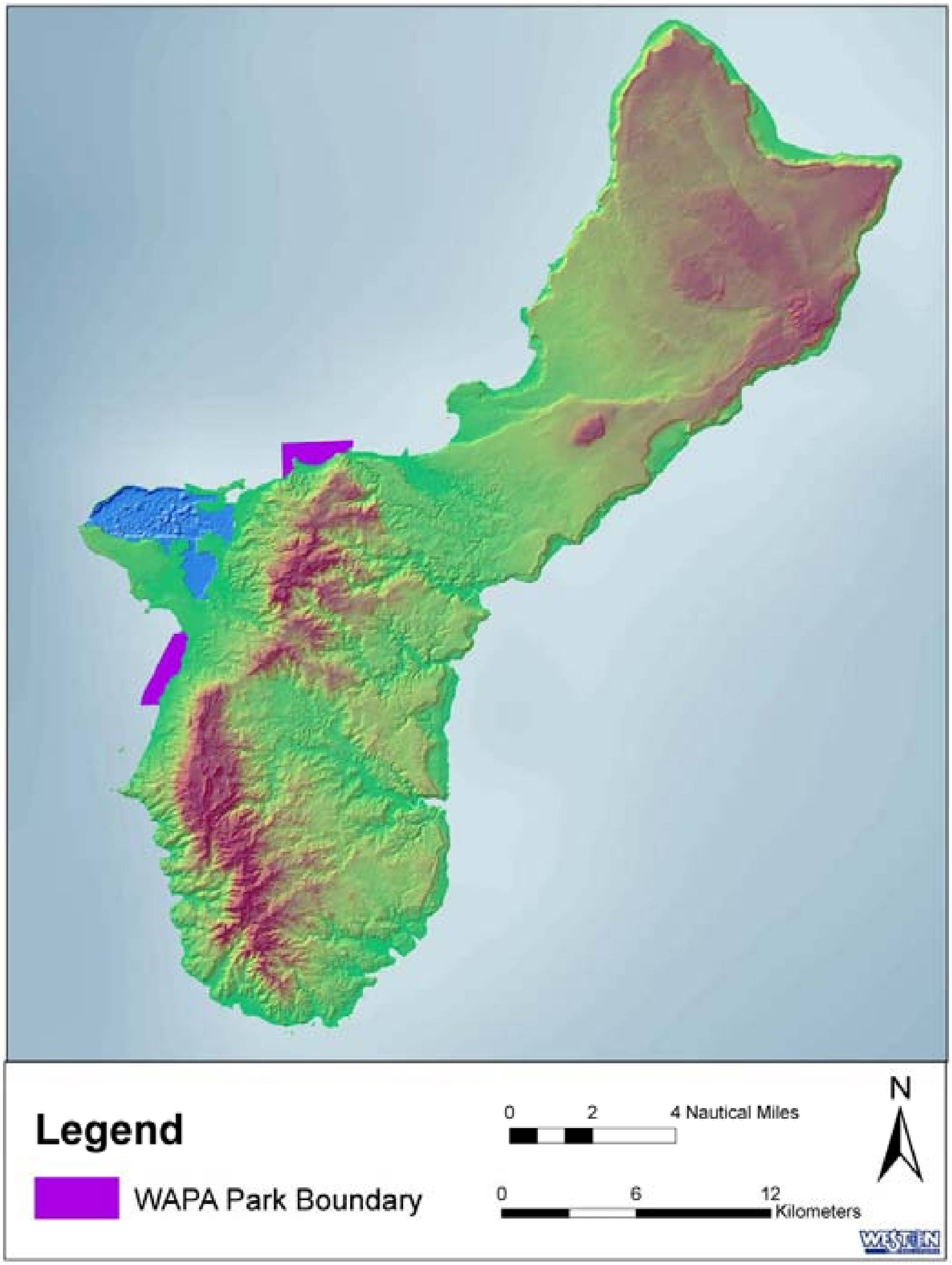

Figure 3-4. ZSF Eliminated Area - Parks

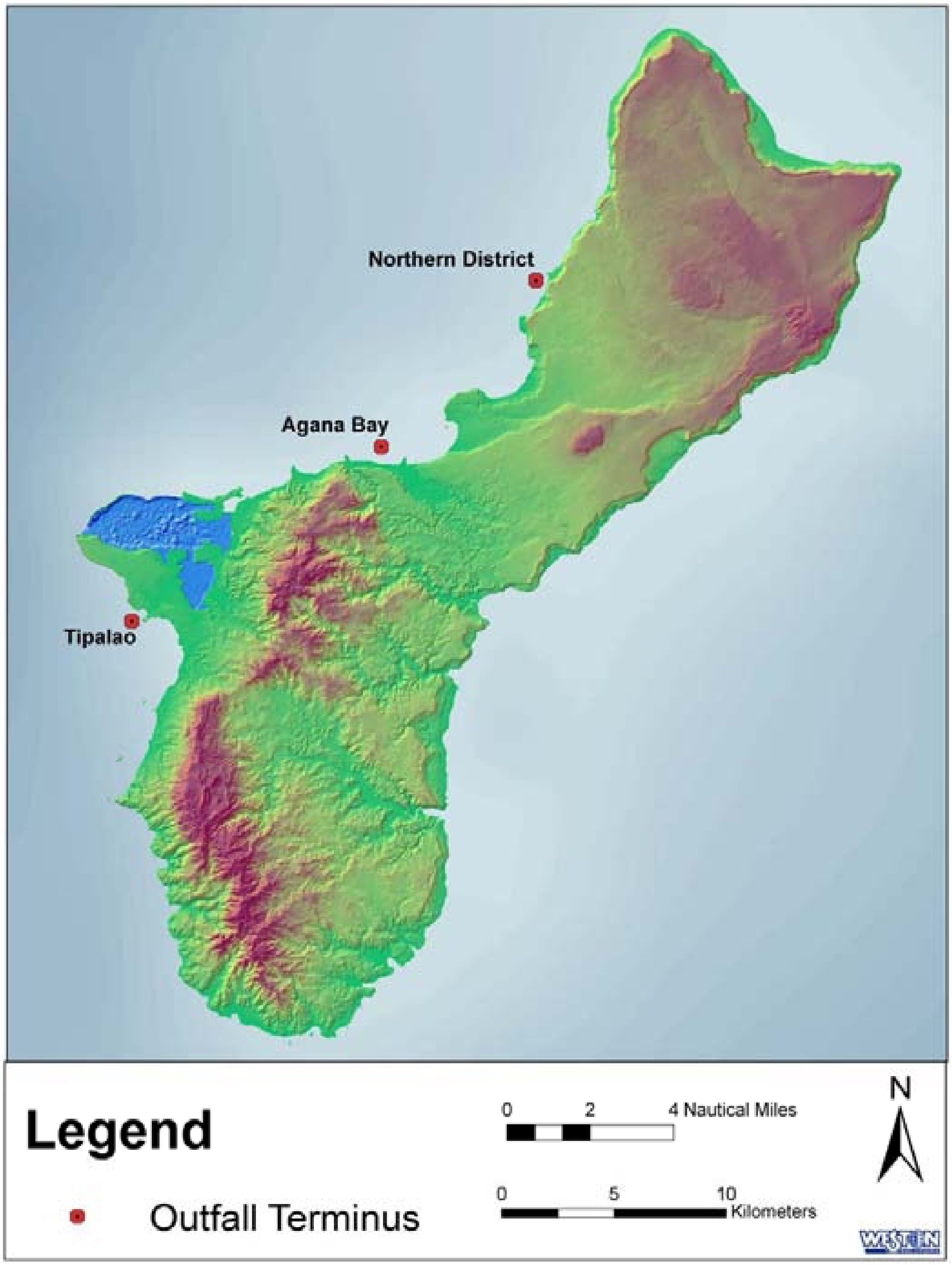

Figure 3-5. ZSF Eliminated Area - Ocean Outfalls

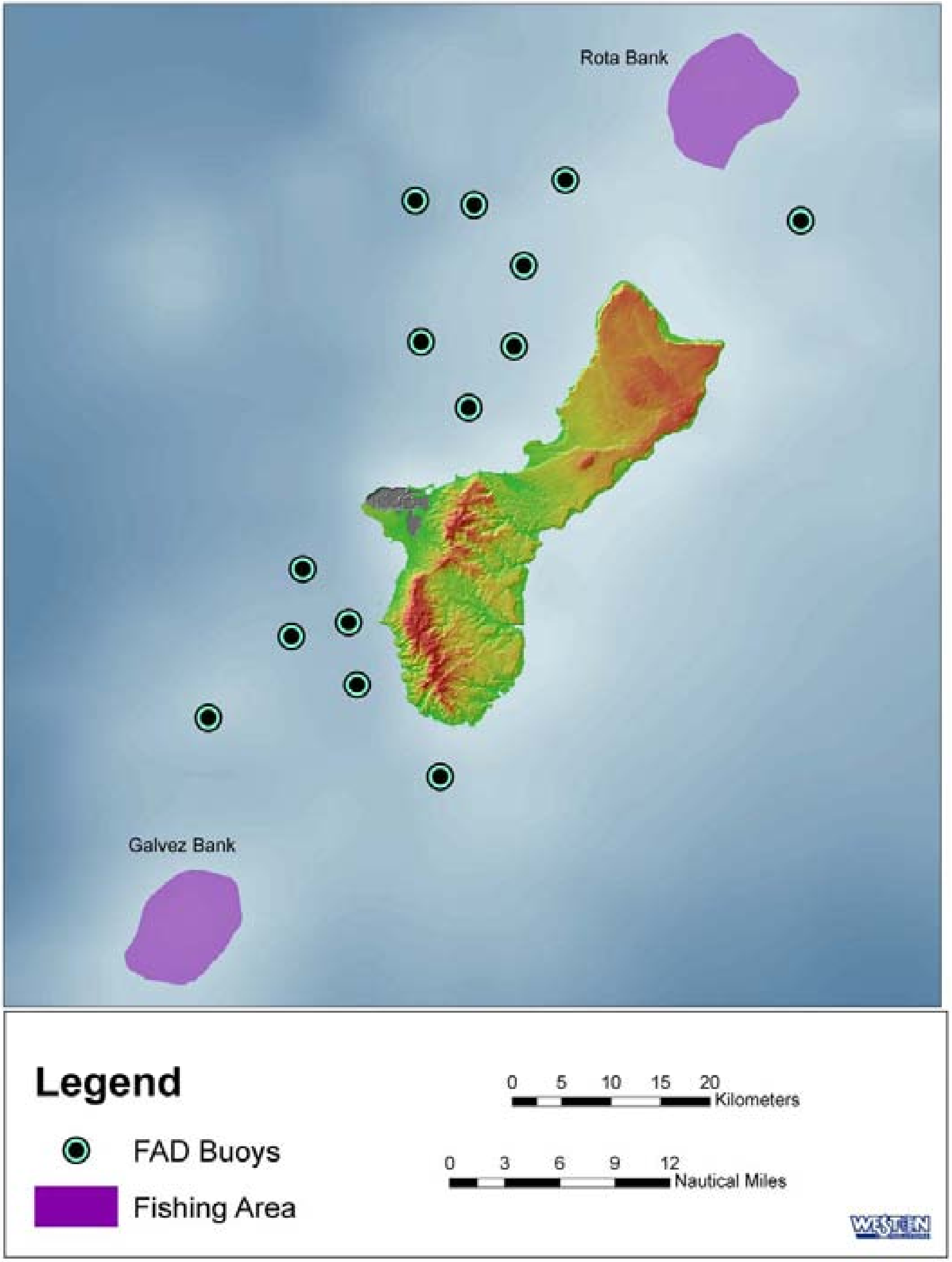

Figure 3-6. ZSF Eliminated Area - Fishing Areas

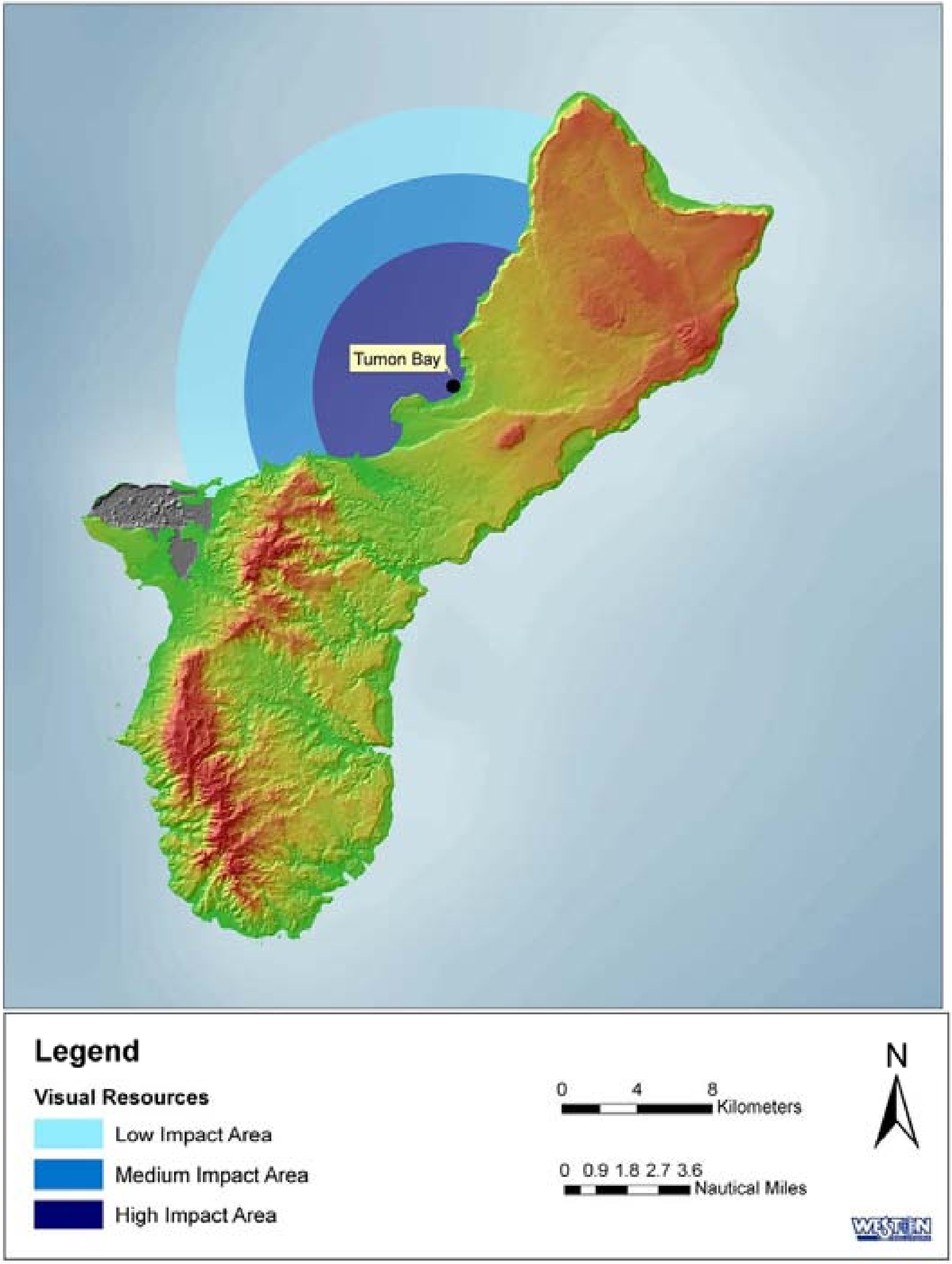

Figure 3-7. ZSF Eliminated Area - Visual Resources

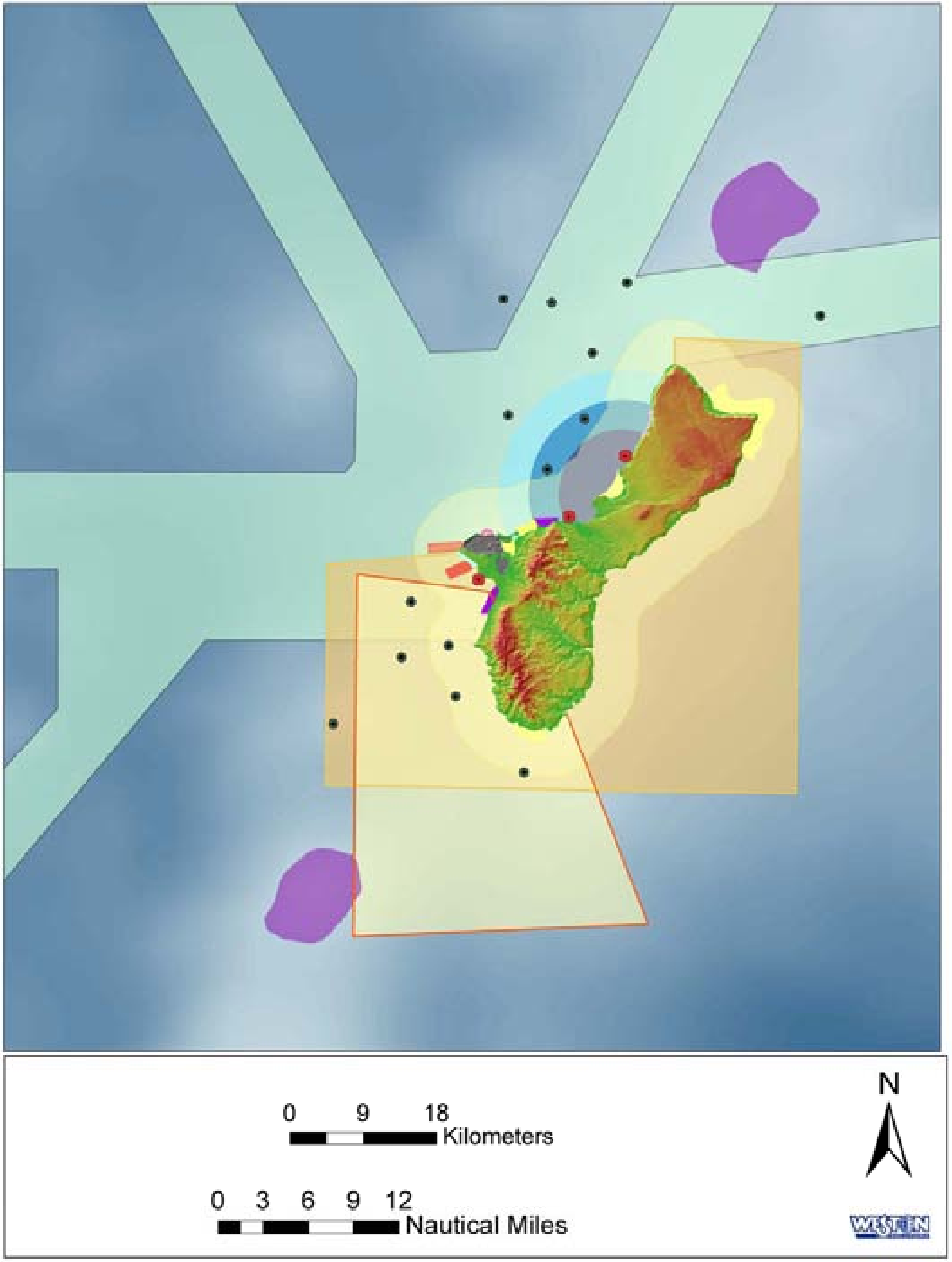

Figure 3-8. Combined ZSF Eliminated Areas

4.0 OPERATIONAL CONSIDERATIONS

4.1 Dredging Methods

There are two categories of dredging operations: mechanical and hydraulic dredging. These two types of dredging techniques vary according to the method used to loosen the material from its *in-situ* state and transport the material from the seafloor to the water surface.

4.1.1 Mechanical (Clamshell or Bucket Dredge)

Mechanical dredging excavates *in-situ* sediments with a grab or bucket. One of the most common types of mechanical dredges is the clamshell dredge, which is named for the type of bucket used in the operation and shown in Figure 4-1. Typically, a large barge is loaded with the bucket dredge and transported to the dredging site with tugs. The barge is then secured in place with spuds. The dredging process consists of lowering the bucket to the seafloor, closing the bucket and raising it back to the water surface, and depositing the dredged material into a scow or, if appropriate, directly into an adjoining land placement site. The efficiency and capacity of this type of dredging is determined by the capacity of the bucket, which varies between 1.5 and 25 cy (1 and 20 m^3), scow capacity, which typically varies from 130 to 3,300 cy (100 to 2,523 m^3; European Union Dredging Association, 2003), and the number of available scows.

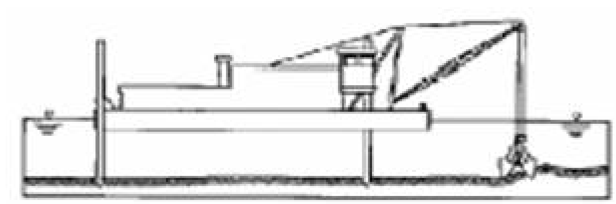

Figure 4-1. Schematic of a Mechanical Dredge (Source: USEPA 1992)

Mechanical dredges operate best in consolidated, hard packed material since dredging buckets have difficulty retaining the loose, fine material that is often washed away as the bucket is raised. Generally, mechanically dredged material consists of 20% slurry (Herbich 2000). Depending on scow characteristics, excess water drains off at the dredging site reducing the water content of the dredged material to approximately 10%.

Mechanical dredges are often used in tightly confined areas, such as harbors, around docks and piers, and in relatively protected channels. This type of dredge is not suitable for rough seas or areas of high vessel traffic. By using numerous scows with one dredge, mechanical dredging can proceed continuously. As one scow is being filled, another can be towed to the placement site.

In Phase I of the Guam DMMP, mechanical dredging was the recommended dredging method for future maintenance and construction projects conducted by the Navy and has been used in past Guam dredging projects around Apra Harbor (MEC-Weston 2005). Mechanical dredging would also be best suited for use in small-scale maintenance dredging projects in Guam's shallow water recreational and small commercial boat marinas.

4.1.2 Hydraulic

In hydraulic dredging, material is loosened from its *in-situ* state and lifted in suspension through a pipe system connected to a centrifugal pump. Hydraulic dredging is most efficient when working with fine materials and sands since they are easily held in suspension. Coarser materials, including gravel, may be hydraulically dredged; however, these materials require a greater demand of pump power and can cause excessive wear on pumps and pipes. The two main types of hydraulic dredges are pipeline and hopper dredges.

4.1.2.1 Hopper Dredge

Hopper dredges have the shape of a conventional ship hull and are equipped with either single or twin trailing suction pipes, as shown in Figure 4-2. A hopper dredge operates much like a floating vacuum cleaner in that material is lifted through the trailing suction pipes by one or more pumps and then the mixture of water and solids is stored in a hopper contained within the hull of the dredger. A hopper dredge operates best by skimming layers of material in long, narrow runs and is primarily used in open water, such as rivers, canals, and open sea. This type of dredge is unable to get into corners (i.e. Inner Apra Harbor), difficult to maneuver in confined spaces, unsuitable for use in shallow water, and is not effective on hard materials such as stiff clays (i.e. Inner Apra Harbor). A hopper dredge can move quickly to a placement area under its own power, but the operation loses efficiency as the transport distance increases.

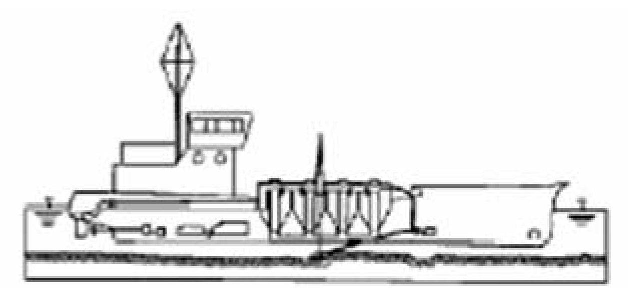

Figure 4-2. Schematic of a Hopper Dredge (Source: USEPA 1992)

Once the hopper is full, material may be discharged onto an open-water placement site by opening the hopper doors located in the bottom of the ship's hull or fluidized by jets and hydraulically pumped from the hopper. For bottom dumping, the entire contents of the hopper can be emptied in a matter of minutes. Upon discharge from the hopper dredge, the dredged material falls through the water column as a well-defined jet of high-density fluid. As with the pipeline dredge, the descent and deposition of the slurry mixture is dependent on the material's physical characteristics. Hydraulic pumpout can take up to 30-60 minutes and discharge slurry is similar in density to cutterhead slurry.

Hopper dredging is typically used as an alternative to hydraulic cutterhead dredging when bottom dumping or when a large distance between the dredge site and placement area precludes the use of a cutterhead dredge.

4.1.2.2 Cutterhead Dredge

A cutter suction dredge is a hydraulic dredge that uses a device consisting of rotating blades or teeth, called a cutterhead, to break up or loosen bottom material, as shown in Figure 4-3. A large centrifugal pump removes the material from the bottom of the channel and pumps the sediment-water slurry through a discharge pipeline to an upland disposal site or dump scow.

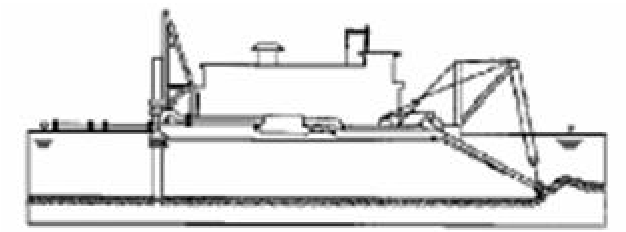

Figure 4-3. Schematic of a Cutterhead Dredge (Source: USEPA 1992)

Material dredged by a cutter suction dredge is most often directly placed into an upland placement area by the discharge pipeline. Dredged material may also be placed into a dump scow for disposal at sea or another location far removed from the dredging site. Cutter suction dredges operate continuously, and are cost effective if the placement site is in relative close proximity to the dredge area. However, because the pipeline is usually floated on the water surface, pipeline dredges are not suited for work in high traffic areas where they would pose an obstruction to navigation. They are also not recommended for areas with heavy debris that can clog pumps and impair efficiency. To avoid these problems, pipelines can be weighted to the seafloor, however this is can be problematic.

Construction dredging within Inner Apra Harbor with a cutter suction dredge is not the recommended method in the Guam DMMP due to the high volume of water and navigational constraints caused by the discharge line. The water content of hydraulically dredged material is much higher than that of mechanically dredged material. Production volume can range from four to six times the dredged volume (Navy 2003). Upland placement of this volume will require more space and ocean disposal by dump scows will require more trips than for mechanical dredging. In addition, the pipeline used in cutter suction dredging may impede naval operations and potentially affect safe navigation within Inner Apra Harbor.

4.2 Dredge Availability

This feasibility study assumes both hydraulic and mechanically based dredge plants would be available for maintenance and construction dredging projects. However, it should be noted, all of the maintenance dredging projects that have historically occurred on Guam used mechanical methods. This is likely a consequence of the relatively small dredge volumes generated during maintenance dredging projects and logistical constraints such as confined navigational areas. Currently, there are no hopper dredges based on Guam or elsewhere in the Mariana Islands. Planned construction projects by the Navy in Apra Harbor, though, would generate a relatively large dredge volume, which may warrant the mobilization of a hopper dredge to the site.

4.3 Environmental Factors

Mechanical dredges would be better adapted for potential dredge projects in Guam. Inner and Outer Apra Harbor, as well as the small boat marinas around Guam, have confined spaces around the wharves and docks that would constrain the efficacy of a hopper dredge. Further, hopper dredges are not as efficient in removing hard coral substrate or natural and anthropogenic debris.

Adverse weather and sea state would constrain both mechanical and hydraulic dredging operations. Guam is located in an area referred to as 'Typhoon Alley'. Typhoons can occur at any on Guam; however, they typically occur during the wet season months between July and October. High winds (sustained over 75 mph [121 kph]), heavy rains and storm surge are characteristic elements of typhoons.

4.4 Disposal Monitoring Considerations

The MPRSA, Section 102(c)(3)(B), specifies that site management plans include a program for monitoring the site. Site monitoring programs are an integral part of the site management process. Results of the monitoring program should be used to support management decisions and changes to the site management plan.

Monitoring programs are designed to ensure that disposal at the ODMDS does not result in unacceptable environmental impacts. Tiered monitoring approaches should be utilized to verify compliance with the site designation criteria, special management conditions and practices, and permits or other documents authorizing disposal at the site. Monitoring programs should be ecomomically and technically feasible, scientifically and statistically sound and be adaptive to site-specific requirements.

Disposal site monitoring, as defined by Title 40 CFR Part 228.09, is conducted to evaluate the impact of disposal activities on the marine environment by comparing monitoring results to baseline conditions. The LA-3 EIS (USEPA and USACE 2004) noted that potential impacts to transient resources (i.e., plankton, epifauna, fish, birds, mammals, threatened or endangered species) tend to be rated as Class III (adverse but insignificant or no anticipated impact; no mitigation measures necessary). Further, long-term dredged material monitoring conducted by USEPA and USACE has shown that monitoring of non-transient resources is more effective than monitoring of transient resources. Therefore, monitoring should focus on the identification of potential, unacceptable adverse impacts to the benthic community.

Automated monitoring systems, i.e. a black box, may be required on the tug and/or dump scow to ensure disposal operations are conducted at the ODMDS according to both the site monitoring plan as well as the site management plan.

5.0 ECONOMIC CONSIDERATIONS

An analysis of dredging costs for hydraulic (hopper dredge) and mechanical (clamshell with tug and dump scows) was conducted to determine a limiting distance offshore for which placement of an ODMDS may become economically infeasible. The variables used in estimating the dredging cost considered the volume of dredged material, duration of the dredging project, the production rate of the dredge plant and haul capacity of the hopper dredge or dump scows. Because production is constant for a particular dredge, transport distance to the disposal site is the factor that most significantly affects dredging costs.

This cost analysis uses a similar approach to that employed in the economic feasibility study for the LA-3 ZSF (USACE 2003). Local dredging costs in Guam were not readily available so unit costs for dredge and disposal equipment are based on unit costs provided in the LA-3 ZSF for equipment typically used in Los Angeles and Orange Counties, California. It should be noted that dredge operations in Guam will likely incur higher mobilization/demobilization costs than those conducted in the continental U.S. Again, due to the lack of available information for Guam, mobilization/demobilization costs used in this analysis are based on the LA-3 ZSF study. It is appropriate to apply the costs and approach developed by the USACE in the LA-3 ZSF to Guam because it assists in determining relative comparisons of dredge equipment and project types (construction vs. maintenance). Further, mobilization/ demobilization costs, although likely higher for Guam, should not factor into the costs associated with haul distances.

Several assumptions were made regarding the project size and production rates for equipment used in these cost analyses. Similar to the LA-3 ZSF study, the representative project dredge volumes used in this analysis are 1,000,000 cy (764,555 m^3) for construction dredging projects (scenario "a") and 200,000 cy (152,911 m^3) for regular maintenance dredging projects (scenario "b"). Scenario "a" assumes higher production rates, larger hauling capacities and faster travel speeds. Conversely, scenario "b" assumes lower production rates, smaller hauling capacities and slower travel speeds. Cost estimates were computed using both a hopper dredge and clamshell dredge for each scenario "a" and scenario "b".

Shutdown time for port operations or traffic and its effect on dredging production efficiency were considered and will likely vary depending on whether dredging occurs by the Navy or PAG. Project working hours anticipated may also vary between construction dredging projects and maintenance dredging projects. In this cost analysis, a non-stop work schedule (24 hours per day) is assumed in computing the daily production and costs for both projects. Based on recent project experiences, typical downtimes of 20% (80% production efficiency) for clamshell dredging and 30% (70% production efficiency) for hopper dredging is incorporated for mechanical, traffic, maneuvering and weather delays. A larger percentage of downtime is likely for dredging at the Navy docks relative to the Commercial Port or small boat marinas due to increased vessel traffic or other constraints within the Navy's jurisdictional area, which although not specifically analyzed here, would increase overall project cost and have the potential to slightly increase economical transport distance.

The type of dredge equipment used for dredging depends on the quantity to be dredged and the equipment available. Recent maintenance and construction dredging in Guam has been conducted by a clamshell dredge and hauled using a dump scow with a blunt bow. These scows have a maximum towing speed of about 4 knots. More modern dump scows, capable of being towed at higher speeds, are currently not available in Guam, but depending on the contractor selected, may be mobilized to the site. Regular maintenance projects are more likely performed by a smaller contractor, or a large contractor using smaller, older equipment. In this cost analysis, scenarios “a” and “b” compare these two different specifications of dredge equipment, with scenario “a” representing new equipment being towed at 7 knots and scenario “b” representing older dump scows being towed at 4 knots.

Table 5-1 presents the equipment specifications, including production rate, haul capacity and travel speeds, and unit costs for the two scenarios analyzed in this study. Mechanical dredging using a clamshell dredge requires the use of a tugboat and dump scow to transport the material. The cutterhead dredge was eliminated from this analysis because of the low production rate when used in conjunction with dump scows for transporting material long distances and the consequential impediment to marine navigation during dredging operations.

Table 5-1. Dredge Equipment Specifications and Associated Unit Costs

Category	Equipment	Scenario	Specifications	Estimated Cost
Hydraulic	Hopper Dredge	"a"	A hopper size of 3,000 cy, an hourly production rate of 1,125 cy, and a traveling speed of 7 knots.	$700 per hour
		"b"	A hopper size of 1,500 cy, an hourly production rate of 1,125 cy, and a traveling speed of 4 knots.	$600 per hour
Mechanical	Clamshell Dredge	"a"	A bucket capacity of 10 cy and a production rate of 450 cy per hour.	$700 per hour
		"b"	A bucket capacity of 5 cy and a production rate of 225 cy per hour	$500 per hour
	Tugboat	"a"	Average traveling speed of 7 knots	$450 per hour
		"b"	Average traveling speed of knots	$350 per hour
	Dump Scow	"a"	4,000 cy scow (capacity of 3,000 to 3,500 cy)	$7,200 per day
		"b"	2,000 cy scow (capacity of 1,500 to 1,750 cy)	$4,800 per day

Notes: "a" Construction and "b" Regular Maintenance
Source: USACE 2003

As previously mentioned, the mobilization/demobilization costs were based upon the LA-3 ZSF study and assumed to be $300,000 for a regular maintenance operation (scenario “b”) and $1,000,000 for a construction project (scenario “a”; USACE 2003). In the clamshell scenario, the dredging and disposal costs were estimated assuming one dredge and one tugboat and two (2) dump scows on an hourly rate, and one hopper dredge for the hopper dredge scenario. Both scenarios incorporated the mobilization/demobilization cost.

Two separate clamshell dredge options were evaluated for each scenario. The first option used two scows alternating between filling and transporting material to the dump site. Scow #1 transports to the disposal site with the tug while scow #2 remains at the dredge site being filled by the dredge. When scow #2 is filled, it is towed to the dumpsite. Scow #1 begins filling when it returns from the disposal site and the dredge has completed filling scow #2. Note the cost per cy remains constant and relatively low for short haul distances, but increases for longer haul distances. This is because the dredge production limits the overall project production. As haul distances increase beyond the distance that allows the scow returning from the dump site to arrive before the scow at the dredge site is filled, then the dredge incurs downtime, daily dredge production decreases, and the cost per cy increases.

The second clamshell dredge option used three scows and two tugs alternating between filling and transporting material to the dump site. This option was evaluated to determine the sensitivity of increasing the number of scows has on the disposal distance and economic feasibility. This option works similar to the first option, with the exception that two scows are in transport (one en route to the site and one returning from the site) at any one particular time and one scow is being filled. For example, scow #3 is filled when scow #1 is returning from the dumpsite and scow #2 is en route to the dumpsite. As noted in the first option, the cost per cy remains constant for short haul distances, but increases for longer haul distances.

Assuming a 200,000 cy (152,911 m^3) maintenance dredging project with a 6 nm (11 km) haul to the disposal site as an example, the cost calculations are presented in Table 5-2. Note the total project cost is more or less the same when the transport, for haul distances up to 18 nm (33 km). This happens because the total project time is equivalent to the dredging time since dredging and filling operations are not limited by towing. A spreadsheet containing all of the calculations used in generating Figure 5-1 and Figure 5-2 is presented in Appendix A.

Table 5-2. Example Cost Calculation for Maintenance Dredging Project; Total Production Not Limited by Haul Distance

Haul Time (one load)	=	Distance to Disposal/Towing Speed * 2 (to and from disposal site)
	=	6 nm / 4 knots * 2 trips
	=	3.0 hrs
Project Haul Time	=	Haul Time * Total Loads for Project
	=	3.0 hrs * 200,000 cy / 1,750 cy per load
	=	342.86 hrs
Project Dredging Time	=	Dredge Production (cy/hr) * Total Project Volume (cy) * Efficiency Rate
	=	225 cy/hr * 200,000 cy * 80%
	=	1,111 hrs
Total Project Cost	=	Σ Project Dredging Hours * Unit Cost of Dredge Plant
	=	1,111 hrs * $350/hr (tug) + 47 days * $4,800/day * 2 scows (1,111 hrs ~ 47 days) + 1,111 hrs * $500/hr (dredge)
	=	**$1,695,644**

In Table 5-3, a cost calculation is presented for an example in which the total production is limited by the haul distance (i.e., the filling of one scow is completed prior to the other scow returning from the ODMDS). In this example the haul distance is 24 nm (44 km).

The hopper dredge project costs are much simpler and linearly related to haul distance. The dredge itself provides the transport of dredged material. Therefore, all haul time negatively impacts production.

Table 5-3. Example Cost Calculation for Maintenance Dredging Project; Total Production Limited by Haul Distance

Haul Time (one load)	=	Distance to Disposal/Towing Speed * 2 (to and from disposal site)
	=	24 nm / 4 knots * 2 trips
	=	12.0 hrs
Project Haul Time	=	Haul Time * Total Loads for Project
	=	24.0 hrs * 200,000 cy / 1,750 cy per load
	=	1,371.43 hrs
Project Dredging Time	=	Dredge Production (cy/hr) * Total Project Volume (cy) * Efficiency Rate
	=	225 cy/hr * 200,000 cy * 80%
	=	1,111 hrs
Total Project Cost	=	Σ Project Dredging Hours * Unit Cost of Dredge Plant
	=	1,371.43 hrs * $350/hr (tug) + 58 days * $4,800/day * 2 scows (1,371.43 hrs ~ 58 days) + 1,371.43 hrs * $500/hr (dredge)
	=	**$2,022,514.29**

Figure 5-1 presents the total cost of various disposal distances using either a clamshell with two scows or a hopper dredge for the regular maintenance and construction dredging operations, whereas Figure 5-2 illustrates the dredging-and-disposal unit costs at various disposal distances for the regular maintenance construction dredging projects. The representative unit cost was computed from the total dredging and disposal cost divided by the total volume dredged.

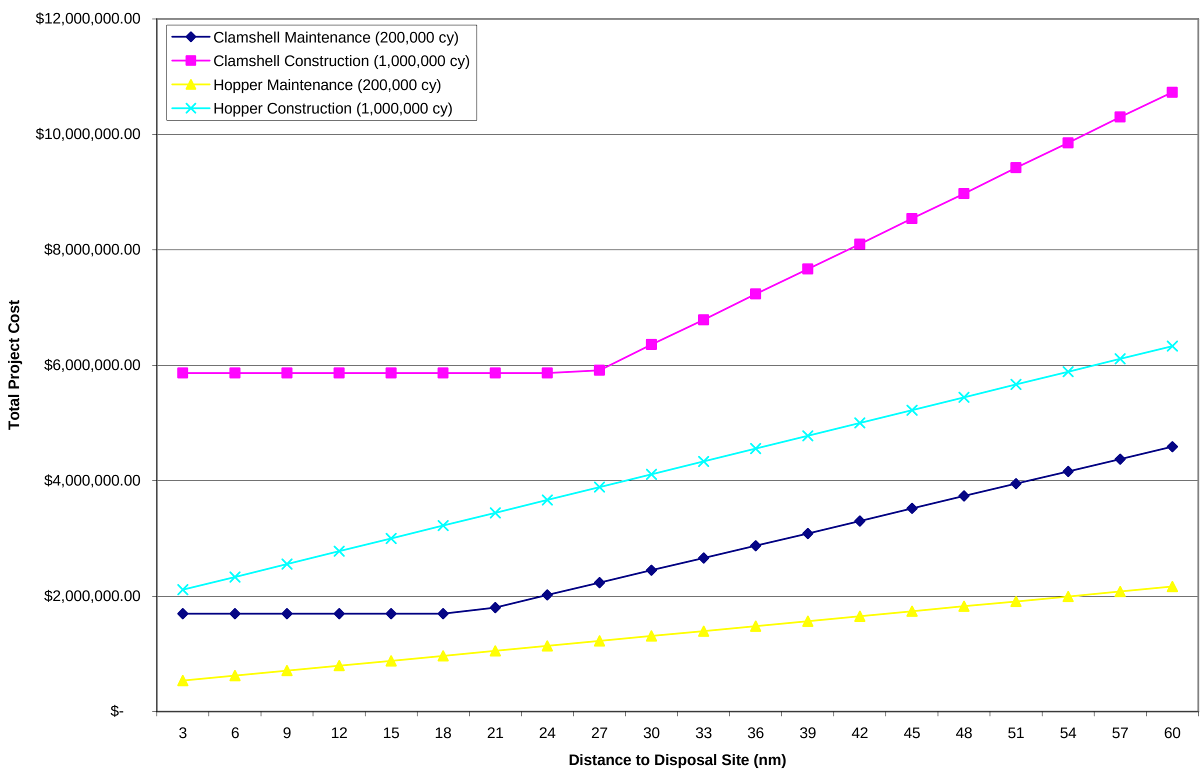

Figure 5-1. Total Project Cost vs. Distance to ODMDS for Mechanically or Hydraulically Dredged Maintenance or Construction Projects

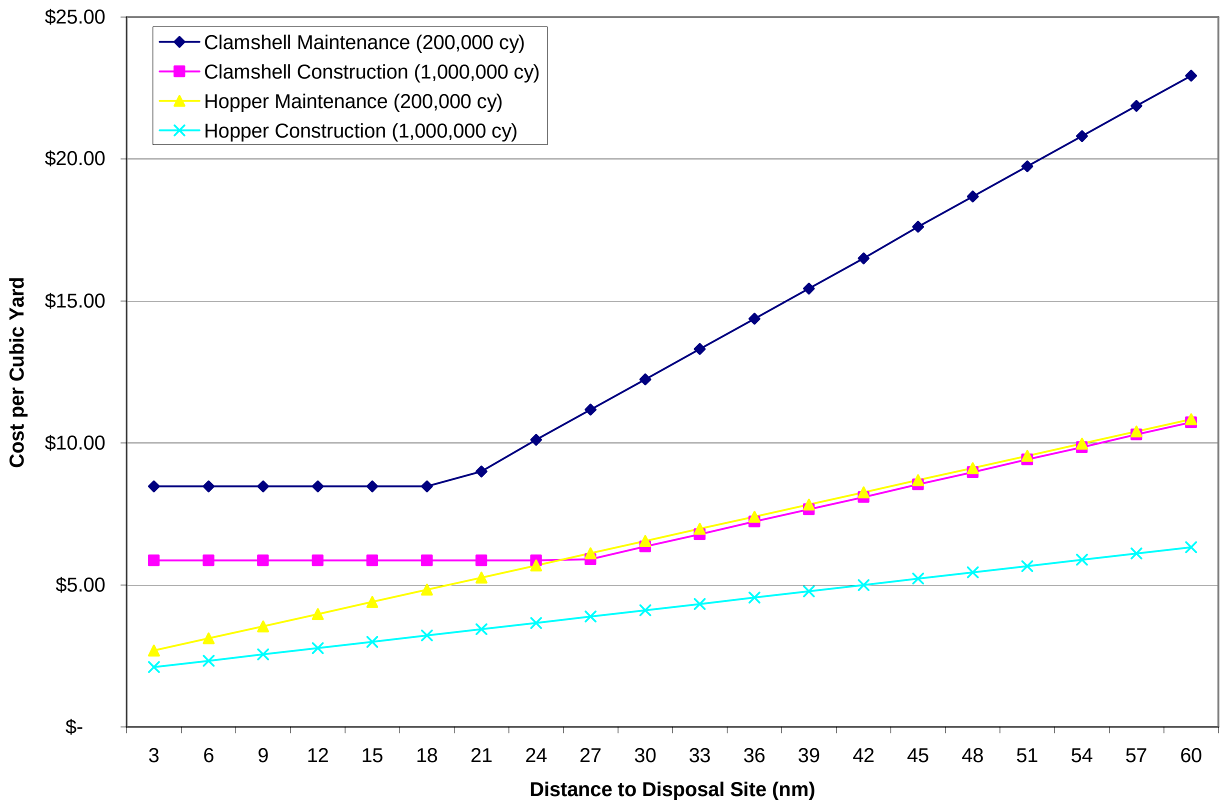

Figure 5-2. Unit Costs per Cubic Yard for Mechanically or Hydraulically Dredged Maintenance or Construction Projects

5.1 Economic Feasible Zone

An analysis of dredging project efficiency to cost (per unit or total project) indicates that for the clamshell dredging options using two scows, the distance to an ocean disposal site does not negatively impact the project until the distance exceeds 18 nm (33 km) for maintenance projects and 27 nm (50 km) for construction projects (Figure 5-1 and Figure 5-2**,** respectively**)**. This disposal distance represents the critical point in which the dredge incurs planned down time because it must stop and wait for a scow to return from the disposal site. In other words, it takes longer to tow a scow to and from the disposal site than it takes for the dredge to fill a scow. Consequently, the inefficiency of the project becomes apparent beyond 18 and 27 nm (33 and 50 km) resulting in the sharp increase in the cost resulting from idle equipment. Assuming a project site at the entrance to Inner Apra Harbor and Outer Apra Harbor is approximately 2 nm (4 km) in length, the ODMDS would need to be located within 16 and 25 nm (29 and 46 km) from the entrance to Outer Apra Harbor, respectively for maintenance or construction dredging projects. Figure 5-3 illustrates these disposal distances as arcs emanating from the entrance to Inner Apra Harbor.

An analysis of the clamshell dredging scenarios using three scows and two tugs provides an indication to the sensitivity that increasing the number of scows (haul capacity) has on the disposal distance. For either maintenance or construction dredging projects, adding a third scow increases the overall cost per cy by nearly 50% without an increase in project efficiency (i.e. the production rate of the dredge plant is not fast enough to maintain three scows in continuous operation without one of the scows standing by idle; Appendix A). A three scow operation is technically more efficient than a two scow operation for disposal sites between 1.7 and 2 times as far as those for a two scow operation, however, the cost per cubic yard is still significantly greater than disposing of dredged material at a potential ODMDS closer (18 nm [33 km]) to shore and is likely not a feasible alternative for dredging projects in Guam, especially for relatively small maintenance and construction dredging projects administered by the PAG.

The increase in distance to the disposal site does not affect the hopper dredge as dramatically due to the all-in-one aspect of this type of dredge. With the dredging operation integrated with the disposal side, there is no idle equipment, and the cost remains linear with respect to the distance. However, a hopper dredge does not allow for continuous dredging since the dredge itself must transport the material to the dump site.

Figure 5-4 superimposes the economic feasible distances for maintenance and construction dredging projects onto the areas eliminated from further consideration (Section 3). The results of this study suggest there are two regions located offshore of Guam that may be suitable for placement of an ODMDS. Since both maintenance and construction dredging projects may dispose of dredged material at the ODMDS, the inner arc, that dependent on maintenance dredging projects, was chosen to set the outer limit of feasibility. The first region, northwest of the entrance to Outer Apra Harbor, is approximately 8.9 nm (16.4 km) offshore of Guam. This region occupies an area approximately 59 sq. mi (152 km^2). The second region, north of the entrance to Outer Apra Harbor, is approximately 12.4 nm (23 km) away. This northern region occupies an area approximately 22 sq. mi (58 km^2).

A third region, located southwest of the entrance to Outer Apra Harbor, was initially identified as meeting the requirements of the ZSF process. However, the most direct route to this disposal area crosses the submerged submarine operating area and a firing danger zone. In order to access this site without crossing these navigational hazards, the disposal vessel would be required to transit due west from Apra Harbor for 10 nm (18 km) then change course to the south for an additional 5.5 nm (10 km) just to reach the nearest boundary of the site. This transit distance is approximately equal to the radius of feasibility arc for maintenance projects (i.e., 18 nm [33km]). Therefore, this region has been excluded from further consideration for placement of an ODMDS.

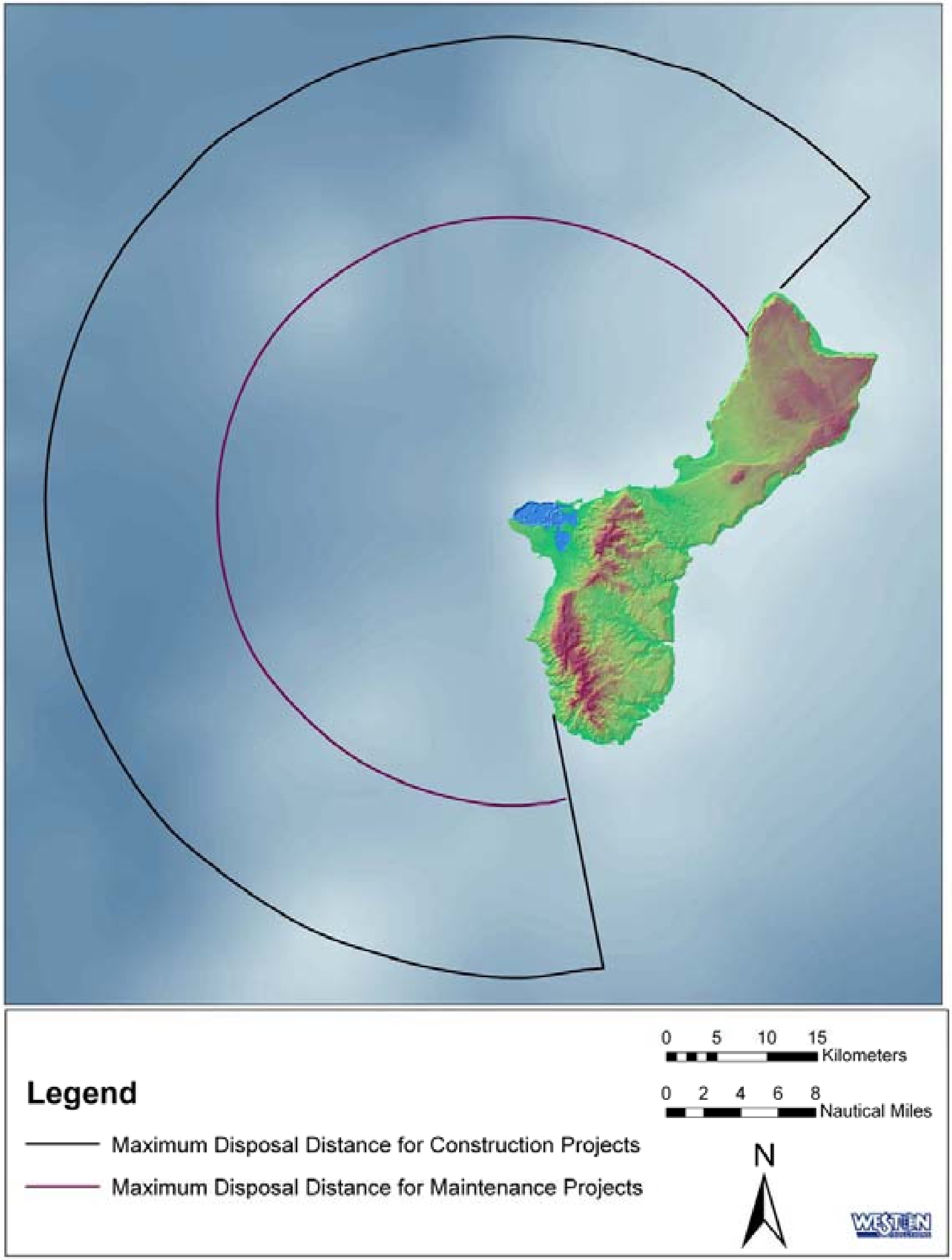

Figure 5-3. Economically Feasible Disposal Zones (Maintenance and Construction Projects) for Mechanically Dredged Material

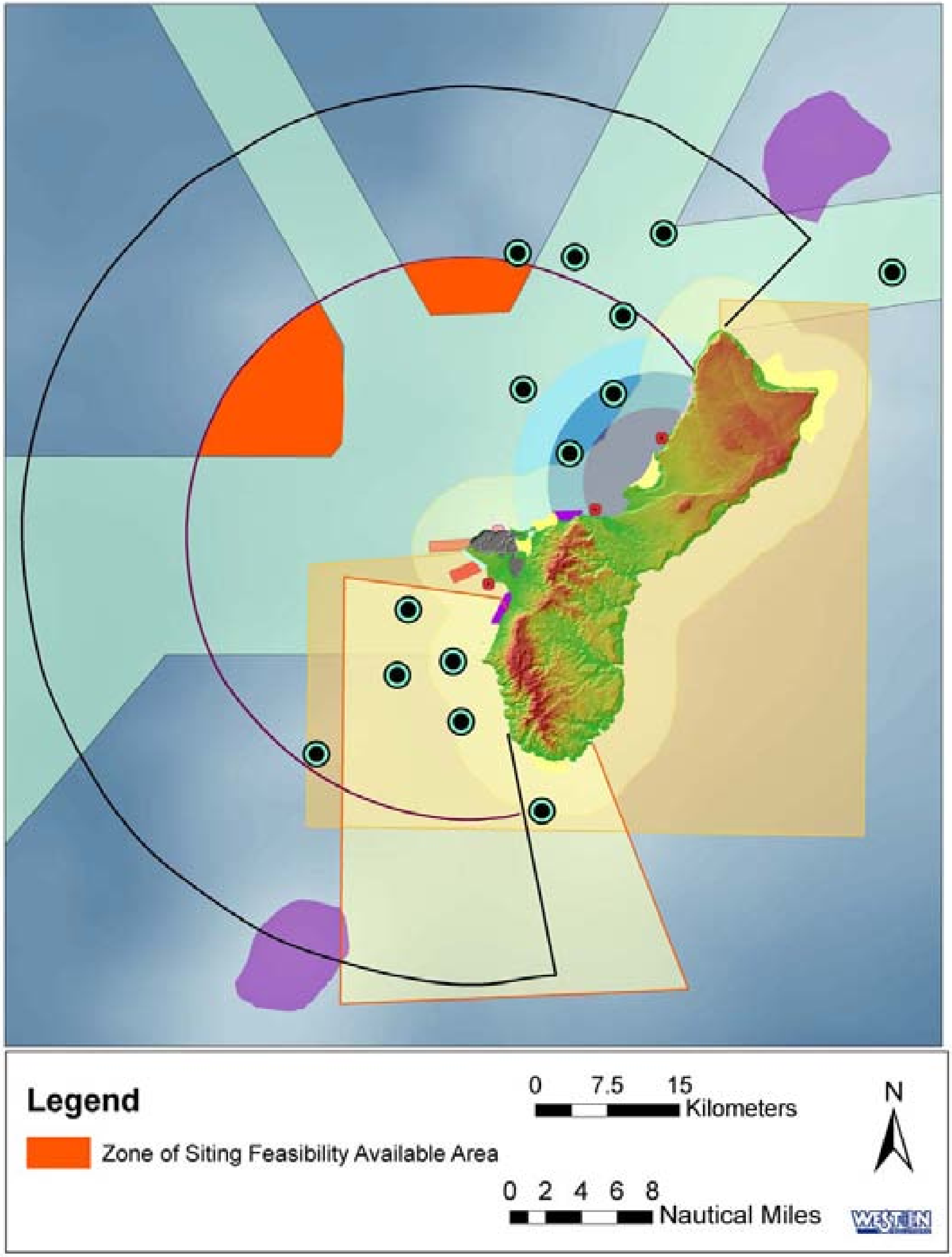

Figure 5-4. Zone of Siting Feasibility

6.0 CONCLUSIONS

Over the next 30 years, it is estimated that the Navy and PAG will require 8,884,700 cy (6,792,841 m^3) of sediment to be dredged throughout Guam, with the majority of this dredged material being generated from Inner and Outer Apra Harbor. Of this quantity, approximately 10% or 888,500 cy (679,307 m^3) may be considered unsuitable for ocean disposal due to elevated levels of contaminants (NRC 1997). Currently, the Navy has the capacity at any one time to dewater or stockpile 847,500 cy (647,960 m^3) of dredged material in CDFs. Beneficial use projects on Navy and PAG property may account for the placement of 2,875,200 cy (2,198,248 m^3) of dewatered material. Disposal alternatives for an additional 5,121,000 cy (3,915,285 m^3) of dredged material would need to be identified. Simply, there is insufficient upland capacity to manage dredged materials expected to be generated through 2036. Therefore, disposal of dredged material at an ODMDS would provide the Navy and PAG with a management alternative beneficial to the mission of each.

This ZSF study was undertaken to identify those offshore areas in which an ODMDS may potentially be sited. The ZSF process involves delineating areas unacceptable for placement of an ODMDS. This study reviewed the location of navigational lanes and hazards, GovGuam jurisdictional boundaries, marine protected areas (ERAs, marine preserves and reserves), parks, ocean outfalls, oil and mineral extraction installations, commercial and recreational fishing areas, visual resources and continental shelf geography to eliminate these areas from further consideration for placement of an ODMDS. For the most part, the two most influencing factors in restricting the placement of an ODMDS were navigational lanes and hazards and GovGuam jurisdictional boundaries. Due to the sharp relief surrounding Guam, many of the other resources are located inshore of the 3-nm limit.

The dredging process (i.e., volume of material to be dredged, production rate of the dredge plant, and hauling capacity of the dump scows or hopper dredge) was evaluated to set a limiting distance offshore of Guam in which an ODMDS may be sited and still be considered "economically feasible". This feasibility study determined for a maintenance dredging project conducted in any particular year, generating approximately 200,000 cy (152,911 m^3) of dredged material by mechanical means, an ODMDS would need to be located within 18 nm (33 km) of the project site. Assuming the entrance to Inner Apra Harbor as the "project site" and Outer Apra Harbor is approximately 2 nm (4 km) in length, the ODMDS would need to be located within 16 nm (29 km) of the entrance to Outer Apra Harbor. For a construction project, also mechanically dredged and consisting of 1,000,000 cy (764,555 m^3), an ODMDS would need to be located within 27 nm (50 km) of the project site, or within 25 nm (46 km) of the entrance to Outer Apra Harbor. Beyond these distances, mechanical dredging operations incur increased costs due to idle equipment waiting for the tug and dump scow to return from the ODMDS. For mechanically dredged construction or maintenance projects, increasing the number of scows available to the project increases the overall cost per cubic yard by nearly 50% without an associated increase in project efficiency.

It should be noted, that although it appears that hopper dredging is the most cost effective means for dredging this project, actual project costs will vary greatly with dredge availability and individual production on the project, which is difficult to predict without experience specific to the equipment used at the specific location. For example, a hopper dredge may not be able to operate within a small berthing area, and certain scows may not be able to transport during higher sea states. Although this cost analysis may not accurately represent the relative cost of using a hopper dredge versus a clamshell dredge, it accurately demonstrates project costs for each type of dredge as directly dependant on transport distance and dredge production.

For both the hopper dredge and clamshell dredge, the effect on dredging costs relative to disposal site distances are greatly dependent on the individual dredge's productivity and transport speed. As mentioned previously, the maximum economical disposal distance for clamshell dredging is that which allows the dredge to work continuously, but the hopper dredge has a directly linear cost increase with disposal distance even for disposal distances. Consequently, other factors such as environmental benefits gained by siting the disposal site further offshore must be considered in weighing the adverse impacts of choosing a disposal site further offshore.

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Appendix A

ZSF Cost Analysis

Miles to Ocean Disposal Area - Nautical miles one-way		3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
Clamshell Dredge Equipment (b) - 5 cy bucket & TWO 2000 cy scows																					
Tug and TWO Scows (b) - one round trip to disposal site (hrs)	Miles to DA one way * 2 ways/ speed (4knots)	1.50	3.00	4.50	6.00	7.50	9.00	10.50	12.00	13.50	15.00	16.50	18.00	19.50	21.00	22.50	24.00	25.50	27.00	28.50	30.00
Tug and TWO Scows (b) - total time (hours)	Round trip haul time * total # trips [1]	171.43	342.86	514.29	685.71	857.14	1028.57	1200.00	1371.43	1542.86	1714.29	1885.71	2057.14	2228.57	2400.00	2571.43	2742.86	2914.29	3085.71	3257.14	3428.57
Total Dredging time (hours)	200,000 cy / 225cy/hr @ 80% prod. effic.	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111
Clam Shell (b) Dredging travel impact - hours waiting	total dredge waiting time (hrs)	(939.68)	(768.25)	(596.83)	(425.40)	(253.97)	(82.54)	88.89	260.32	431.75	603.17	774.60	946.03	1,117.46	1,288.89	1,460.32	1,631.75	1,803.17	1,974.60	2,146.03	2,317.46
Total Project time (hours)	Greater of dredging vs hauling time	1,111	1,111.11	1,111.11	1,111.11	1,111.11	1,111.11	1,200.00	1,371.43	1,542.86	1,714.29	1,885.71	2,057.14	2,228.57	2,400.00	2,571.43	2,742.86	2,914.29	3,085.71	3,257.14	3,428.57
Tug (b) total cost	Total Tug (b) hrs * $350/hr	$ 388,889	$ 388,889	$ 388,889	$ 388,889	$ 388,889	$ 388,889	$ 420,000	$ 480,000	$ 540,000	$ 600,000	$ 660,000	$ 720,000	$ 780,000	$ 840,000	$ 900,000	$ 960,000	$ 1,020,000	$ 1,080,000	$ 1,140,000	$ 1,200,000
Total Scow Cost (2 Scows)	Total barge time * $4800/day *2 scows	$ 451,200	$ 451,200	$ 451,200	$ 451,200	$ 451,200	$ 451,200	$ 480,000	$ 556,800	$ 624,000	$ 691,200	$ 758,400	$ 825,600	$ 892,800	$ 960,000	$ 1,036,800	$ 1,104,000	$ 1,171,200	$ 1,238,400	$ 1,305,600	$ 1,372,800
Total Dredge Cost	Total dredging time * **$500 / hr** [5]	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 600,000	$ 685,714	$ 771,429	$ 857,143	$ 942,857	$ 1,028,571	$ 1,114,286	$ 1,200,000	$ 1,285,714	$ 1,371,429	$ 1,457,143	$ 1,542,857	$ 1,628,571	$ 1,714,286
Mobilization/Demobilization	LS for mob/demob	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000
Clamshell Dredge Total cost of Project (b)		$ 1,695,644.44	$ 1,695,644.44	$ 1,695,644.44	$ 1,695,644.44	$ 1,695,644.44	$ 1,695,644.44	$ 1,800,000.00	$ 2,022,514.29	$ 2,235,428.57	$ 2,448,342.86	$ 2,661,257.14	$ 2,874,171.43	$ 3,087,085.71	$ 3,300,000.00	$ 3,522,514.29	$ 3,735,428.57	$ 3,948,342.86	$ 4,161,257.14	$ 4,374,171.43	$ 4,587,085.71
Cost per Cubic Yard		$ 8.48	$ 8.48	$ 8.48	$ 8.48	$ 8.48	$ 8.48	$ 9.00	$ 10.11	$ 11.18	$ 12.24	$ 13.31	$ 14.37	$ 15.44	$ 16.50	$ 17.61	$ 18.68	$ 19.74	$ 20.81	$ 21.87	$ 22.94
Clamshell Dredge Equipment (b) - 5 cy bucket & THREE 2000 cy scows (TWO Tugs)																					
Tug and Scow (b) - one round trip to disposal site (hrs)	Miles to DA one way * 2 ways/ speed (4 knots)	1.50	3.00	4.50	6.00	7.50	9.00	10.50	12.00	13.50	15.00	16.50	18.00	19.50	21.00	22.50	24.00	25.50	27.00	28.50	30.00
TWO Tugs and THREE Scows (b) - total time (hours)	Round trip haul time * total # trips [1]	85.71	171.43	257.14	342.86	428.57	514.29	600.00	685.71	771.43	857.14	942.86	1028.57	1114.29	1200.00	1285.71	1371.43	1457.14	1542.86	1628.57	1714.29
Total Dredging time (hours)	200,000 cy / 225cy/hr @ 80% prod. effic.	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111	1,111
Clam Shell (b) Dredging travel impact - hours waiting	total dredge waiting time (hrs)	(1,025.40)	(939.68)	(853.97)	(768.25)	(682.54)	(596.83)	(511.11)	(425.40)	(339.68)	(253.97)	(168.25)	(82.54)	3.17	88.89	174.60	260.32	346.03	431.75	517.46	603.17
Total Project time (hours)	Greater of dredging vs hauling time	1,111	1,111.11	1,111.11	1,111.11	1,111.11	1,111.11	1,111.11	1,111.11	1,111.11	1,111.11	1,111.11	1,111.11	1,114.29	1,200.00	1,285.71	1,371.43	1,457.14	1,542.86	1,628.57	1,714.29
Tug (b) total cost	Total Tug (b) hrs * $350/hr * TWO tugs	$ 777,778	$ 777,778	$ 777,778	$ 777,778	$ 777,778	$ 777,778	$ 777,778	$ 777,778	$ 777,778	$ 777,778	$ 777,778	$ 777,778	$ 780,000	$ 840,000	$ 900,000	$ 960,000	$ 1,020,000	$ 1,080,000	$ 1,140,000	$ 1,200,000
Total Scow Cost (2 Scows)	Total barge time * $4800/day *THREE scows	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 676,800	$ 720,000	$ 777,600	$ 835,200	$ 878,400	$ 936,000	$ 979,200	$ 1,036,800
Total Dredge Cost	Total dredging time * **$500 / hr** [5]	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 555,556	$ 557,143	$ 600,000	$ 642,857	$ 685,714	$ 728,571	$ 771,429	$ 814,286	$ 857,143
Mobilization/Demobilization	LS for mob/demob	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000	$ 450,000
Clamshell Dredge Total cost of Project (b)		$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,460,133.33	$ 2,463,942.86	$ 2,610,000.00	$ 2,770,457.14	$ 2,930,914.29	$ 3,076,971.43	$ 3,237,428.57	$ 3,383,485.71	$ 3,543,942.86
Cost per Cubic Yard		$ 12.30	$ 12.30	$ 12.30	$ 12.30	$ 12.30	$ 12.30	$ 12.30	$ 12.30	$ 12.30	$ 12.30	$ 12.30	$ 12.30	$ 12.32	$ 13.05	$ 13.85	$ 14.65	$ 15.38	$ 16.19	$ 16.92	$ 17.72
Clamshell Dredge Equipment (a) - 10 cy bucket & TWO 4000 cy scows																					
Tug and Scow (a) - one round trip to disposal site (hrs)	Miles to DA one way * 2 ways/ speed	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
Tug and Scow (a) total time (hours)	Round trip haul time * total # trips [1]	286	571	857	1143	1429	1714	2000	2286	2571	2857	3143	3429	3714	4000	4286	4571	4857	5143	5429	5714
Total Dredging time (hours)	1,000,000 cy / 450cy/hr @ 80% prod. effic.	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778
Clam Shell (a) Dredging travel impact - hours waiting	total dredge waiting time (hrs)	$ (2,492)	$ (2,206)	$ (1,921)	$ (1,635)	$ (1,349)	$ (1,063)	$ (778)	$ (492)	$ (206)	$ 79	$ 365	$ 651	$ 937	$ 1,222	$ 1,508	$ 1,794	$ 2,079	$ 2,365	$ 2,651	$ 2,937
Total Project time (hours)	Greater of dredging vs hauling time	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,857	3,143	3,429	3,714	4,000	4,286	4,571	4,857	5,143	5,429	5,714
Tug (a) total cost	Total Tug (b) hrs * $450/hr	$ 1,250,000	$ 1,250,000	$ 1,250,000	$ 1,250,000	$ 1,250,000	$ 1,250,000	$ 1,250,000	$ 1,250,000	$ 1,250,000	$ 1,285,714	$ 1,414,286	$ 1,542,857	$ 1,671,429	$ 1,800,000	$ 1,928,571	$ 2,057,143	$ 2,185,714	$ 2,314,286	$ 2,442,857	$ 2,571,429
Total Scow (a) Cost (2 Scows)	Total barge time * $7200/day *2 scows	$ 1,670,400	$ 1,670,400	$ 1,670,400	$ 1,670,400	$ 1,670,400	$ 1,670,400	$ 1,670,400	$ 1,670,400	$ 1,670,400	$ 1,728,000	$ 1,886,400	$ 2,059,200	$ 2,232,000	$ 2,404,800	$ 2,577,600	$ 2,750,400	$ 2,923,200	$ 3,096,000	$ 3,268,800	$ 3,441,600
Total Dredge Cost	Total dredging time * **$700/ hr** [5]	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 2,000,000	$ 2,200,000	$ 2,400,000	$ 2,600,000	$ 2,800,000	$ 3,000,000	$ 3,200,000	$ 3,400,000	$ 3,600,000	$ 3,800,000	$ 4,000,000
Mobilization/Demobilization	LS for mob/demob	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Clamshell Dredge Total cost of Project (a)		$ 5,864,844.44	$ 5,864,844.44	$ 5,864,844.44	$ 5,864,844.44	$ 5,864,844.44	$ 5,864,844.44	$ 5,864,844.44	$ 5,864,844.44	$ 5,864,844.44	$ 6,013,714.29	$ 6,500,685.71	$ 7,002,057.14	$ 7,503,428.57	$ 8,004,800.00	$ 8,506,171.43	$ 9,007,542.86	$ 9,508,914.29	############	$ 10,511,657.14	$ 11,013,028.57
Cost per Cubic Yard		$ 5.86	$ 5.86	$ 5.86	$ 5.86	$ 5.86	$ 5.86	$ 5.86	$ 5.86	$ 5.86	$ 6.01	$ 6.50	$ 7.00	$ 7.50	$ 8.00	$ 8.51	$ 9.01	$ 9.51	$ 10.01	$ 10.51	$ 11.01
Clamshell Dredge Equipment (a) - 10 cy bucket & THREE 4000 cy scows (TWO) Tugs																					
Tug and Scow (a) - one round trip to disposal site (hrs)	Miles to DA one way * 2 ways/ speed	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
Tug and Scow (a) total time (hours)	Round trip haul time * total # trips [1]	143	286	429	571	714	857	1000	1143	1286	1429	1571	1714	1857	2000	2143	2286	2429	2571	2714	2857
Total Dredging time (hours)	1,000,000 cy / 450cy/hr @ 80% prod. effic.	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778
Clam Shell (a) Dredging travel impact - hours waiting	total dredge waiting time (hrs)	$ (2,635)	$ (2,492)	$ (2,349)	$ (2,206)	$ (2,063)	$ (1,921)	$ (1,778)	$ (1,635)	$ (1,492)	$ (1,349)	$ (1,206)	$ (1,063)	$ (921)	$ (778)	$ (635)	$ (492)	$ (349)	$ (206)	$ (63)	$ 79
Total Project time (hours)	Greater of dredging vs hauling time	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,778	2,857
Tug (a) total cost	Total Tug (b) hrs * $450/hr	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,571,429
Total Scow (a) Cost (2 Scows)	Total barge time * $7200/day *2 scows	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,505,600	$ 2,592,000
Total Dredge Cost	Total dredging time * **$700/ hr** [5]	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 1,944,444	$ 2,000,000
Mobilization/Demobilization	LS for mob/demob	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Clamshell Dredge Total cost of Project (a)		$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,450,044.44	$ 8,663,428.57
Cost per Cubic Yard		$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.45	$ 8.66
Hopper Dredge Equipment (b) - 1,500 cy hopper 7 knot sail speed																					
Dredge - one round trip to disposal site (hrs)	Miles to DA one way * 2 ways/ speed	0.86	1.71	2.57	3.43	4.29	5.14	6.00	6.86	7.71	8.57	9.43	10.29	11.14	12.00	12.86	13.71	14.57	15.43	16.29	17.14
Total Trips	Round trip haul time * total # trips [3]	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167	167
Total sailing time (hours)	Total # trips * trip duration	143	286	429	571	714	857	1000	1143	1286	1429	1571	1714	1857	2000	2143	2286	2429	2571	2714	2857
Total dredging Time (hours)	Total volume / production (cy/hr) @ 70% effic.	254	254	254	254	254	254	254	254	254	254	254	254	254	254	254	254	254	254	254	254
Total Project time (hours)	Total dredging time + total haul time	397	540	683	825	968	1111	1254	1397	1540	1683	1825	1968	2111	2254	2397	2540	2683	2825	2968	3111
Mobilization	LS for mob/demob	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000	$ 300,000
Hopper Dredge Total Cost Project (b)		$ 538,095	$ 623,810	$ 709,524	$ 795,238	$ 880,952	$ 966,667	$ 1,052,381	$ 1,138,095	$ 1,223,810	$ 1,309,524	$ 1,395,238	$ 1,480,952	$ 1,566,667	$ 1,652,381	$ 1,738,095	$ 1,823,810	$ 1,909,524	$ 1,995,238	$ 2,080,952	$ 2,166,667
Cost per Cubic Yard		$ 2.69	$ 3.12	$ 3.55	$ 3.98	$ 4.40	$ 4.83	$ 5.26	$ 5.69	$ 6.12	$ 6.55	$ 6.98	$ 7.40	$ 7.83	$ 8.26	$ 8.69	$ 9.12	$ 9.55	$ 9.98	$ 10.40	$ 10.83
Hopper Dredge Equipment (a) - 3,000 cy hopper 7 knot sail speed																					
Dredge - one round trip to disposal site (hrs)	Miles to DA one way * 2 ways/ speed	0.86	1.71	2.57	3.43	4.29	5.14	6.00	6.86	7.71	8.57	9.43	10.29	11.14	12.00	12.86	13.71	14.57	15.43	16.29	17.14
Total Trips	Round trip haul time * total # trips [4]	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370	370
Total sailing time (hours)	Total # trips * trip duration	317	635	952	1270	1587	1905	2222	2540	2857	3175	3492	3810	4127	4444	4762	5079	5397	5714	6032	6349
Total dredging Time (hours)	Total volume / production (cy/hr) @ 70% effic.	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270	1270
Total Project time (hours)	Total dredging time + total haul time	1587	1905	2222	2540	2857	3175	3492	3810	4127	4444	4762	5079	5397	5714	6032	6349	6667	6984	7302	7619
Mobilization	LS for mob/demob	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000
Hopper Dredge Total Cost Project (b)		$ 2,111,111.11	$ 2,333,333.33	$ 2,555,555.56	$ 2,777,777.78	$ 3,000,000.00	$ 3,222,222.22	$ 3,444,444.44	$ 3,666,666.67	$ 3,888,888.89	$ 4,111,111.11	$ 4,333,333.33	$ 4,555,555.56	$ 4,777,777.78	$ 5,000,000.00	$ 5,222,222.22	$ 5,444,444.44	$ 5,666,666.67	$ 5,888,888.89	$ 6,111,111.11	$ 6,333,333.33
Cost per Cubic Yard		$ 2.11	$ 2.33	$ 2.56	$ 2.78	$ 3.00	$ 3.22	$ 3.44	$ 3.67	$ 3.89	$ 4.11	$ 4.33	$ 4.56	$ 4.78	$ 5.00	$ 5.22	$ 5.44	$ 5.67	$ 5.89	$ 6.11	$ 6.33

1 - 200,000cy project assuming 1750 cy per scow load
2 - 1,000,000 cy project assuming 3500 cy per scow load
3 - 200,000 cy project assuming 1200 per hopper load
4 - 1,000,000 cy project assuming 2700 per hopper load
5 - Dredge costs assumes a tender tug included with dredge cost

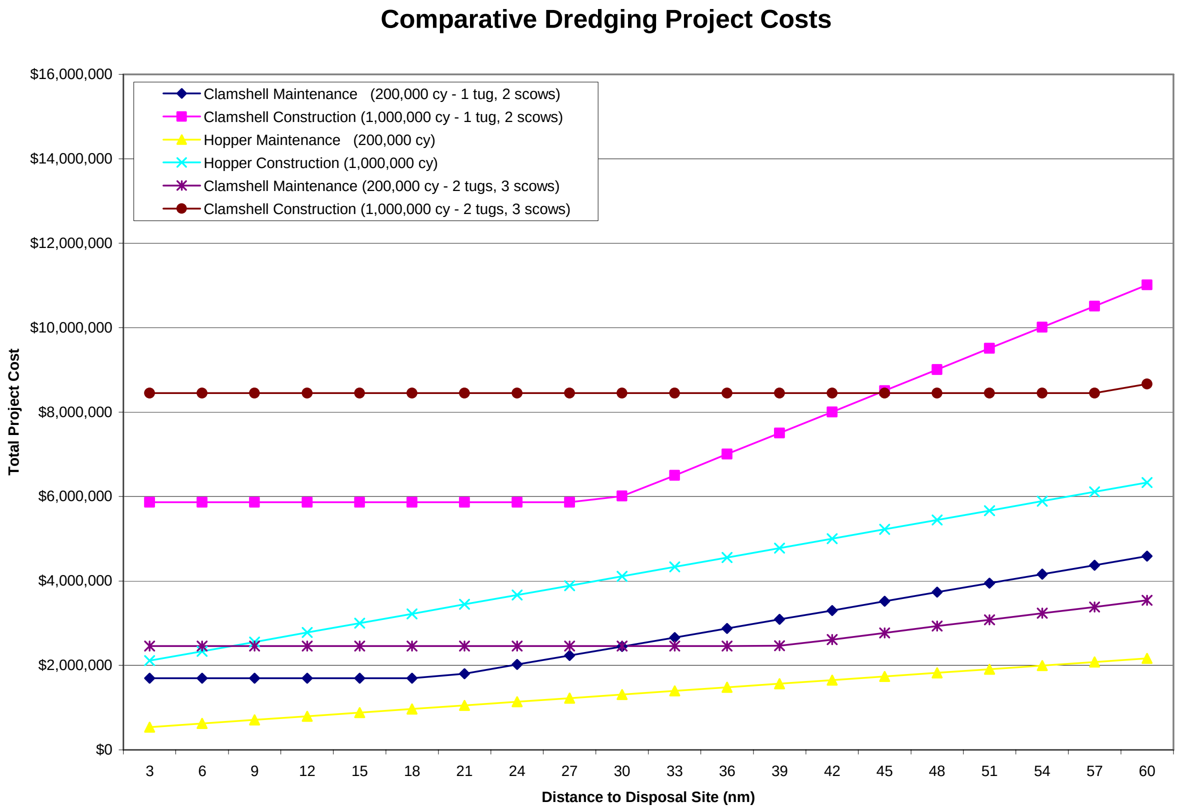

Figure A-1. Total Project Cost vs. Distance to ODMDS for Mechanically (Including 2 or 3 Scow Options) or Hydraulically Dredged Maintenance or Construction Projects

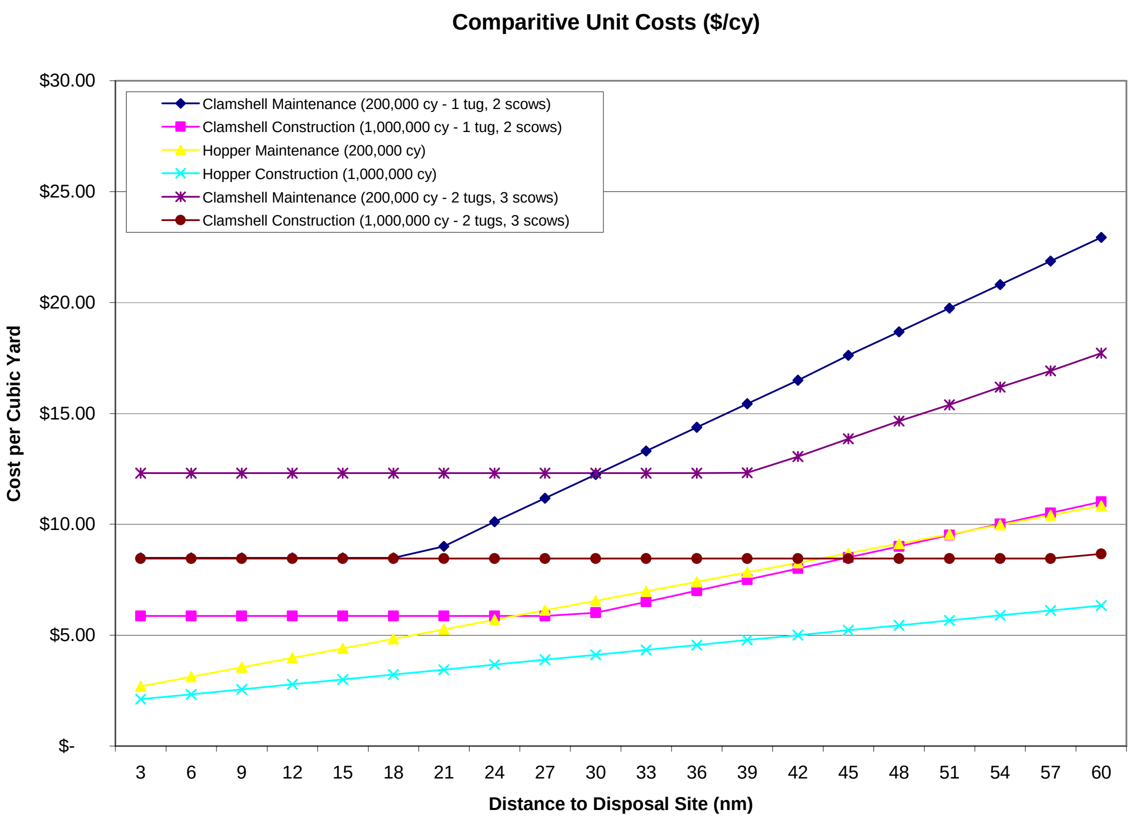

Figure A-2. Unit Costs per Cubic Yard for Mechanically (Including 2 or 3 Scow Options) or Hydraulically Dredged Maintenance or Construction Projects