# REQUEST FOR INCIDENTAL HARASSMENT AUTHORIZATION FOR THE INCIDENTAL HARASSMENT OF MARINE MAMMALS RESULTING FROM THE TRIDENT SUPPORT FACILITIES SECOND EXPLOSIVES HANDLING WHARF ON NAVAL BASE KITSAP AT BANGOR, WASHINGTON CONSTRUCTION YEAR 3

**July 16, 2014, through February 15, 2015**

Submitted to:

**Office of Protected Resources,**

**National Marine Fisheries Service,**

**National Oceanographic and Atmospheric Administration**

Prepared by:

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Prepared for:

**Strategic Systems Program**

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| °C | degrees Celsius |
| °F | degrees Fahrenheit |
| °N | North |
| °W | West |
| μPa | micropascal |
| BMP | Best Management Practice |
| BSS | Beaufort Sea State |
| CA | California |
| CDF | cumulative distribution functions |
| CERC | Coastal Engineering Research Center |
| CFR | Code of Federal Regulations |
| CISS | Cast-in-Steel-Shell |
| CSL | California sea lion |
| cu yd | cubic yard |
| CV | coefficient of variation |
| dB re 1 μPa | decibels referenced at 1 micropascal |
| dB | decibel |
| dBA | decibel with A-weighting filter |
| DDESB | Department of Defense Explosives Safety Board |
| DPS | Distinct Population Segment |
| EHW | Explosives Handling Wharf |
| EHW-2 | second Explosives Handling Wharf |
| EIS | Environmental Impact Statement |
| ESA | Endangered Species Act |
| ft | feet |
| ft-lbs | foot-pounds |
| ft/sec | feet per second |
| FR | *Federal Register* |
| GPS | Global Positioning System |
| Hz | hertz |
| IHA | Incidental Harassment Authorization |
| kHz | kilohertz |
| km | kilometer |
| Leq | equivalent level |
| LID | low impact development |
| Lmax | maximum level |
| m | meter |
| MHHW | mean higher high water |
| MLLW | mean lower low water |
| MMPA | Marine Mammal Protection Act |
| msec | millisecond |
| N/A | not available |
| Navy | United States Navy |
| NBK | Naval Base Kitsap |
| NEPA | National Environmental Policy Act |
| NMFS | National Marine Fisheries Service |
| NMSDD | Navy Marine Species Density Database |
| NOSSA | Naval Ordnance Safety and Security Activity |
| OR | Oregon |

| | |
|---|---|
| PCB | polychlorinated biphenyl |
| PSU | practical salinity unit |
| PTS | permanent threshold shift |
| NOAA | National Oceanic and Atmospheric Administration |
| RMS | root-mean-square |
| SAIC | Science Applications International Corporation |
| SAR | stock assessment report |
| SEL | sound exposure level |
| SMS | Sediment Management Standards |
| SPL | sound pressure level |
| SQS | Sediment Quality Standards |
| sq ft | square feet |
| sq km | square kilometer |
| SSBN | OHIO Class ballistic missile submarine |
| SSGN | OHIO Class guided missile submarine |
| SSL | Steller sea lion |
| TL | transmission loss |
| TPP | Test Pile Program |
| TRIDENT | Trident Fleet Ballistic Missile |
| TTS | temporary threshold shift |
| U.S. | United States |
| USACE | U.S. Army Corps of Engineers |
| USFWS | U.S. Fish and Wildlife Service |
| W | watt |
| WA | Washington |
| WAC | Washington Administrative Code |
| WDFW | Washington Department of Fish and Wildlife |
| WDOE | Washington Department of Ecology |
| WRA | waterfront restricted area |
| WSDOT | Washington State Department of Transportation |
| ZOI | zone of influence |

# EXECUTIVE SUMMARY

The United States Navy (U.S. Navy) is applying for an Incidental Harassment Authorization (IHA) for the incidental take of marine mammals resulting from the third year of construction (July 16, 2014, through February 15, 2015) of a second Explosives Handling Wharf (EHW-2) on Naval Base Kitsap (NBK) at Bangor. NBK at Bangor, Washington, is located on Hood Canal approximately 20 miles west of Seattle, Washington, and provides berthing and support services to Navy OHIO Class ballistic missile submarines (SSBN), hereafter referred to as TRIDENT submarines. The purpose of the proposed action is to support future TRIDENT program requirements for the eight TRIDENT submarines currently homeported on NBK at Bangor and the TRIDENT II Strategic Weapons System. A second EHW is needed because the existing EHW alone will not be able to support TRIDENT program requirements.

Vibratory and impact pile driving associated with construction of the EHW-2 are the proposed activities with the potential to affect marine mammals within the waterways adjacent to NBK at Bangor and that could result in harassment under the Marine Mammal Protection Act (MMPA) of 1972, as amended.

Eight species of marine mammals have been documented within the past 15 years in the waters adjacent to NBK at Bangor: the humpback whale (*Megaptera novaeangliae*), the Steller sea lion (*Eumetopias jubatus*), the California sea lion (*Zalophus californianus*), the harbor seal (*Phoca vitulina*), the transient killer whale (*Orcinus orca*), the Dall's porpoise (*Phocoenoides dalli*), the harbor porpoise (*Phocoena phocoena*), and the gray whale (*Eschrichtius robustus)*. Occurrences of all of these species in Washington inland marine waters are briefly summarized, but five of them, including Steller sea lion, California sea lion, harbor seal, transient killer whale, and harbor porpoise, are carried forward in the analysis in this IHA application based on the potential for exposure to Level B behavioral harassment from noise associated with vibratory and impact pile driving during project construction.

The Navy proposes to construct and operate the EHW-2 adjacent to, but separate from the existing EHW. The EHW-2 will consist of the wharf proper, or operations area, located approximately 600 feet offshore in water depths of 60 to 100 feet, and two trestles connecting the wharf to shore. Both the wharf and trestles will be pile-supported on up to 1,250 in-water steel pipe piles ranging in size from 24 to 48 inches in diameter. Construction will involve the temporary installation of up to 150 falsework piles used as an aid to guide the placement of permanent piles. Falsework piles will likely be steel piles ranging in size from 18 to 24 inches in diameter. All falsework piles will be removed upon installation of the permanent piles and will not increase the area of the seafloor affected by the project. The construction of an abutment where the trestle comes ashore at the shoreline cliff will require up to an additional 55 piles that will be driven on land. Falsework and abutment piles were accounted for in the overall construction schedule and pile driving duration and in the analysis of impacts from pile installation on marine mammals. The duration of in-water pile driving will be 200 to 400 days for the entire project. An additional 11 days of pile driving will be required on land to install the abutment piles. There will be a maximum of 195 days of pile driving during the third year of construction covered by this IHA.

All piles will be driven with a vibratory pile driver for their initial embedment depths, and select piles (every four to five piles) will be impact driven for their final 10–15 feet for proofing.[1] Any piles that cannot be driven to their desired depths using the vibratory hammer may need to be impact driven for the remainder of their required driving depth. Noise attenuation measures (i.e., bubble curtain) will be used during all impact hammer operations. Impact pile driving will also use a “soft start” (initial pile strikes at low intensity) to allow marine mammals to move away prior to the start of normal pile driving. Marine mammal monitoring will be conducted during pile driving, and work will shut down when marine mammals come within distances (no less than 25 meters) where injury could potentially occur. Pile installation will involve the use of vibratory pile drivers to the greatest extent possible. It is anticipated that most piles will be vibratory driven to within several feet of the required depth. If difficult subsurface driving conditions (i.e., cobble/boulder zones) are encountered, it may be necessary to use an impact hammer to drive some piles for the remaining portion of their required depth. Up to three vibratory rigs could operate concurrently during construction of the EHW-2, but only one impact hammer rig will operate at a time. However, the construction schedule requires the operation of the impact rig at the same time as the vibratory rigs.

For pile driving activities, the Navy used National Marine Fisheries Service (NMFS)-promulgated thresholds for assessing pile driving impacts (NMFS 2005, 2009), outlined in Section 6. To estimate potential marine mammal exposures, the Navy used methods consistent with the project’s prior two IHA applications and reviewed onsite acoustic monitoring data from 2011 and 2012 acoustic monitoring (Illingworth & Rodkin 2012, 2013). Predicted exposures are outlined in Section 6 and summarized in Table ES–1. The calculations predicted no Level A harassments would occur associated with pile driving activities. The modeling predicts that 16,755 Level B harassments may occur during the third year of construction of the EHW-2 from underwater sound. No incidents of harassment were predicted from airborne sounds associated with pile driving. Conservative assumptions (including marine mammal densities and other assumptions) used to estimate the exposures are likely to overestimate the potential number of exposures and their severity.

Compensatory mitigation projects for impacts to marine habitats and prey populations will be undertaken within Hood Canal that will restore the habitat and prey base functions affected by the project. The Mitigation Action Plan (Appendix F of the Environmental Impact Statement for the project) describes the proposed compensatory habitat mitigation more fully, as well as the various proposed impact avoidance and minimization measures.

[1] “Proofing” is driving the pile the last few feet into the substrate to determine the capacity of the pile. The capacity during proofing is established by measuring the resistance of the pile to a hammer that has a piston with a known weight and stroke (distance the hammer rises and falls) so that the energy on top of the pile can be calculated. The blow count in “blows per inch” is measured to verify resistance, and pile compression capacities are calculated using a known formula.

**Table ES–1. Number of Potential Exposures of Marine Mammals, Year 3, EHW-2 Project**

| Species | Underwater | Airborne |
|---|---|---|
| | Behavioral Harassment Threshold, All Species (160 dB RMS) | Behavioral Harassment Threshold, Harbor Seal (90 dB RMS), Other Pinnipeds (100 dB RMS) |
| Steller sea lion | 585 | 0 |
| California sea lion | 6,630 | 0 |
| Harbor seal | 8,580 | 0 |
| Harbor porpoise | 1,170 | N/A |
| Transient killer whale | 180[1] | N/A |
| Total | 16,755 | 0 |

**Source:** Navy 2013

dB = decibels; RMS = root-mean-square

1. The calculated number of potential exposures using the density formula was zero for underwater behavioral harassment. However, transient killer whales remain in Hood Canal for extended periods during the rare occasions when they are present. Therefore, the Navy estimates that harassment exposures may occur due to underwater vibratory pile driving based on possible exposure of six transient killer whales during 30 days of pile driving.

Pursuant to MMPA Section 101(a)(5)(D), the Navy submits this application to the NMFS for an IHA for the incidental, but not intentional, taking of five marine mammal species during pile driving activities in the third year of construction of the EHW-2 between July 16, 2014, and February 15, 2015. The taking would be in the form of non-injurious, temporary harassment and is expected to have a negligible impact to these species. In addition, the taking would not have an adverse impact to the availability of these species for subsistence use.

Regulations governing the issuance of incidental take under certain circumstances are codified at 50 Code of Federal Regulations (CFR) Part 216, Subpart I (Sections 216.101–216.108). Section 216.104 sets out 14 specific items that must be addressed in requests for take pursuant to Section 101 (a)(5)(D) of the MMPA. These 14 items are addressed in Sections 1 through 14 of this IHA application.

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# 1 DESCRIPTION OF ACTIVITIES

*A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.*

## 1.1 Proposed Action

This Incidental Harassment Authorization (IHA) application covers the third year of construction (July 16, 2014, through February 15, 2015) of the second Explosives Handling Wharf (EHW-2), during which a maximum of 195 days of pile driving would occur. This number of pile driving days is based on an estimated 6.5 pile driving days per week and 30 weeks during the in-water work season (July 16 through February 15).

This section of the application describes the proposed action in its entirety to provide a context for understanding the third year's construction activities, including construction actions other than pile driving that may affect marine mammals. This is also important for consistency with other environmental documentation for this project, including the Environmental Impact Statement. It has not been determined exactly what parts of the project would be constructed during the third year, other than a maximum of 195 days of pile driving will occur, along with the general construction activities described below.

The EHW-2 will consist of two components: (1) the wharf proper (or Operations Area), including the warping wharf; and (2) two access trestles.[2] The Operations Area will include a support building and wharf cover. The warping wharf will be a long, narrow wharf extension used to position submarines prior to moving into the Operations Area. Access trestles will allow vehicles to travel between the Operations Area and the shore.

The wharf proper will lie approximately 600 feet offshore at water depths of 60 to 100 feet, and will consist of a main wharf, warping wharf, and lightning protection towers, all pile-supported. It will include a slip (docking area) for submarines, surrounded on three sides by operational wharf area. The warping wharf will extend out from the main wharf and be used to line up submarines to move into the slip. The main wharf will include an operations support building (25,700 square feet) providing office and storage space and mechanical/electrical system component housing. Additional facility support at the wharf will include heavy duty cranes suspended from the cover, power utility booms, six large lightning protection towers, and camels (operational platforms that float next to a moored vessel). The elevation of the top of the wharf deck will be 20.5 feet above mean lower low water (MLLW), and the bottom of the wharf deck will be 13 feet above MLLW. The six lightning towers will be steel frame structures, each 30 by 30 feet (total of 5,400 square feet).

The access trestles will connect the wharf to the shore. There will be an entrance trestle and an exit trestle; these will be combined over shallow water to reduce overwater area (Figures 1–1 and 1–2). The trestles will be pile-supported on 24-inch steel pipe piles driven approximately 30 feet

[2] A trestle is a framework of vertical, slanted supports and horizontal crosspieces supporting a bridge or road.

into the seafloor. Spacing between bents (rows of piles) will be 25 feet. Concrete pile caps will be cast in place and will support pre-cast concrete deck sections.[3]

The top elevation of the trestle deck will vary between 20.5 feet above MLLW at the connection to the wharf to 28.0 feet above MLLW at the shore. The bottom deck elevation will vary between 15.2 feet above MLLW at the connection to the wharf to 22.7 above MLLW at the shore.

The use of grating in construction of the trestles was considered to allow additional light to penetrate to the water. Through the design process, the United States Navy (U.S. Navy) determined that grating would be ineffective at transmitting light, due to the weight and thickness of grating required to support the operational vehicle load as required by the *Facility Design Criteria* (Lockheed Martin 2010). Additionally, it would not be possible to control stormwater runoff into Hood Canal if grating was used. Therefore, grating is not proposed for the EHW-2.

A total of up to 1,250 permanent piles ranging in size between 24 and 48 inches in diameter will be driven in water to construct the wharf (Section 1.1.1). Construction will also involve temporary installation of up to 150 falsework piles used as an aid to guide permanent piles to their proper locations (used like a template). Falsework piles will likely be steel pipe piles and will be driven and removed using a vibratory driver. Typically, falsework piles will be driven, extracted, and used as falsework at another location. At the end of their use on this project, the piles will be reused or recycled. These temporary falsework piles will be removed upon installation of the permanent piles and will not increase the area of seafloor occupied by piles. The falsework piles are accounted for in the in the overall construction schedule and pile driving duration and in the analysis of impacts from pile installation on noise, seafloor disturbance, and water quality.

The upland component of the proposed action includes an abutment as well as road and utility work at the site where the trestle comes ashore, as well as construction of three new buildings to house the functions of four buildings to be demolished (Section 1.1.3). An additional 55 piles that are 24 inches in diameter will be driven "in the dry" for the shoreline abutment to be built where the trestle comes ashore. Upland construction of the road and utility work will result in a total of approximately 3.4 acres being permanently occupied by new roads, buildings, and utilities, plus an additional 6.9 acres that will be temporarily disturbed by construction and revegetated with native species following construction. These 6.9 acres include a 5-acre laydown/staging area, which will also be cleared for construction use and revegetated following construction.

The proposed activities with the potential to affect marine mammals within the waterways adjacent to Naval Base Kitsap (NBK) at Bangor that could result in harassment under the Marine Mammal Protection Act (MMPA) of 1972, as amended in 1994, are vibratory and impact pile driving operations associated with construction of the EHW-2.

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[3] Pile caps that are cast in place are constructed at their final location by placing wooden forms and rebar and pouring concrete. Once cured, the forms are removed. Pre-cast components are formed and poured at an offsite location. They are brought to the site in their finished form and placed with a crane in their final location.

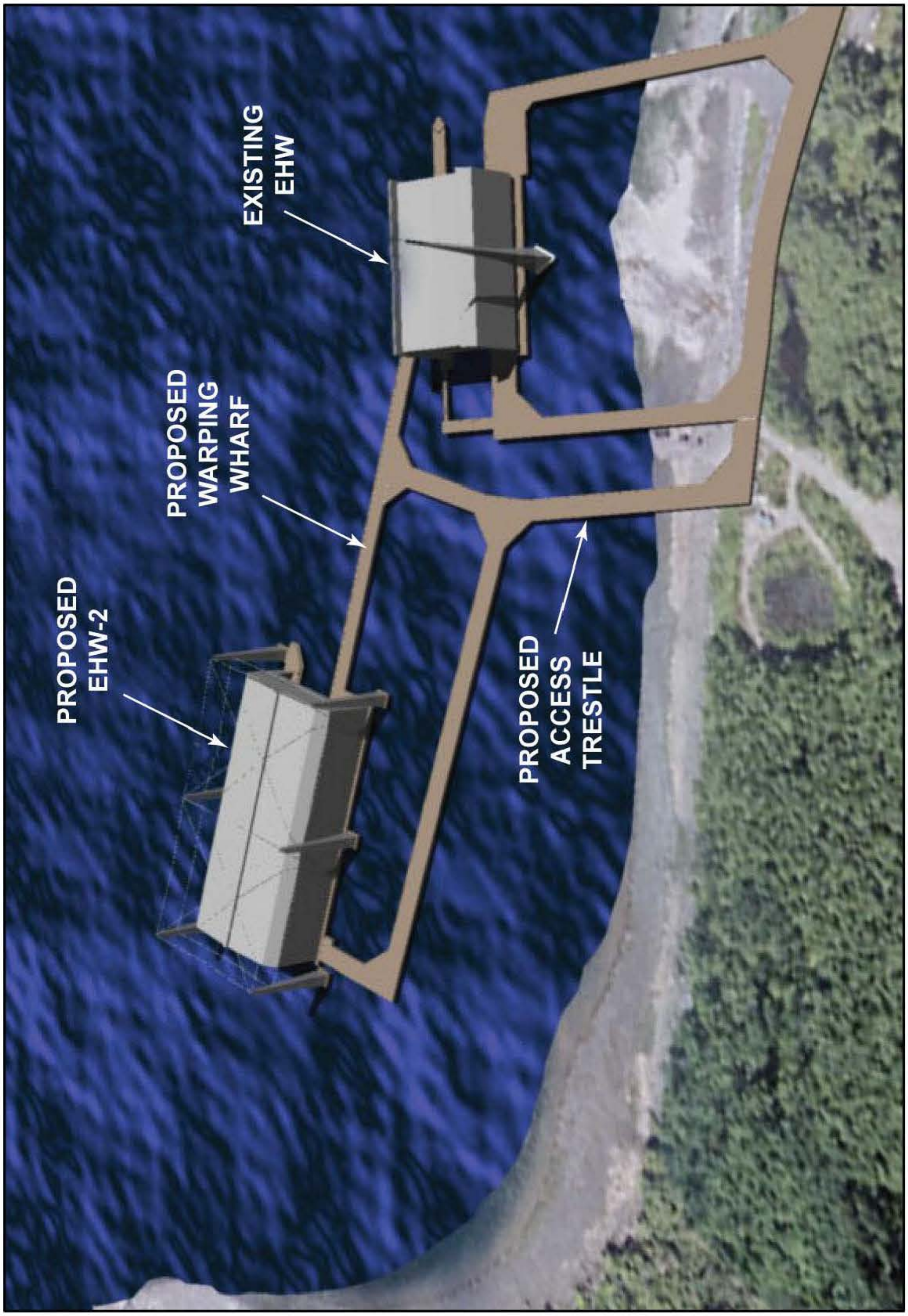


**Figure 1–1. Conceptual View of Existing EHW and Proposed EHW-2**

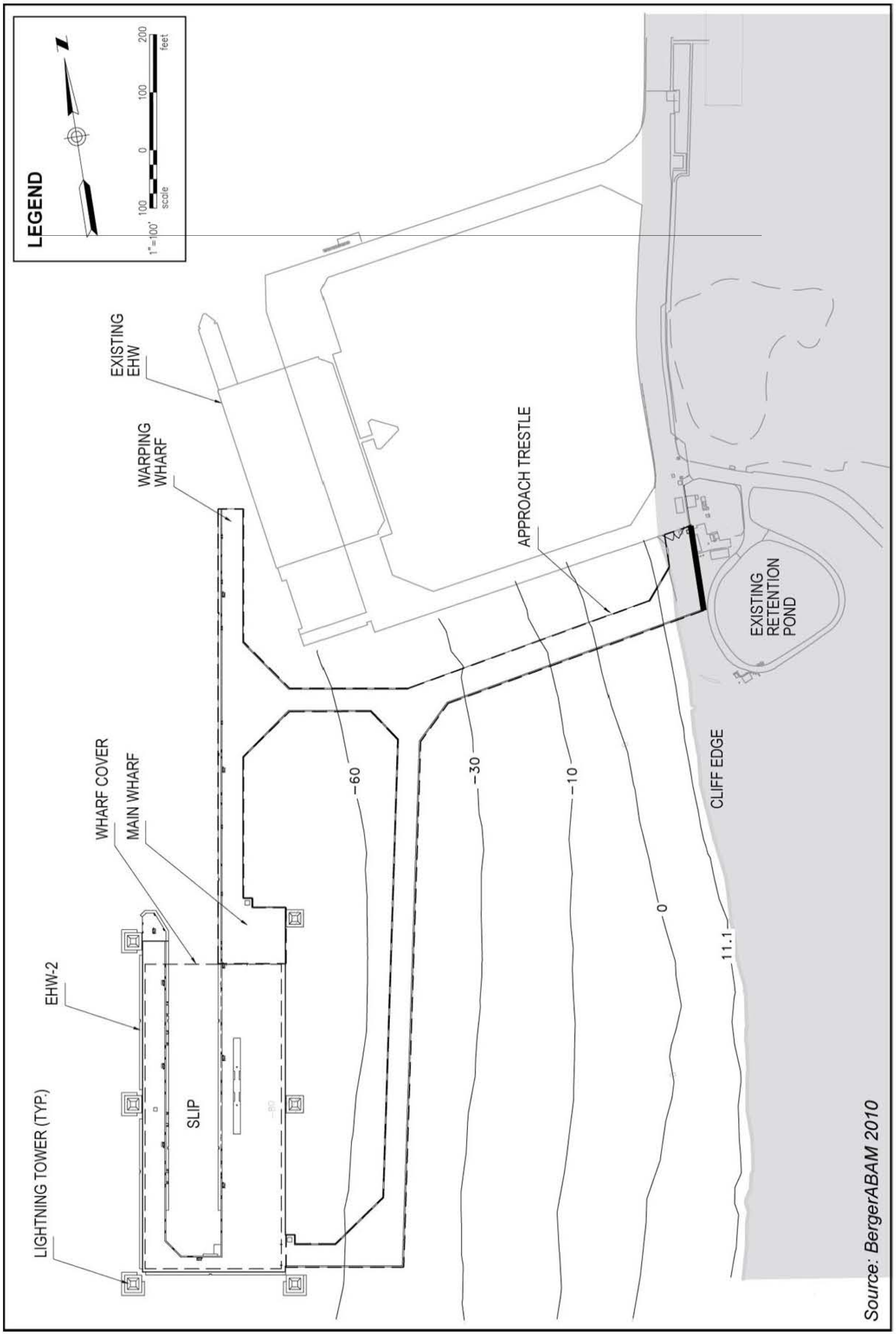


**Figure 1–2. Bathymetric View of Proposed EHW-2**

### 1.1.1 Description of Pile Driving Operations

The Navy anticipates using two types of equipment to install piles: a vibratory pile driver and an impact hammer.[4] Up to three vibratory rigs with one impact hammer rig could operate concurrently. Pile installation will utilize vibratory pile drivers to the greatest extent possible. It is anticipated that most piles will be vibratory driven to within several feet of the required depth.[5] Unless difficult driving conditions are encountered, an impact hammer will only be used only to verify ("proof") the load-bearing capacity of approximately every fourth or fifth pile. The industry standard is to proof every pile with an impact hammer. However, in an effort to reduce blow counts, the engineer of record has agreed to only proof every fourth or fifth pile. Proofing involves striking a driven pile with an impact hammer to verify that it provides the required load-bearing capacity, as indicated by the number of hammer blows per foot of pile advancement. A maximum of 200 strikes will be required to proof each pile. Pile production rates are dependent upon required embedment depths, the potential for encountering difficult driving conditions, and the ability to drive multiple piles without a need to relocate the driving rig. For the shallow piles, driving in optimal conditions, using multiple driving rigs, it may be possible for the contractor to vibrate enough pilings that would require proofing up to five piles in a day. It is estimated that on most days, a single impact hammer would be used to proof up to five piles, with each pile requiring a maximum of 200 strikes. Under this likely scenario, it is estimated that up to a maximum of 1,000 strikes would be required per day.

If difficult subsurface driving conditions (i.e., cobble/boulder zones) are encountered that cause "refusal" with the vibratory equipment, it may be necessary to use an impact hammer to drive some piles for the remaining portion of their required depth. The worst-case scenario is that a pile will be driven for its entire length using an impact hammer. All piles will be driven into subsurface conditions that consist of glacial till with the large potential for encountering cobbles and boulders. Given the uncertainty in the types and quantities of erratics that may be encountered, and the depth at which they may be encountered, the number of strikes necessary to drive a pile its entire length could range from about 1,000 to 2,000 strikes per pile.

Under the likely pile driving scenario described above, less than 1,000 impact strikes would be required per day. A less likely, but possible scenario estimates driving three piles full length (2,000 strikes per pile) after the piles have become hung on large boulders early in the installation process, and the proofing of an additional two piles at 200 strikes each with an impact hammer. This worst-case scenario would result in a maximum of 6,400 strikes per day.

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[4] Vibratory pile drivers use hydraulic-powered weights to vibrate a pile until the surrounding sediment liquefies; this enables the pile to be driven into the ground using the weight of the pile plus the pile driver. Impact hammers use a rising and falling piston to repeatedly strike a pile and drive it into the ground.

[5] Pile drivability is, to a large degree, a function of soil conditions and pile hammer. The soil conditions encountered during geotechnical explorations indicate existing conditions generally consist of fill or sediment of very dense glacially overridden soils. Recent experience at two other construction locations along the Bangor waterfront at NBK indicates that the piles should be able to be driven with a vibratory hammer to proper embedment depth. However, difficulties during pile driving may be encountered as a result of obstructions that may exist throughout the project area. Such obstructions may consist of rocks or boulders within the glacially overridden soils. If difficult driving conditions occur, increased usage of an impact hammer will occur.

Depending on the type of piles being driven and the number of rigs operating, between one and eight piles would be driven per day. Up to three vibratory rigs and one impact rig could be used at a time. The number of in-water pile days for the project as a whole will range between 200 and 400 depending on pile driving scenarios (minimum and maximum impact driving). Pile production rate (number of piles driven per day) is affected by many factors: size, type (vertical vs. angled), and location of piles; weather; number of driver rigs operating; equipment reliability; sound mitigation requirements; geotechnical (subsurface) conditions; and work stoppages for security or environmental reasons (such as presence of marbled murrelets or marine mammals). Similar to the first and second construction periods, it is possible that the contractor may operate up to three rigs onsite. Due to space constraints, only one rig can maneuver in to drive the shallow piles while the other two rigs have room to maneuver in the deeper water. The minimum pile driving day scenario was developed conservatively assuming up to three rigs operating at once and the following pile production rates:

- Shallow trestle piles (24 inches): 4 per day
- Other trestle piles (36 inches): 6 per day
- Lightning tower plumb (large vertical 36 inches) piles: 4 per day
- Lightning tower batter (angled 36 inches) piles: 2 per day
- Wharf/warping wharf plumb piles (48/36 inches): 3 to 4 per day
- Dolphin batter piles: 1 to 2 per day
- Fender piles (24 inches): 7 to 8 per day
- These assumptions result in an estimated 200 in-water pile driving days plus 11 land-based pile driving days (Section 1.1.3) for the entire project.

The maximum pile driving day scenario assumed no more than two rigs operating at once and the following production rates:

- Shallow trestle piles: 2 per day
- Other trestle piles: 3 per day
- Lightning tower plumb piles: 2 per day
- Lightning tower batter piles: 1 per day
- Wharf/warping wharf plumb piles: 2 per day
- Dolphin batter piles: 1 per day
- Fender piles: 5 per day
- These assumptions result in an estimated 400 in-water pile driving days plus 11 land-based pile driving days (Section 1.1.3) for the entire project.

Pile driving will typically take place 6 days per week, but could occur 7 days per week. The allowable season for in-water work, including pile driving, on NBK at Bangor is July 16 through February 15, which was established by the regulatory agencies (Washington Department of Fish and Wildlife [WDFW] in coordination with the National Marine Fisheries Service [NMFS] and the U.S. Fish and Wildlife Service [USFWS]) to protect juvenile salmon. Impact pile driving during the first half of the in-water work window (July 16 to September 23) will only occur between 2 hours after sunrise and 2 hours before sunset to protect breeding marbled murrelets. Between September 24 and February 15, construction activities occurring in the water will occur during daylight hours (sunrise to sunset). Other construction will occur between 7:00 a.m. and 10:00 p.m. 6 days per week, but could occur 7 days per week.

Under either the 200-day or 400-day pile driving scenario, there will be no more than 195 in-water pile driving days in the third work season covered by this IHA application. This number was established by calculating the maximum number of days available during the in-water work season (July 16, 2014, through February 15, 2015), assuming 6.5 days of pile driving activity per week and 30 weeks between July 16 and February 15.

The number of construction barges (derrick and material) onsite at any one time will vary between two and eight depending on the type of construction taking place. The maximum number of eight barges will likely be present at the beginning of construction, with multiple rigs and their support barges required to complete the work at various areas of the wharf. As pile installation progresses, the area will become congested, limiting the space available to support the pile driving rigs and barges. Also, as sections of the wharf are completed (e.g., the abutment, trestle) the need for some of the rigs/barges will be reduced. As a result, fewer barges will likely be necessary in each subsequent construction window. Tug boats will tow barges to and from the construction site and position the barges for construction activity. Tug boats will leave the site once these tasks were completed and so will not be onsite for extended periods; there will be no more than two tug boats onsite at any one time. Up to six smaller skiff type boats (less than 30 feet in length) will be onsite performing various functions in support of construction and sensitive species monitoring. Measures will be implemented to ensure that mooring lines do not drag on the seafloor or entangle vegetation.

#### 1.1.2 Project Details

For the access trestles and wharf combined, total overwater area will be 273,108 square feet (6.3 acres). There will be up to 1,250 permanent piles displacing 9,015 square feet of seafloor (Table 1–1).

Total length of the access trestles will be 1,849 feet. Approximately 1,400 feet of this will be 40 feet wide (trestles separate) and 449 feet will be 48 feet wide (trestles combined). Total overwater area for the trestles will be 81,208 feet (1.9 acres). The length of trestle lying above -30 feet MLLW will be approximately 407 feet, with an area of 17,859 square feet (0.4 acre).

A total of 290 trestle piles will be required, 90 of which will lie above -30 feet MLLW. Spacing between bents (rows of piles) will be 25 feet. Concrete pile caps will be cast in place (onsite) and will support pre-cast (offsite) concrete deck sections. Pile driving equipment will be a 4,400 inch-pound vibratory driver and a 122,435 foot-pound impact hammer. Pile driving for the trestle will require one large derrick barge (70 by 200 feet) and one pile barge (50 by 200 feet); deck construction will require one smaller derrick barge and one material barge (50 by 200 feet).

The main wharf will be approximately 632 by 250 feet. Total overwater area, including the covered area, will be 152,200 square feet (Figure 1–2) including 43,500 square feet for the slip. The warping wharf will be approximately 688 by 40 feet (34,300 square feet including the wider connection to the access trestle), for a total wharf overwater area of 186,500 square feet. In addition, the six lightning towers will each be 30 by 30 feet (total of 5,400 square feet). Total overwater area for the main wharf, warping wharf, lightning towers, and trestles will be 273,108 square feet (6.3 acres).

**Table 1–1. Physical Features of the Proposed EHW-2**

| Facility Feature | Quantity/Dimensions |
|---|---|
| Main Wharf Dimensions and Area | 632 × 250 feet: 158,000 sq ft<br>(152,200 sq ft covered overwater area) |
| Warping Wharf Dimensions and Area | 688 × 40 feet: 34,300 sq ft<br>including connection to access trestle |
| Lightning Tower Dimensions and Area | Six, each 30 × 30 feet<br>Total area 5,400 sq ft |
| Trestle Dimensions and Area | 1,849 feet long; 40–48 feet wide:<br>81,208 sq ft |
| Total Overwater Area | 273,108 sq ft (6.3 acres) |
| Overwater Area Shallower than -30 feet MLLW | 17,859 sq ft (0.4 acre) |
| Total Number of In-Water Piles | Up to 1,250 |
| Number and Size of Main Wharf Piles | 140 24-inch<br>157 36-inch<br>263 48-inch |
| Number and Size of Warping Wharf Piles | 80 24-inch<br>190 36-inch |
| Number and Size of Lightning Tower Piles | 40 24-inch<br>90 36-inch |
| Number and Size of Trestle Piles | 57 24-inch<br>233 36-inch |
| Number of Piles Shallower than<br>-30 feet MLLW | Approximately 90 |
| Falsework piles (temporary) | Up to 150, 18- to 24-inch |
| Area of Seafloor Displaced by Piles | 9,015 sq ft (0.2 acre) |
| Trestle Abutment at Shore | 103 feet long with 69-foot wing wall on north end |
| Number of Abutment Piles (upland) | 55 (all 24 inch) |
| Excavation for Abutment | 2,760 cu yd, 300 cu yd below MHHW<br>Armor rock: 520 cu yd |
| New Impervious Surface (paved road) | 3.6 acres |
| Construction Laydown Area (temporary) | 5 acres |
| Upland Vegetation Disturbed | Temporary: 6.9 acres<br>Permanent: 3.4 acres |
| Pile Driving Duration | Maximum of 195 pile driving days in third in-water work season covered by this IHA (July 16, 2014, through February 15, 2015). Total of 211–411 days over 3 in-water work seasons* |
| Total Construction Duration | 42–48 months |

cu yd = cubic yards; MHHW = mean higher high water; sq ft = square feet

* In-water work season is July 16 to February 15.

The wharf deck will consist of pre-cast concrete sections, supported on cast-in-place concrete pile caps. The elevation of the bottom of the wharf deck will be +13 feet MLLW. The cover of the operations area and the lightning towers will be steel frame structures.

The wharf will be supported on a combination of large diameter (48-inch) plumb (vertical) piles, and smaller (24- to 36-inch) plumb and batter (angled) piles, all of which will be located in greater than 60 feet of water (Figure 1–2).There will be 263 48-inch piles and 297 piles ranging in diameter from 24 to 36 inches (Table 1–1). Piles will be driven into the seafloor to a depth of approximately 60 feet. Spacing between bents (rows of piles) will range from 25 to 26 feet. The primary pile driving method will be vibratory pile driver (156,000 to 264,000 inch-pounds).

Impact hammer (122,500 to 297,700 foot-pounds) pile driving will also be needed. Pile driving for the wharf portion will require one to two large derrick barges (approximately 70 by 200 feet) and one to two pile barges for the duration of pile driving. One derrick barge and two material barges will be needed for wharf deck construction; construction of the lightning towers will require one derrick barge and one material barge.

The combined duration (wharf and trestle) of pile driving will be 211 to 411 days, including 11 days for the upland abutment piles, over three in-water construction seasons. The combined duration of construction will be 42 to 48 months including three in-water construction seasons. In the third construction season covered by this IHA application, there will be a maximum of 195 pile driving days.

Operational lighting on the wharf and access trestles will range from 100-watt (W) metal halide lights to 1,500W quartz lights. Lights over the surrounding water will consist of pulse-start metal halide lights, plus 1,500W quartz back-up lights.

The wharf will be provided with full hotel service capability including power, potable water, fire protection, sewage connections, Ship Overboard Drainage collection, telephone, cable, and Local Area Network service.

#### 1.1.3 Upland Component

Except for the abutment piles discussed below, the upland component of the project will not affect marine mammals. This component is described briefly here for completeness and to provide the context for the overall proposed action.

At the site where the EHW-2 trestles come ashore, three short roads will be constructed, three culverts will be installed to provide drainage from the roads and seeps in the area, two retaining walls will be constructed, and various utilities will be installed (Figure 1-3). The water in the culverts will be treated using low impact development (LID) water quality catch basins prior to discharge to Hood Canal through a single combined outfall. A total of 1.4 acres will be permanently occupied by the new roads, culverts, retaining walls, and utility structures. An additional 1.6 acres will be temporarily disturbed and revegetated with native species following construction. A 0.2-acre wetland will be impacted. Upland construction will use standard construction techniques, equipment, and Best Management Practices (BMPs).

A concrete abutment will be built at the face of the shore cliff, under the trestle(s) where the trestle(s) comes ashore. This abutment will be 10 feet high and 103 feet long plus a 69-foot wing wall, and require 520 tons of armor rock. Excavation will be 2,760 cubic yards; all of this material will be used for backfill either at the abutment or at another part of the adjoining upland construction site. The abutment will be pile-supported and constructed from the land side. Following construction, the exposed part of the abutment will lie above mean higher high water (MHHW), although excavation and pile installation below MHHW will be needed for construction. Beach contours will be restored to pre-construction conditions. The abutment will be supported by 55 24-inch steel piles. These piles will be installed in the same manner as the in-water piles discussed above. Abutment construction will take about 20 days including 11 days for pile installation.

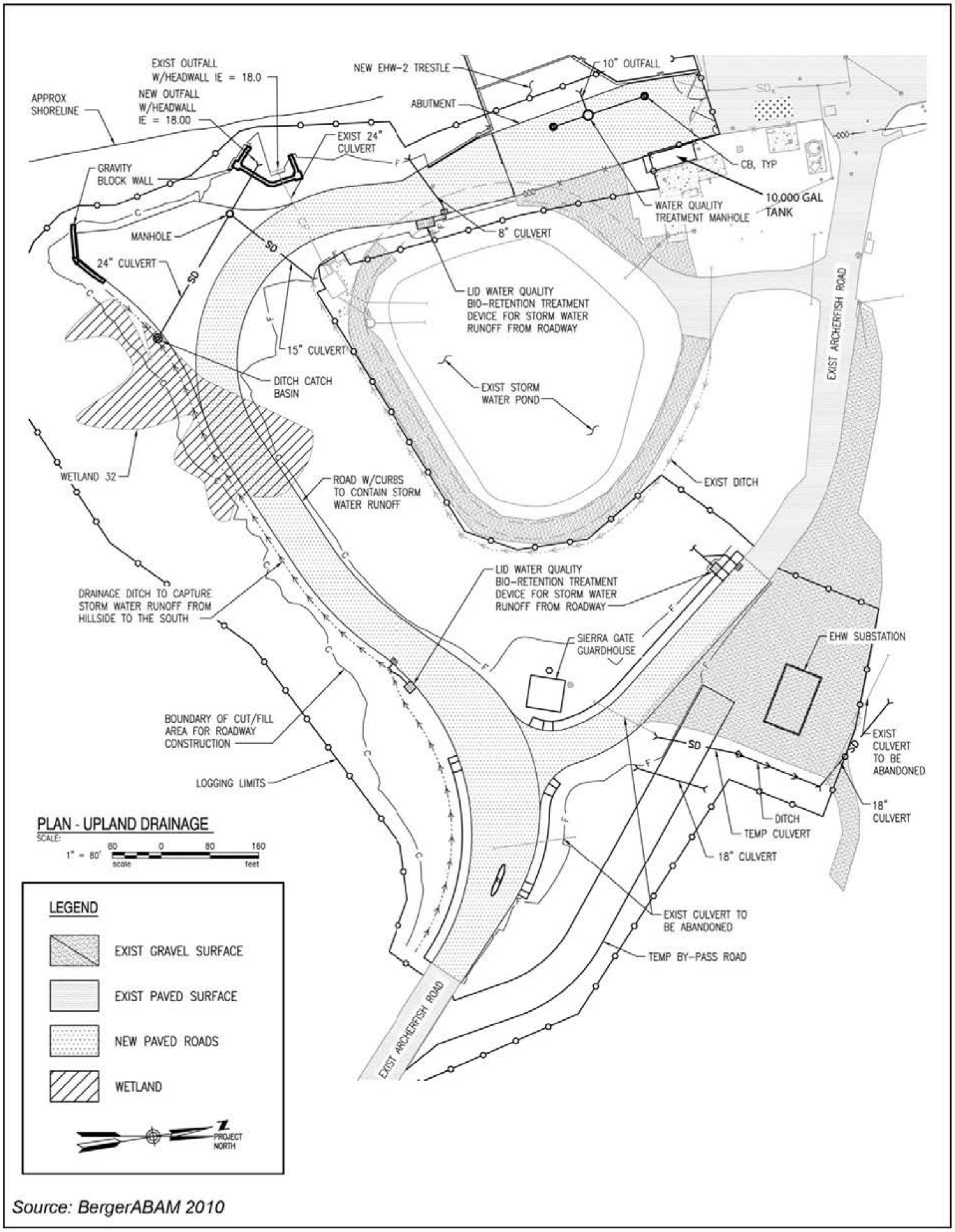


**Figure 1–3. Upland Project Features**

A 5-acre laydown area will be needed for the upland construction; the proposed site is vegetated, has no wetlands, and is located on the east side of Archerfish Road approximately 4,000 feet south of the proposed EHW-2. Storage of material and equipment as well as soil stockpiling will occur within the laydown area. Following construction, this area will be revegetated with native forest species. No new parking lots for construction parking or operational parking will be needed. Archerfish Road will be the primary haul route for construction.

Non-pile driving construction will take place between 7:00 a.m. and 10:00 p.m. 6 days per week, but could occur 7 days per week. The number of construction workers will be approximately 100. Construction material will arrive via truck and barge. Construction debris will be hauled off of the site to an approved disposal facility.

As part of the proposed action, approximately 20 existing facilities and/or structures in proximity to the EHW-2 will be modified or demolished to comply with Department of Defense Explosives Safety Board (DDESB) and Naval Ordnance Safety and Security Activity (NOSSA) requirements to protect buildings located in the vicinity of explosives handling operations. The scope of facility modifications will primarily include replacement of doors and windows and possibly the modification or addition of building structural components, such as walls, interior and exterior columns, beams, and joists, and the replacement of existing roof systems. These modifications will not affect vegetated or undeveloped areas near the buildings to be modified.

Three new buildings will be constructed to house the functions of four of the buildings to be demolished. Three buildings will be at a single site at an existing parking lot on the Lower Base, approximately 2,500 feet from the shoreline (Figure 2–2). The buildings and associated roads, parking, and sidewalks will permanently occupy approximately 2.6 acres.

A fourth facility, the pure water facility, will be relocated to the landward end of the southern trestle to Delta Pier, about a mile south of the existing EHW. The new facility will cover approximately 0.5 acre.

#### 1.1.4 Work Accomplished Under First-Year and Second-Year IHAs

During the first in-water work season, the contractor completed installation of 184 piles to support the main segment of the access trestle. Driven piles ranged in size from 24 to 36 inches in diameter in depths ranging from 0 to 50 feet. A maximum of two vibratory rigs were operated concurrently and only one impact hammer rig was operated at a time. All piles were driven with a vibratory pile driver to the greatest extent possible, after which selected piles were impact driven for their final 10 to 15 feet for proofing. Any piles that could not be driven to their desired depths using the vibratory hammer were impact driven for the remainder of their required driving depth. Noise attenuation measures (i.e., bubble curtain) were used during all impact hammer operations. Marine mammal monitoring was conducted during pile driving.

In the first IHA application, NMFS Headquarters requested a soft-start approach prior to vibratory pile driving. In the first year of construction, the soft start was implemented during vibratory pile installation, but the soft start resulted in a near-miss accident (cheek plates weighing 200 pounds sheared off the crane block and fell to the barge deck, narrowly missing construction personnel) and unexpected damage to the crane block and boom.

A Navy investigation determined that the incident was caused by damage to the crane from powering down the vibratory hammer after the soft-start procedure. During power down from soft start, energy from the vibratory hammer was transferred to the crane boom and block via the load fall cables and rigging, resulting in unexpected damage to both the crane block and crane boom. The cranes were purchased new at the beginning of construction. After the first in-water construction season, the crane manufacturer (Skanska USA) inspected the crane booms and discovered structural fatigue in the boom lacing and main structural components. This would ultimately result in a collapse of the crane boom. The vibratory hammer manufacturer (American Piledriving Equipment) visited the work site on multiple occasions to attempt to install dampers to mitigate the problem. Results were unsuccessful.

The Navy is using American Piledriving Equipment (APE) 600 hammers to vibrate the EHW-2 piles through stiff glacial soil to get as close as possible to required embedment depth. This reduces the need for impact hammer driving. A smaller APE 400 hammer was used during the 2011 test pile program, but this equipment did not achieve an adequate embedment depth. EHW-2 will be one of the deepest pile-supported wharves in the world, and is a larger pile driving effort than recent WSDOT projects. Other projects such as the Bremerton Ferry Terminal wingwall repair project have implemented soft-start procedures for vibratory drivers. However, the Bremerton project involves driving sixteen 24-inch piles and four 30-inch piles in depths ranging from 16 to 26 feet below MLLW, in contrast to the large number of 36-inch and 48-inch piles that will be installed in depths ranging up to 60 feet below MLLW for EHW-2. The significantly shorter piles in the WSDOT projects requires less energy to drive and a smaller hammer resulting in less weight on the crane.

Based on the equipment damage and the life-threatening near-miss incident during the first construction year, NMFS agreed to remove the requirement for a soft-start procedure during vibratory pile driving for construction year 2. Because the same pile driving equipment and pile sizes will be used during construction year 3 for EHW-2, the Navy does not propose to implement soft starts for vibratory pile driving. During the second season, installation of 411 total piles, including all 315 of the wharf deck plumb piles (non-fender) and 24 of the 34 total wharf deck Lead Rubber Bearing dolphins (clusters of 4 piles per dolphin) was completed. Installed piles ranged in size from 36 to 48 inches in diameter in depths ranging from 40 to 95 feet. A maximum of two vibratory rigs operated concurrently and only one impact hammer rig operated at a time. All piles were driven with a vibratory pile driver to the greatest extent possible, after which selected piles were impact driven for their final 10 to 15 feet for proofing. Any piles that could not be driven to their desired depths using the vibratory hammer were impact driven for the remainder of their required driving depth. Noise attenuation measures (i.e., bubble curtain) were used during all impact hammer operations. Marine mammal and marbled murrelet monitoring was conducted during pile driving.

During the third season, final installation of the wharf deck Lead Rubber Bearing dolphins, piling for the warping wharf, lightning towers, and trestle deck closure, as well as all fender piles, is expected to be completed. The overall intensity of pile driving will remain unchanged from seasons one and two. The project remains on schedule to complete in January 2016.

#### 1.1.5 Operations

Operation of the EHW-2 will not result in an increase in boat traffic along the Bangor waterfront on NBK. Rather, a portion of the ongoing operations and boat traffic at the existing EHW and other facilities within the Waterfront Restricted Area (e.g., Delta Pier and Marginal Wharf) will be diverted to the EHW-2. The EHW-2 may be used as a backup explosives handling facility for OHIO class guided missile submarines (SSGNs) currently homeported on NBK at Bangor when there are no TRIDENT operations at the existing EHW. The EHW-2 may also provide temporary berthing when no ordnance handling operations are occurring at either wharf. No increase in boat traffic will be required to achieve planned operations. The increase in future operations at the waterfront will only require that boats remain at an EHW longer when in port for maintenance and upgrades. The overall level of traffic and activity along the Bangor waterfront on NBK will not increase as a result of operating the EHW-2. Operation of the EHW-2 may require approximately 20 additional military and civilian personnel. The EHW-2 will be staffed 24 hours per day, 7 days per week.

Maintenance of the EHW-2 will include routine inspections, repair, and replacement of facility components as required. It will not be necessary to replace piles during the design life of the EHW-2. Fouling organisms will not be removed from piles.

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# 2 LOCATION AND DURATION OF ACTIVITIES

*The dates and duration of such activity and the specific geographical region where it will occur.*

## 2.1 Region of Activity

NBK at Bangor is located on Hood Canal, which is a long, narrow, fjord-like basin of the western Puget Sound (Figure 2–1). Oriented northeast to southwest, the portion of the canal from Admiralty Inlet to a large bend, called the Great Bend, at Skokomish, Washington, is 52 miles long. East of the Great Bend, the canal extends an additional 15 miles to the headwaters at Belfair. Throughout its 67-mile length, the width of the canal varies from 1 to 2 miles and exhibits strong depth/elevation gradients and irregular seafloor topography in many areas. Although no official boundaries exist along the waterway, the northeastern section of the canal extending from the mouth of the canal at Admiralty Inlet to the southern tip of Toandos Peninsula is referred to as northern Hood Canal. The proposed project area is located within this region.

The proposed location for the EHW-2 is immediately south of the existing EHW (Figure 2–2). Two restricted areas are associated with NBK at Bangor, Naval Restricted Areas 1 and 2 (33 Code of Federal Regulations [CFR] 334.1220), which are depicted in Figure 2–3 relative to the project area. The regulations associated with Naval Restricted Area 1 indicated that no persons or vessels shall enter this area without permission from the Commander, Naval Submarine Base at Bangor, or his/her authorized representative. The regulations associated with Naval Restricted Area 2 indicate that Navigation will be permitted within that portion of the circular area not lying within Naval Restricted Area 1 at all times except when magnetic silencing operations are in progress.

## 2.2 Activity Area Description

### 2.2.1 Bathymetric Setting

In northern Hood Canal, water depths in the center of the waterway near Admiralty Inlet vary between 300 and 420 feet. As the canal extends southwestward toward the Olympic Mountain Range and Thorndyke Bay, water depths shoal to approximately 160 feet over a moraine deposit. This deposit forms a sill across the short axis of the canal in the vicinity of Thorndyke Bay, which limits seawater exchange with the rest of Puget Sound. The Bangor waterfront on NBK occupies approximately 5 miles of the shoreline within northern Hood Canal (1.7 percent of the entire Hood Canal coastline) and lies just south of the sill feature. Depths of the in-water project site are provided in Figure 2–4. The width of the canal is approximately 1.5 miles at the site, 2.2 miles at the northern end of NBK at Bangor, and constricts to approximately 1.1 miles near the southern end near Hazel Point. The furthest direct line of site from the project site is 8.4 miles to the north and 4.2 miles to the south (see Figure 2–4).

Figure 2–1. Vicinity Map

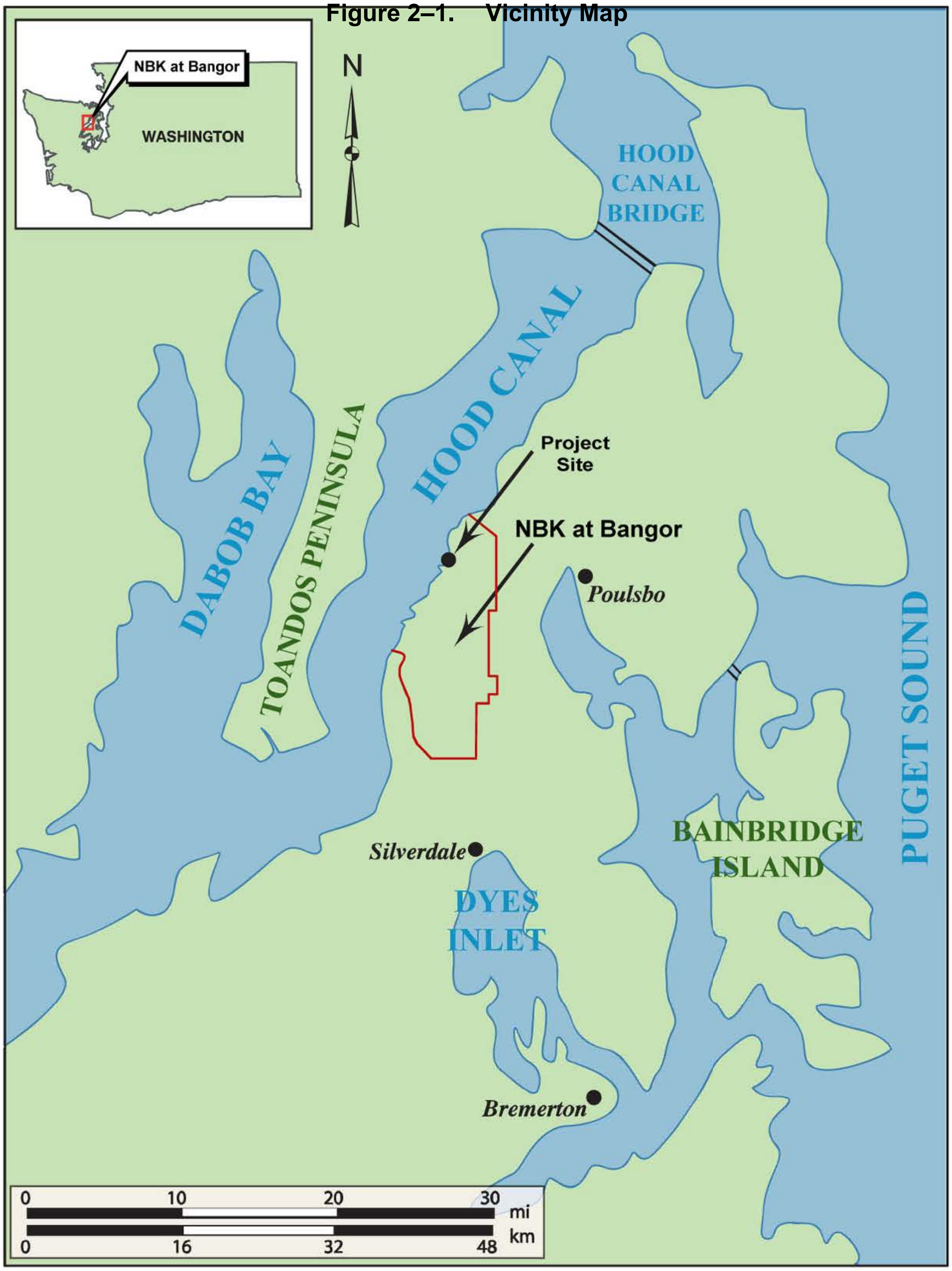



Figure 2–1. Vicinity Map

**Figure 2–2. Location of the Proposed Project at the Bangor Waterfront**


Figure 2–2. Location of the Proposed Project at the Bangor Waterfront


Figure 2–3. NBK at Bangor Restricted Areas

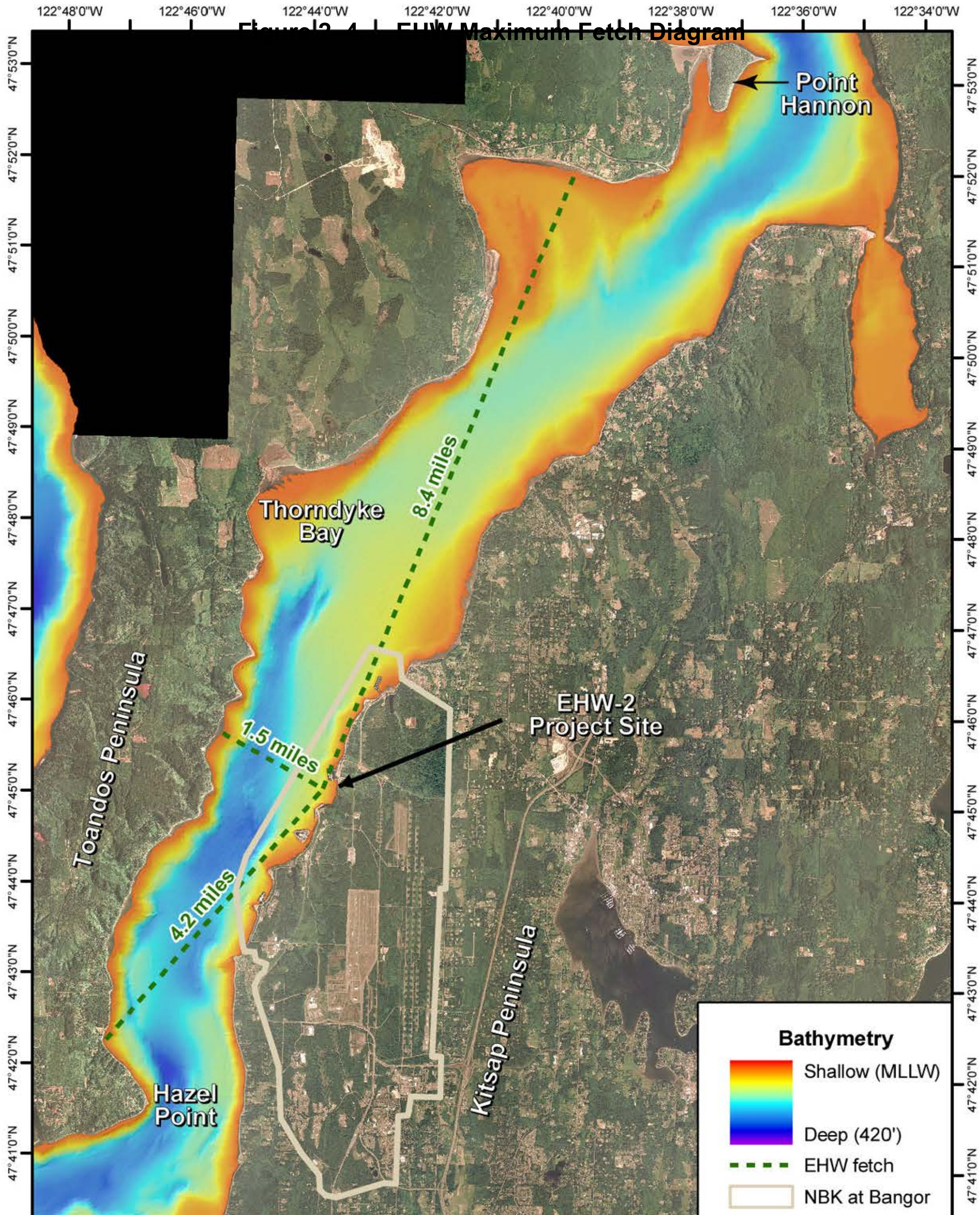



**Figure 2–4. EHW Maximum Fetch Diagram**

0 1 2
Miles

*NOTE:*
*Coordinate System: WA State Plane (North)*
*Horizontal Datum: NAD83*
*Vertical Datum: MHW*
*Units: feet*
*DEM provided by University of Washington*

### 2.2.2 Tides

The tides in Hood Canal are mixed, diurnal-semidiurnal with a range directly dependent upon the phase and alignment of the lunar and solar gravitational influences on the regional tides (URS 1994; Morris et al. 2008). The astronomic influences (tides) on water level within Puget Sound and Hood Canal result in one flood and one ebb tidal event with a small to moderate range (1 to 6 feet) and a second flood and second ebb with a larger range (8 to 16 feet) during a 24-hour and 50-minute tidal day. As a result, higher high, lower high, higher low, and lower low water levels are recorded within each tide day.

Since the tides within Hood Canal are mixed diurnal-semidiurnal, this body of water is subject to one major flushing event per tide day when approximately $1.1326 \times 10^9$ cubic yards (or 3 percent of the total canal volume) is exchanged over a 6-hour period. Due to the wide range of tidal heights that can occur in this body of water, the actual seawater exchange volume for Hood Canal ranges from 1 percent during a minor tide to 4 percent during a major tide.

Despite considerable tidally driven seawater influx within the basin, some studies have estimated water residence time in the southern and middle portions of Hood Canal can be up to one year due to the natural limitation on seawater exchange (i.e., bathymetry) (Warner et al. 2001; Warner 2007). However, at the project site, the majority of the daily volume of seawater exchange flows directly across the Bangor waterfront area on NBK. As a result, the degree of flushing that occurs at the project area is relatively high and the characteristics of this seawater more closely track the physical, chemical, and biological conditions of Puget Sound than southern Hood Canal.

### 2.2.3 Circulation and Currents

Tidal currents and resulting circulation patterns within Hood Canal are complex due to the configuration of the basin, as well as the mixed diurnal-semidiurnal tidal regime. Current measurements obtained from the reaches of northern Hood Canal in the summer of 2007 indicate that tidal phase and range have a significant impact to the velocity of currents associated with the flood and ebb tides (Morris et al. 2008). The larger tidal ranges promote higher velocity currents and increased flushing of the basin, while small to moderate tidal ranges yield a diminished tidal current regime and limit the volume of seawater exchange between Hood Canal and Puget Sound. Seawater that enters the canal from Puget Sound during an incoming flood tide tends to be cooler, more saline, and well-oxygenated relative to the Hood Canal waters. As a result, the incoming Puget Sound water has a tendency to sink to the bottom of the canal as it flows over the sill and move south during each flood tide, while the lower density Hood Canal water tends to remain in the upper water column.

Current flow (speed and direction) at the project area is primarily a function of tidal action based on the phase and range of each tide within the mixed diurnal-semidiurnal regime, and current velocities in the shallower water areas (less than 50 feet) around the project area are variable and complex. The magnitude or instantaneous velocity of these fluctuating water column currents ranges from 0 to 0.88 foot per second (ft/sec) within the 30- to 65-foot water depth interval. However, current flow in any one direction is short-lived and inconsistent in magnitude, with relatively few periods of time when sufficient energy (0.7 ft/sec) exists to exceed the threshold for re-suspending deposits of unconsolidated material on the seafloor (Boggs 1995). Statistical summaries show that time-averaged net flow is within the 0.07 to 0.10 ft/sec range in the upper water column and less than 0.03 ft/sec in proximity to the seafloor.

The nearshore current observations at the project area and other NBK at Bangor piers and wharves in the summer of 2006 suggest that tidal currents were inconsistent with water level (tide) measurements. Rather than the typical relationship where maximum current corresponds to mid-flood or mid-ebb in the water level record, maximum flow velocities at the EHW-2 project site aligned with water levels at the high and low tide. Furthermore, the direction of nearshore flow often ran counter to expectations in a normal system, with flood tide coinciding with northeastward currents and ebb tide resulting in southwesterly currents (Morris et al. 2008).

#### 2.2.4 Sea State

Apart from larger impacts associated with large-scale changes in weather and ocean circulation in the Pacific Basin, seasonal variability in Hood Canal circulation can occur in the winter, when strong meteorological events (e.g., storms, high winds) are more prevalent. Regardless of direction, winds with velocities in excess of 25 knots occur relatively infrequently in the Puget Sound region (Morris et al. 2008). The typically light winds afforded by the surrounding highlands (Olympic and Cascade Mountain Ranges) coupled with the fetch-limited environment of Hood Canal result in relatively calm wind conditions throughout most of the year. However, the northern and middle sections of Hood Canal are oriented in the southwest to northeast direction. Therefore, organized coastal storm events that reach land in the late autumn and winter months, as well as fair weather systems in the spring and summer exhibiting wind speeds in excess of 20 knots, have the capability to generate substantial wind waves due to increased fetch and/or alter normal tidal flow within the basin.

However, the project area is afforded some protection by the coastline of both Kitsap and Toandos Peninsulas (see Figure 2–4). Using a maximum fetch of 8.4 miles between the project area and the north shore of Thorndyke Bay to the north-northeast, estimates indicate that a 20-knot sustained wind has the capability to generate average wave heights of 1.9 feet (Beaufort Sea State [BSS] of 2) and a 30-knot wind event could produce wave heights of 3.1 feet (BSS=3) (Coastal Engineering Research Center [CERC] 1984). The maximum fetch to the southwest is one-half that to the northeast (4.2 miles), and could yield average waves of 1.3 feet in height (BSS=2) in a 20-knot wind, and 1.9 feet (BSS =2) in a 30 knot wind. Maximum wave heights that would be expected in these weather conditions would actually be 67 percent higher than average estimates reported above. Thus, a weather event capable of generating waves with an average height of 3.1 feet (BSS=3) could also yield waves with maximum heights of 5.1 feet (BSS=4) (CERC 1984).

#### 2.2.5 Water Temperature

Water temperatures in the Strait of Juan de Fuca and Puget Sound typically range from 44 to 46 degrees Fahrenheit (°F) throughout the winter months (mid-December through mid-March). Surface waters slowly warm throughout the spring and summer due to increased solar heating, reaching temperatures of 50°F in mid-May or early June to a maximum temperature of 54°F during the month of August. Beginning in September, water temperatures begin to decrease over time, falling 6 to 8°F over the next 3 months due to decreasing levels of solar radiation. Occasionally, anomalies in this pattern of heating and cooling are detected in the data record, but are often short in duration (1 to 2 weeks). Monthly mean water temperatures along the Bangor waterfront on NBK in 2005–2006 are summarized in Table 2–1. Similar water temperature patterns were measured in 2007–2008 (Hafner and Dolan 2009). Nearshore areas (water depths range from 1 to 60 meters) are susceptible to greater temperature variations due to seasonal fluxes in solar radiation input.

**Table 2–1. Monthly Mean Surface Water Temperatures (°C/°F)**

| Sampling Month | Nearshore Temperature | Offshore Temperature |
|---|---|---|
| July 2005 | 14.3°C (57.8°F) | 11.6°C (52.9°F) |
| August 2005 | 13.8°C (56.8°F) | 13.5°C (56.3°F) |
| September 2005 | 14.9°C (58.8°F) | 11.6°C (52.9°F) |
| January 2006 | 8.2°C (46.8°F) | --- |
| February 2006 | 8.1°C (46.6°F) | --- |
| March 2006 | 8.5°C (47.3°F) | 8.3°C (46.9°F) |
| April 2006 | 9.6°C (49.3°F) | 9.3°C (48.7°F) |
| May 2006 | 10.9°C (51.6°F) | 11.0°C (51.8°F) |
| June 2006 | 13.2°C (55.8°F) | --- |

**Source:** Phillips et al. 2009

°C = degrees Celsius; °F = degrees Fahrenheit

Data are from 13 nearshore and 4 offshore stations along the Bangor waterfront on NBK. Those stations near the EHW-2 project site are shown in Figure 2–5.

--- No data were collected at this depth during this sampling month.

### 2.2.6 Stratification and Salinity

The waters of Hood Canal surrounding the EHW-2 project site reflect a stratified water column with less saline surface water overlying cooler saline water with depth. The salinity of the upper water layer is sensitive to the amount of freshwater input and may become more diluted during heavy precipitation (URS 1994). Variances due to seasonal changes (such as freshwater input, wind-induced mixing, and solar heating) are common (URS 1994).

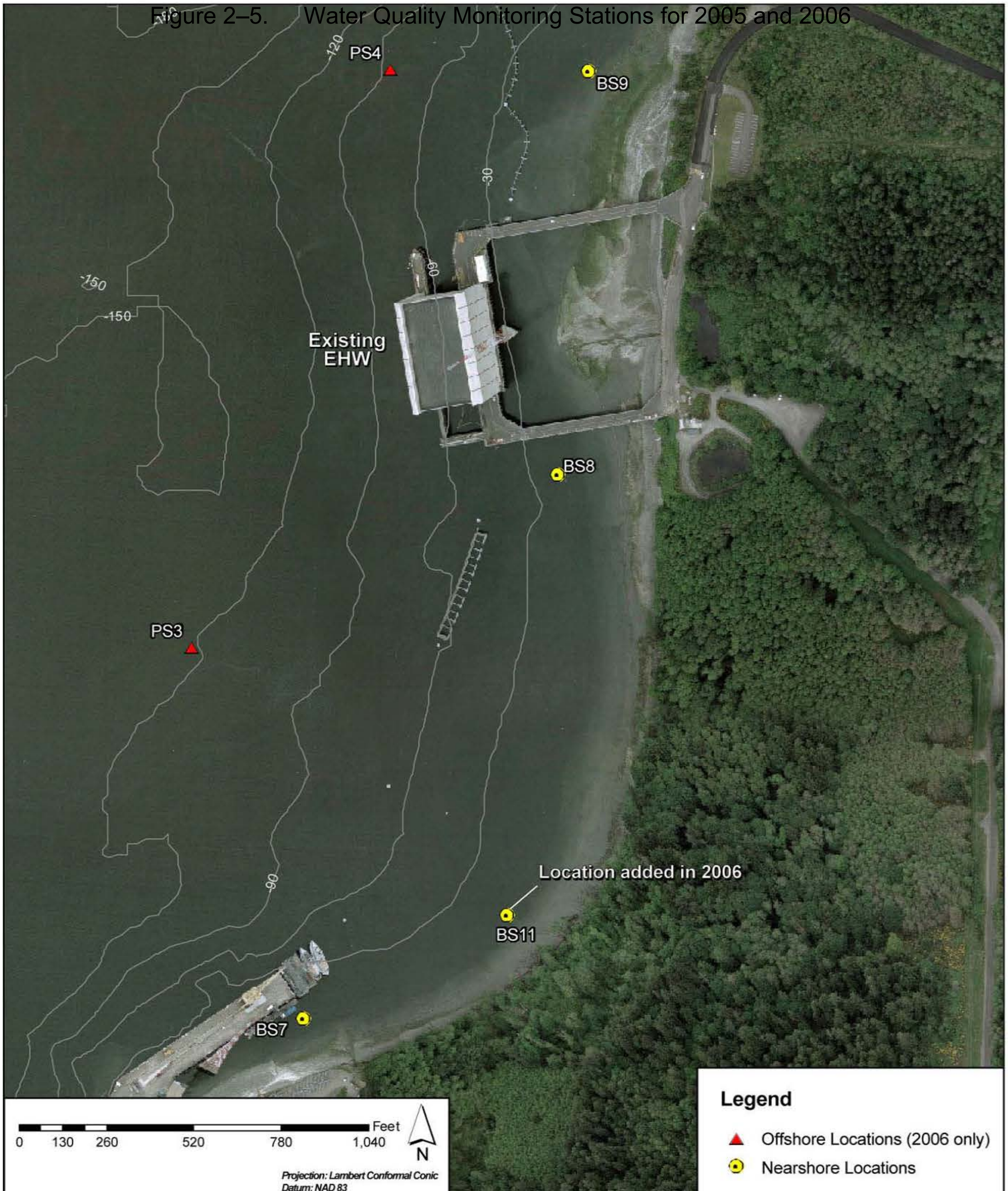
Freshwater input into Hood Canal comes from creeks, rivers, groundwater (including artesian wells [deep underground aquifer]), and stormwater outfalls. The freshwater inputs affect the salinity in Hood Canal. Artesian wells also contribute to freshwater inputs, with estimated flows of 2,000 to 2,500 gallons per minute (Washington Department of Ecology [WDOE] 1981). Overland flow from much of the western portion of NBK at Bangor is routed to Hood Canal through a series of stormwater outfalls. Saltwater and freshwater mixing zones exist at the mouths of each of these streams and outfalls (URS 1994).

During water quality surveys from 2005 through 2008, average surface water salinity levels along the Bangor waterfront on NBK ranged from 24 to 34 practical salinity units (PSU) (Phillips et al. 2009). Salinity measurements with depth reflected a stratified water column, with less saline surface water overlying cooler saline water at depth. The transition between the lower salinity surface waters and higher salinity subsurface waters occurred at a depth of about 33 feet (Phillips et al. 2009). The lowest surface water salinity (18.4 PSU) was measured in February 2007 when freshwater (low salinity) input may have been high due to winter storms and runoff (Hafner and Dolan 2009). The range of salinity along the Bangor waterfront on NBK is typical for marine waters in Puget Sound (Newton et al. 1998, 2002).

### 2.2.7 Sediments

Existing sediment information is based on results from sampling at the project area during 2007 (Hammermeister and Hafner 2009); sampling locations are shown in Figure 2–6. Sediment quality at the project site is generally good; levels of contaminants meet applicable state standards. Marine sediments are composed of gravelly sands with some cobbles in the intertidal zone, transitioning to silty sands in the subtidal zone (Hammermeister and Hafner 2009).

Figure 2–5. Water Quality Monitoring Stations for 2005 and 2006




Source: Phillips et al. 2009

**Figure 2–5. Water Quality Monitoring Stations for 2005 and 2006**

Subsurface coring studies conducted in 1994 found the presence of glacial till approximately 6 feet below mud line in the intertidal zone, increasing to over 10 feet in the subtidal zone (URS 1994). The composition of sediment samples from the project area ranged from 65 to 100 percent for sand, less than 1 to 7 percent for gravel, 2 to 32 percent silt, and 2 to 11 percent clay.

#### 2.2.8 Ambient Underwater Sound

Underwater ambient noise at the project area is widely variable over time due to a number of natural and anthropogenic sources. A number of sources of underwater sound exist in the vicinity of the EHW-2 project site. Sources of naturally caused underwater noise include wind, waves, precipitation, and biological sources (such as shrimp, fish, and cetaceans). Noise derived from biological organisms can be absent or dominant over narrow and broad frequency ranges. Precipitation can contribute up to 35 decibels (dB) to the existing sound level, and increases in wind speed of 5 to 10 knots can cause a 5 dB increase in ambient ocean noise across most frequencies (Urick 1983). The highest noise levels occur in nearshore areas where the sound of surf can increase underwater noise levels by 20 dB or more within 200 yards from the surf zone in the 200 hertz (Hz) to 2 kilohertz (kHz) regime (Wilson et al. 1985). In addition, wakes from boat traffic cause breaking waves in the surf zone.

Underwater sound from human activities includes ship traffic noise, use of sonar and echo sounders in commercial fishing to locate fish schools, industrial ship noise, and recreational boat use. Ship and small boat noise comes from propellers and other on-board rotating equipment. Small powerboats generate peak narrow band sound pressure levels (SPLs) of 150 to 165 dB referenced at 1 micropascal (dB re 1 μPa)[6] at 3 feet in the 350 to 1,200 Hz region, with mean SPLs of 148 dB at 3 feet (Barlett and Wilson 2002). Fishing vessels can generate peak spectral densities of 140 dB at 3 feet in the 250 to 1,000 Hz regime (Hildebrand 2004). Other sources of underwater noise at industrial waterfronts could come from cranes, generators, and other types of mechanized equipment on wharves or the adjacent shoreline.

Carlson et al. (2005) measured the underwater baseline noise at Hood Canal Bridge and found that broadband (24 kHz bandwidth) underwater noise levels ranged from 115 to 135 dB. In a study conducted in Haro Strait, San Juan Islands, the ambient half-hourly SPL in Haro Strait ranged from 95 to 130 dB (Veirs and Veirs 2005), demonstrating the range over which localized human-generated noise can vary by specific locations and time periods. The Washington State Department of Transportation (WSDOT) summarized underwater broadband (20 Hz to 20 kHz) noise over three consecutive 24-hour periods at ferry terminals in Mukilteo, Port Townsend, Anacortes, Edmonds, and Seattle (Laughlin 2012, summarized in WSDOT 2014), as follows: "The decibels reported for these locations represent 50 percent of the cumulative distribution functions (CDF) of these three periods for daytime sound levels. The CDF is the function that maps values to their percentile rank in a distribution, which in this case is a log-normal distribution. The normal distribution shows the probability that a certain value will fall within a certain range and the CDF maps that distribution. The 50$^{th}$ percentile of the CDF is reported for underwater background sound levels as a measure of central tendency."

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[6] Underwater sound pressure levels are referenced to 1 μPa. Unweighted airborne sound pressure levels are referenced to 20 μPa.

**Figure 2–6. Sediment Sampling Locations**


*Source: Hammermeister and Hafner 2009*

**Figure 2–6. Sediment Sampling Locations**

Based on WSDOT's recent research, the broadband sound level at Mukilteo is 124 dB, at Port Townsend is 107 dB, at Anacortes is 133 dB, at Edmonds is 123 dB, and at Seattle is 141 dB.

Underwater ambient noise measurements taken approximately 1.85 miles from the project area at the EHW during the 2011 Test Pile Program (TPP) project ranged from 112.4 dB root-mean-square (RMS) between 50 Hz and 20 kHz at mid depth to 114.3 dB at deep depth (Illingworth & Rodkin 2012). In 2009, the average broadband ambient underwater noise levels were measured at 114 dB between 100 Hz and 20 kHz (Slater 2009). The primary source of noise was industrial activity along the waterfront (e.g., at the EHW, Marginal Wharf, Delta Pier, and Service Pier), small boat traffic, and wind-driven wave noise. Peak spectral noise from industrial activity was noted below the 300 Hz frequency, with maximum levels of 110 dB noted in the 125 Hz band. In the 300 Hz to 5 kHz range, average levels ranged between 83 and 99 dB. Wind-driven wave noise dominated the background noise environment at approximately 5 kHz and above, and ambient noise levels flattened above 10 kHz.

#### 2.2.9 Ambient Airborne Sound

Maximum airborne noise levels are produced by common industrial equipment, including trucks, cranes, compressors, generators, pumps, and other equipment that might typically be employed along NBK at Bangor's industrial waterfront and at the ordnance handling areas. Airborne sound measurements were taken during a two-day period in October 2010 within the waterfront industrial area near the project site (Navy 2010). During this period, daytime noise levels ranged from 60 to 104 A-weighted decibels (dBA), with average values of approximately 64 dBA. Evening and nighttime levels ranged from 64 to 96 dBA, with an average level of approximately 64 dBA. Thus, daytime maximum levels were higher than nighttime maximum levels, but average nighttime and daytime levels were similar. These higher noise levels are produced by a combination of sound sources including heavy trucks, forklifts, cranes, marine vessels, mechanized tools and equipment, and other sound-generating industrial/military activities. Measured levels were comparable to estimated noise levels from literature. Per published literature, presuming multiple sources of noise may be present at one time, maximum combined levels may be as high as 94 dBA. This assumes that two co-located sources combined together will increase noise levels by 3 dB over the level of a single piece of equipment by itself (WSDOT 2014). These maximum noise levels are intermittent in nature and not present at all times. Existing maximum baseline noise conditions at the waterfront during a typical work week are expected to be approximately 80 to 104 dBA due to typical truck, forklift, crane, and other industrial activities. Average noise levels are expected to be in the 60 to 68 dBA range, consistent with urbanized or industrial environments where equipment is operating.

## 2.3 Duration of Activities

For this IHA application covering the third year of construction, pile driving will begin on July 16, 2014, and conclude on February 15, 2015. There will be a maximum of 195 days of pile driving during this period (an average of 6.5 days per week during this 30-week period). Construction for the entire project is estimated to last for 42 to 48 months, concluding in 2016, although a fourth in-water work season will not be required. A total of 1,250 piles ranging in diameter from 24 to 48 inches will be driven for the overall project. An estimated 200 to 400 days of in-water pile driving (plus 11 days for land-based pile driving) are expected. Up to three vibratory and one impact hammer pile driving rigs could operate concurrently. The number of impact hammer strikes will range from 1,000 per day to a most-conservative case of 6,400 per day.

# 3 MARINE MAMMAL SPECIES AND NUMBERS

*The species and numbers of marine mammals likely to be found within the activity area.*

Eight marine mammal species, including five cetaceans and three pinnipeds, have been documented in the waters near NBK at Bangor in Hood Canal. These include the humpback whale, transient killer whale, gray whale, harbor porpoise, Dall's porpoise, Steller sea lion, California sea lion, and harbor seal. All marine mammal species are protected under the MMPA. One species listed under the Endangered Species Act (ESA) has been documented in Hood Canal waters in recent years. The humpback whale, which is listed as endangered, occurs in small numbers in Puget Sound (Falcone et al. 2005). After a period of at least 15 years with no confirmed sightings in Hood Canal (Orca Network 2012), an individual was observed in several locations including Dabob Bay several times in January and February 2012. This occurrence was likely a stray individual outside the normal range for this species in Washington inland waters. The Southern Resident killer whale stock, which is listed as endangered, occurs in Puget Sound but was excluded from further analysis in this IHA application because it has not been seen in Hood Canal in over 18 years (Ford 1991; Unger 1997; NMFS 2006, 2008c).

Section 3.1 summarizes the species description and population abundance of all species with any documented occurrences in Hood Canal since 1995 and specifies those that are likely to be affected by the proposed action. All of the species listed in Table 3–1 were evaluated in the IHA applications for the first and second years of EHW-2 project construction, based on limited available information on the occurrence of marine mammal species in Hood Canal. The analysis approach in this IHA application for the third year of construction utilizes newer evaluations of occurrence data in Washington inland marine waters and focuses on those species that are actually potentially vulnerable to project effects. This includes species that are regularly present in the project area (California sea lion, Steller sea lion, harbor seal, and harbor porpoise) and the transient killer whale, which is not regularly present but has remained in Hood Canal waters for extended periods on the rare occasions when they are present. The stock abundance, period of occurrence in Hood Canal, and density of these species are listed in Table 3–1. The other documented but rare species (humpback whale, gray whale, and Dall's porpoise) are not carried forward in this evaluation, as explained more fully in the individual species accounts in Section 3.1. Section 4 contains detailed life history information for the five species likely to be affected by the proposed action. The methods and assumptions used to derive marine mammal densities in the project area are described in Appendix A.

**Table 3–1. Marine Mammals Sighted in Hood Canal in the Vicinity of NBK at Bangor and Evaluated in this IHA Application**

| Species | Stock(s) Abundance[1] | Season(s) of Occurrence | Relative Occurrence[a] | Density[b] (Individuals per sq km) Within In-water Work Season[c] |
|---|---|---|---|---|
| **Steller sea lion**<br>*Eumetopias jubatus*<br>Eastern U.S. stock/DPS | 58,334–72,223[2] | Fall to spring (October–May) | Seasonal | 0.025 |
| **California sea lion**<br>*Zalophus californianus*<br>U.S. stock | 296,750[3] | Late summer to late spring (August–early June) | Seasonal | 0.28 |
| **Harbor seal**<br>*Phoca vitulina*<br>WA inland waters stock | 14,612[4] (CV=0.15) | Year-round; resident species in Hood Canal | Likely | 1.06 |
| **Killer whale**<br>*Orcinus orca*<br>West Coast transient stock | 354[5,d] | Year-round in Puget Sound, last seen in Hood Canal in 2005 | Rare | 0.001914 (summer)[e]<br>0 (fall)<br>0.003828 (winter)<br>0.00574 (spring) |
| **Harbor porpoise**<br>*Phocoena phocoena*<br>WA inland waters stock | 10,682[6] (CV=0.38) | Year-round | Likely | 0.149000 |

**Sources:**

1. NMFS marine mammal stock assessment reports (SARs) at: http://www.nmfs.noaa.gov/pr/sars/species.htm.
2. Allen and Angliss 2009 SAR as presented in Allen and Angliss 2013.
3. Carretta et al. 2008 SAR as presented in Carretta et al. 2013.
4. Jeffries et al. 2003.
5. Allen and Angliss 1999 SAR as presented in Allen and Angliss 2013.
6. Carretta et al. 2003 SAR as presented in Carretta et al. 2013.

CV = coefficient of variation; DPS = Distinct Population Segment; sq km = square kilometer

a. Rare: The distribution of the species is near enough to the area that the species could occur there or there are a few confirmed sightings (e.g., humpback in Hood Canal; transient killer whale in Hood Canal); Likely: Confirmed and regular sightings of the species in the area year-round (e.g., harbor seal); Seasonal: Confirmed and regular sightings of the species in the area on a seasonal basis (e.g., California sea lion and Steller sea lion).
b. Source: Navy 2014a. Navy Marine Species Density Database. See density estimation methods and calculations in Appendix A.
c. In-water work season is the period from July 16–February 15.
d. Combined catalog counts for West Coast stock.
e. See Appendix A. Seasonal densities were derived from one anomalous occurrence of 6 animals over a 172-day period in 2005.

## 3.1 ESA-Listed Marine Mammals

### 3.1.1 Humpback Whale (*Megaptera novaeangliae*), (CA/OR/WA Stock)

<u>*Species Description*</u>

The humpback whale is a large baleen whale with a worldwide distribution in all ocean basins (Allen and Angliss 2013), although it is less common in Arctic waters. In the summer, most humpback whales are found in high latitude or highly biologically productive feeding grounds. In the winter, they congregate in subtropical or tropical waters for mating.

The stock structure of humpback whales is defined based on feeding areas because distinct populations have a higher degree of fidelity to specific feeding areas than to breeding areas (Calambokidis et al. 2008; Carretta et al. 2013). In the eastern Pacific, the waters off northern Washington may be an area of mixing between the California (CA)/Oregon (OR)/Washington (WA) stock and a southern British Columbia stock. Alternatively, humpback whales in northern Washington and southern British Columbia may be a distinct feeding population (Calambokidis et al. 2008) and a separate stock.

*Population Abundance*

Humpback whales are increasing in abundance in much of their range, including the CA/OR/WA stock (NMFS 2012a). Carretta et al. (2013) reported the best estimate for the CA/OR/WA stock is 2,043 (coefficient of variation = 0.10) based on mark-recapture estimated by Calambokidis et al. (2009). However, this estimate excludes some whales in Washington. Population trends from mark-recapture estimates have shown an overall long-term increase of approximately 7.5 percent per year for the CA/OR/WA stock (Calambokidis et al. 2009).

*Occurrence in Project Area*

A humpback whale was sighted in Hood Canal several times in January and February 2012 (Orca Network 2012). Review of the sightings information indicated they were of one individual (Calambokidis 2012, personal communication). Locations included Dabob Bay and other locations southward to the Great Bend. Prior to these sightings, there were no confirmed reports of humpback whales entering Hood Canal (Calambokidis 2012, personal communication). No other reports of humpback whales in Hood Canal were found in the Orca Network database, the scientific literature, or agency reports. Construction of the Hood Canal Bridge occurred in 1961 and could have contributed to the lack of historical sightings (Calambokidis 2010, personal communication). Only a few records of humpback whales near Hood Canal (but north of the Hood Canal Bridge) are in the Orca Network database. Two were from the northern tip of Kitsap Peninsula (Foulweather Bluff/Point No Point) and a few others from Port Madison Bay in Puget Sound. The humpback whale is not carried forward in the analyses in this IHA application because they are very unlikely to be present in the affected area during the EHW-2 construction project.

## 3.2 Non-ESA Listed Marine Mammals

### 3.2.1 Steller Sea Lion (*Eumetopias jubatus*), (Eastern U.S. Stock)

*Species Description*

Steller sea lions are the largest members of the Otariid (eared seal) family. Steller sea lions show marked sexual dimorphism, in which adult males are noticeably larger and have distinct coloration patterns from females. Males average approximately 1,500 pounds and 10 feet in length; females average about 700 pounds and 8 feet in length. Adult females have a tawny to silver-colored pelt. Males are characterized by dark, dense fur around their necks that appears like a mane and light tawny coloring over the rest of their body (NMFS 2008a).

*Population Abundance*

The eastern DPS of Steller sea lions includes the species distribution east of 144°W longitude (Loughlin 1997), including southeast Alaska, Canada, Washington, Oregon, and California (62 *Federal Register* [FR] 30772). The eastern stock was estimated by NMFS in the *Recovery Plan for the Steller Sea Lion* to number between 45,000 and 51,000 animals (NMFS 2008a). This stock has been increasing approximately 4.3 percent per year over the entire range since the late 1970s (NMFS 2012c). The most recent population estimate for the eastern stock ranges from 58,334 to 72,223 (Allen and Angliss 2009 SAR as presented in Allen and Angliss 2013).

The eastern stock is stable or increasing throughout the northern portion of its range (Southeast Alaska and British Columbia) and stable or increasing slowly in the central portion of its range (Oregon through northern California) (Allen and Angliss 2013; Olesiuk 2008). Although the population size has increased overall, the status of this stock relative to its optimum sustainable population is unknown (Allen and Angliss 2013).

Steller sea lions occupy major winter haul-out sites on the coast of Vancouver Island in the Strait of Juan de Fuca and the Georgia Basin (Bigg 1985; Olesiuk 2008); the closest breeding rookery to the project area is at Carmanah Point, British Columbia, Canada on Vancouver Island near the western entrance to the Strait of Juan de Fuca. There are no breeding rookeries in Washington. In Washington inland waters, up to 10 animals have been observed at Toliva Shoals in south Puget Sound (Jeffries et al. 2000), and up to 11 individuals have been observed on a given day at Delta Pier on NBK at Bangor (HDR 2012; Navy 2013; Hart Crowser 2013).

*Occurrence in Project Area*

Steller sea lions have been observed hauled out on submarines at Delta Pier on NBK at Bangor since 2008 during fall through spring months (September to April) (Bhuthimethee 2008, personal communication; Navy 2013; Hart Crowser 2013; HDR 2013) (see detailed discussion in Section 6.5.1). Other potential haul-out sites include isolated islands, rocky shorelines, jetties, buoys, rafts, and floats (Jeffries et al. 2000). Steller sea lions likely utilize foraging habitats in Hood Canal similar to those of the California sea lion and harbor seal, which include marine nearshore and deeper water habitats.

### 3.2.2 California Sea Lion (*Zalophus californianus*), (U.S. Stock)

*Species Description*

California sea lions are also members of the Otariid family. The species *Zalophus californianus* includes three subspecies: *Z. c. wollebaeki* (on the Galapagos Islands), *Z. c. japonicus* (in Japan, but now thought to be extinct), and *Z. c. californianus* (found from southern Mexico to southwestern Canada; referred to here as the California sea lion) (Carretta et al. 2013).

*Population Abundance*

California sea lions occur in the marine waters nearby NBK at Bangor. The entire population cannot be counted because all age and sex classes are never ashore at the same time, and population estimates are extrapolated from pup counts and counts of all age classes at rookeries and haul-out sites. The most recent estimate of population size is 296,750 individuals (Carretta et al. 2008 SAR as presented in Carretta et al. 2013). These numbers are derived from counts during the 2005 breeding season of animals that were ashore at the four major rookeries in southern California and at haul-out sites north to the Oregon/California border. Sea lions that were at-sea or hauled out at other locations were not counted (Carretta et al. 2013). An estimated 3,000 to 5,000 California sea lions migrate to Washington and British Columbia waters during the non-breeding season from September to May (Jeffries et al. 2000). Peak numbers of up to 1,000 sea lions occur in Puget Sound (including Hood Canal) during this time period (Jeffries et al. 2000).

*Occurrence in Project Area*

Although haul-outs were not documented in Hood Canal during Washington Department of Fish and Wildlife (WDFW) surveys, California sea lions have been observed on NBK at Bangor hauled out on submarines, the floating security fence, and barges (Agness and Tannenbaum 2009; Tannenbaum et al. 2009; Navy 2013). More recent dedicated surveys on NBK at Bangor have reported as many as 122 California sea lions hauled out daily from late August through early June on submarines, buoys, pontoons of the floating security fence, and barges on NBK at Bangor (HDR 2012; Navy 2013; Hart Crowser 2013). Most documented haul-outs of California sea lions along the Bangor waterfront on NBK have been on submarines docked at Delta Pier and on pontoons of the security fence in the vicinity of the projects. California sea lions have been observed swimming near the existing EHW and the EHW-2 construction area (Hart Crowser 2013), and likely forage in nearshore and deep-water marine habitats within the vicinity.

### 3.2.3 Harbor Seal (*Phoca vitulina*) (WA Inland Waters Stocks [Hood Canal, Southern Puget Sound, Washington Northern Inland Waters])

*Species Description*

Pacific Ocean harbor seals, which are members of the family Phocidae ("true seals"), inhabit coastal and estuarine waters and shoreline areas from Baja California to western Alaska. For management purposes, differences in mean pupping date (i.e., birthing) (Temte 1986), movement patterns (Jeffries 1985; Brown 1988), pollutant loads (Calambokidis et al. 1985), and fishery interactions have led to the recognition of three separate harbor seal stocks along the west coast of the continental U.S. (Boveng 1988). The three distinct stocks are: (1) inland waters of Washington State (including Hood Canal, Puget Sound, and the Strait of Juan de Fuca out to Cape Flattery), (2) outer coast of Oregon and Washington, and (3) California (Carretta et al. 2013). Interchange between inland and coastal stocks is unlikely, based on radiotelemetry results (Jeffries et al. 2003). Recent genetic evidence and studies of pupping phenology of harbor seals in Washington and Canada-U.S. transboundary waters confirm the currently recognized stock boundary between the Washington Coast and Washington inland waters harbor seal stocks, but three genetically distinct populations are also evident within the Washington inland waters stock (Huber et al. 2010, 2012). NMFS has proposed three new prospective harbor seal stocks: (1) Southern Puget Sound (south of the Tacoma Narrows Bridge); (2) Washington Northern Inland Waters (including Puget Sound north of the Tacoma Narrows Bridge, the San Juan Islands, and the Strait of Juan de Fuca; and (3) Hood Canal (Caretta et al. 2013). The Hood Canal population of the Washington Inland Waters stock is the only population that is expected to occur within the project area.

*Population Abundance*

Estimated population numbers for the Washington inland waters harbor seal stock are 14,612 (CV=0.15) individuals (Jeffries et al. 2003). The harbor seal is the only species of marine mammal that is consistently abundant and considered resident in Hood Canal (Jeffries et al. 2003).

The population of harbor seals in Hood Canal is a closed population, meaning they do not have much movement outside of Hood Canal (London 2006). The abundance of harbor seals in Hood Canal has stabilized in recent decades, and the population may have reached its carrying capacity in the mid-1990s with an approximate abundance of 1,000 harbor seals (Jeffries et al. 2003).

*Occurrence in Project Area*

Harbor seals have been observed swimming in the waters along NBK at Bangor in every month of surveys conducted from 2007 to 2010 (Agness and Tannenbaum 2009; Tannenbaum et al. 2009, 2011). Harbor seals accounted for the vast majority of marine mammal sightings during the TPP and EHW-2 construction projects (HDR 2012; Hart Crowser 2013). Harbor seals have not been observed hauled out along the shoreline of NBK at Bangor but have been observed hauled out on manmade structures such as the floating security fences, wavescreen at Carderock Pier, buoys, barges, marine vessels, and logs (Agness and Tannenbaum 2009; Tannenbaum et al. 2009, 2011). Most documented occurrences of harbor seals hauling out along the Bangor waterfront on NBK were on pontoons of the security fence close to Delta Pier. In addition, harbor seals were seen hauled out on manmade floating structures near K/B Dock and Delta Pier. On two occasions, the group size was four to six individuals near Delta Pier.

#### 3.2.4 Killer Whale (*Orcinus orca*), (Transient Ecotype)

*Species Description*

Killer whales are members of the Delphinid (dolphin) family and are the most widely distributed cetacean (e.g., whales, dolphins, and porpoises) species in the world. Based on appearance, feeding habits, vocalizations, social structure, and distribution and movement patterns, there are three ecotypes of killer whales (Ford et al. 2000; Krahn et al. 2002). Three distinct forms or types of killer whales are recognized in the North Pacific Ocean: (1) residents, (2) transients, and (3) offshores. The resident and transient populations have been subdivided further into different subpopulations based primarily on genetic analyses, distribution, and social affiliations; not enough is known about the offshore whales to divide them into subpopulations (Krahn et al. 2004; Hoelzel et al. 1998, 2007).

Within the transient ecotype, association data (Ford et al. 2000; Ford and Ellis 1999; Matkin et al. 1999), acoustic data (Saulitis 1993; Ford and Ellis 1999), and genetic data (Hoelzel et al. 1998, 2002; Barrett-Lennard 2000) confirm that three communities of transient whales exist and represent three discrete populations. These populations include: (1) Gulf of Alaska, Aleutian Islands, and Bering Sea transients; (2) AT1 transients; and (3) West Coast transients. Among the genetically distinct assemblages of transient killer whales in the northeastern Pacific, only the West Coast transient stock, which occurs from southern California to southeastern Alaska, may occur in the project area.

*Population Abundance*

The West Coast transient stock includes animals that occur in California, Oregon, Washington, British Columbia, and southeastern Alaska. Analysis of photographic data resulted in the following minimum counts for West Coast transient stock killer whales. In British Columbia and southeastern Alaska, 219 transients have been catalogued (Ford and Ellis 1999, Dahlheim et al. 1997). Off the coast of California, 105 transients have been identified (Black et al. 1997), 10 of which match photos of whales in other catalogs and the remaining 95 were linked by association. An additional 14 whales in southeastern Alaska and 16 whales off the coast of

California have been provisionally classified as transient by association. Combined, these counts give a minimum number of 354 (219 + 95+10+14+16) individuals belonging to the West Coast transient stock (Allen and Angliss 1999 SAR as presented in Allen and Angliss 2013). A mark-recapture estimate for the West Coast Transient population, excluding whales from California, resulted in an estimate of 243 (95 percent probability interval = 180 to 339) in 2006 (DFO 2009). This estimate applies to the population of West Coast Transient whales that occur in southeastern Alaska, British Columbia, and northern Washington (Allen and Angliss 2013). However, the number in Washington waters at any one time is probably fewer than 20 individuals (Wiles 2004).

*Occurrence in Project Area*

In 2003 and 2005, small groups of transient killer whales (6 to 11 individuals per event) visited Hood Canal to feed on harbor seals and remained in the area for significant periods of time (59 to 172 days) between the months of January and July (London 2006). These whales used the entire expanse of Hood Canal for feeding. No other confirmed sightings of transient killer whales in Hood Canal were found in the literature.

#### 3.2.5 Gray Whale (*Eschrichtius robustus*) (Eastern North Pacific Stock)

*Species Description*

The gray whale is a baleen whale that is the only representative of the family Eschrichtiidae. The North Pacific gray whale stock is divided into two distinct stocks: eastern and western (Rice et al. 1984). The eastern North Pacific stock ranges from Alaska, where they occupy summer feeding areas in the Bering and Chuckchi seas, to Baja California, where they migrate to calve in the winter. Eastern North Pacific gray whales are a coastal species usually found over the continental shelf (WDFW 2011).

A group of a few hundred gray whales known as the Pacific Coast Feeding Group feeds along the Pacific coast between southeastern Alaska and southern California throughout the summer and fall (Calambokidis et al. 2002). Recent studies suggest the Pacific Coast Feeding Group is a demographically distinct feeding group (Calambokidis et al. 2010; Lang et al. 2011; Mate et al. 2010; Frasier et al. 2011); therefore, this group may be classified as a distinct stock by NMFS in the future (Carretta et al. 2013).

*Population Abundance*

Population abundance estimates indicate a steady increase from the 1960s until the 1980s, with a peak in 1987/1988 (Allen and Angliss 2012). The 2007 population estimate for eastern Pacific gray whales was 19,126 (CV=7.1). An unusual mortality event occurred in 1999/2000, in which a high number of gray whales stranded on the west coast of North America (Moore et al. 2001; Gulland et al. 2005). However, this mortality event appears to have been a short-term, acute event associated with unusual oceanographic conditions and not a chronic trend (Allen and Angliss 2012). Despite this event, the population trend over the past several decades is a 3.2 percent annual rate of increase.

*Occurrence in Project Area*

Gray whales have been sighted in Hood Canal south of the Hood Canal Bridge on six occasions since 1999, including a stranded whale at Belfair State Park (Calambokidis 2013, personal communication). The most recent report in Hood Canal was of characteristic “blows” (air exhaled through the whale's blowhole) in the waters near Lilliwaup in November 2010 (Calambokidis 2013, personal communication). The gray whale is not carried forward in the analyses in this IHA application because they are unlikely to be present in the affected area during project construction.

#### 3.2.6 Dall's Porpoise (*Phocoenoides dalli*) (CA/OR/WA Stock)

*Species Description*

Dall's porpoises are members of the Phocoenid (porpoise) family and are common in temperate waters of the North Pacific Ocean. The distribution of Dall's porpoise through its range is highly variable between years and appears to be affected by oceanographic conditions (Forney 1997; Forney and Barlow 1998). The stock structure of eastern North Pacific Dall's porpoise is not known. For MMPA stock assessment reports, Dall's porpoises within the Pacific U.S. Exclusive Economic Zone, i.e., a distance of 200 nautical miles out from the U.S. Pacific coast, are divided into two discrete, noncontiguous areas: (1) waters off California, Oregon, and Washington; and (2) those in Alaskan waters (Carretta et al. 2013). Individuals from the California/Oregon/Washington stock may occur within the project area.

*Population Abundance*

The NMFS population estimate for the CA/OR/WA stock is the geometric mean of estimates from 2005 (Forney 2007) and 2008 (Barlow 2010), or 42,000 (CV=0.33) animals (Carretta et al. 2013). Additional numbers of Dall's porpoise occur in the inland waters of Washington State, but the most recent estimate obtained in 1996 (900 animals; CV=0.40) (Calambokidis et al. 1997) is not included in the overall estimate of abundance for this stock due to the need for more up-to-date information.

*Occurrence in Project Area*

Dall's porpoises may occasionally occur in Hood Canal (Jeffries 2006, personal communication); one was observed in deeper water in the vicinity of NBK at Bangor in summer 2008 during boat-based surveys of the Bangor waterfront on NBK (Tannenbaum et al. 2009). At the time the first IHA application was submitted for the EHW-2 project in August 2011, it was conservatively assumed that the species was present in Hood Canal based on this observation. However, no Dall's porpoises were detected during subsequent monitoring efforts in Hood Canal for the TPP in late 2011 and the first year of EHW-2 construction in the winter of 2012/13. No other records of occurrence in Hood Canal were found in a review of databases and other records such as Orca Network sighting reports. Therefore, Dall's porpoise is not carried forward in the analyses in this IHA application because they are unlikely to be present in the affected area during project construction.

#### 3.2.7 Harbor Porpoise (*Phocoena phocoena*)

*Species Description*

Harbor porpoises belong to the Phocoenid (porpoise) family and are found extensively along the North Pacific coast. Recent preliminary genetic analyses of samples ranging from Monterey, California, to Vancouver Island, British Columbia, indicate that there is small-scale subdivision within the U.S./Vancouver Island, British Columbia, portion of this range (Chivers et al. 2002). These genetically distinguishable groupings are not geographically distinct by latitude, but results suggest a low mixing rate and limited movement of harbor porpoise along the west coast of

North America. Survey data found significant differences in harbor porpoise mean densities between coastal Oregon/Washington waters and inland Washington/British Columbia waters (Calambokidis et al. 1993), although a specific stock boundary line cannot be identified based upon biological or genetic differences. Since harbor porpoise movements and rates of intermixing within the eastern North Pacific are restricted, and there was a significant decline in harbor porpoise sightings within southern Puget Sound from the 1940s until recently (Calambokidis 2010, personal communication), NMFS conservatively recognizes two stocks in Washington waters: the Oregon/Washington Coast stock and the Washington Inland Waters stock (Carretta et al. 2013). Individuals from the Washington Inland Waters stock are expected to occur in the project area.

Harbor porpoise sightings have increased in Puget Sound and northern Hood Canal in recent years and are now considered to regularly occur year-round in these waters (Calambokidis 2010, personal communication; HDR 2012). This may represent a return to historical conditions, when harbor porpoises were considered one of the most common cetaceans in Puget Sound (Scheffer and Slipp 1948).

*Population Abundance*

Aerial surveys of the inside waters of Washington and southern British Columbia were conducted during August of 2002 and 2003 (J. Laake, unpublished data in Carretta et al. 2013). These aerial surveys included the Strait of Juan de Fuca, San Juan Islands, Gulf Islands, and Strait of Georgia, which includes waters inhabited by the Washington Inland Waters stock of harbor porpoise as well as harbor porpoises from British Columbia. An average of the 2002 and 2003 estimates of abundance in U.S. waters resulted in an uncorrected abundance of 3,123 (CV=0.10) harbor porpoises in Washington inland waters (J. Laake, unpublished data in Carretta et al. 2013). When corrected for availability and perception bias, using a correction factor of 3.42 (1/g(0); g(0)=0.292, CV=0.366) (Laake et al. 1997), the estimated abundance for the Washington Inland Waters stock of harbor porpoise is 10,682 (CV=0.38) animals (Carretta et al. 2003 SAR as presented in Carretta et al. 2013).

*Occurrence in Project Area*

Harbor porpoise may be occasionally present in Hood Canal year round and conservatively are assumed to use the entire area. The Navy conducted boat surveys of the waterfront area from July to September 2008 (Tannenbaum et al. 2009) and November 2009 to May 2010 (Tannenbaum et al. 2011). During one of the surveys a single harbor porpoise was sighted in May 2010 in deeper waters in the vicinity of the EHW. Overall, these nearshore surveys indicated a low occurrence of harbor porpoise within waters adjacent to the base. Surveys conducted during the TPP indicated that the abundance of harbor porpoise within Hood Canal in the vicinity of NBK at Bangor is greater than anticipated from earlier surveys and anecdotal evidence (HDR 2012). During these surveys, while harbor porpoise presence in the immediate vicinity of the naval base (i.e., within 1 kilometer) remained low, harbor porpoises were frequently sighted within several kilometers of the base, mostly to the north or south of the project sites, but occasionally directly across from the existing EHW. Monitoring of the EHW-2 Year 1 construction project detected harbor porpoise in Hood Canal as close as 800 meters to the construction area (Hart Crowser 2013).

## 3.3 Marine Mammal Modeling Parameters

### 3.3.1 Density Estimates

Marine mammal densities are a key element used in estimating exposures to Navy activities. Density estimates presented in the first IHA for the EHW-2 project relied on limited survey data available at the time the application was submitted (December 2011), and the second IHA (submitted in December 2012) used the same densities for the sake of consistency with the earlier application. Subsequently, however, the Navy refined estimates of marine mammal densities in Washington inland waters with regional marine mammal expert participation and developed the Navy Marine Species Density Database (NMSDD) (Navy 2014a). The Navy has utilized the NMSDD, in tandem with local observational data, to support several pile driving projects whose applications have been submitted to NMFS. For this application, the Navy is using NMSDD densities for harbor seal, transient killer whale, and harbor porpoise, and is using local observational data for Steller sea lion and California sea lion. The Northwest region's NMSDD densities were finalized in 2012. However, density assumes that marine mammals are uniformly distributed within a given area, although this is rarely the case. Marine mammal distributions are usually clumped in areas of greater importance, for example, areas of high prey abundance, safe calving or haul-out sites, areas with lower predation risk, etc. In locations where the actual abundance of marine mammals can be determined, such as pinniped haul-out sites, these numbers are used in preference to density. The densities listed in Table 3–1 are NMSDD data for marine mammals that occur in Hood Canal. Cetacean species and the harbor seal appear to range throughout Hood Canal; the analysis in this IHA application assumes that harbor seal, transient killer whale, and harbor porpoise are relatively uniformly distributed in the project area and uses NMSDD densities to estimate exposure to project impacts. In contrast, Steller sea lions and California sea lions appear to be attracted to the project area primarily because of the availability of haul-out sites on NBK at Bangor. Therefore, the analysis of exposure to project effects uses site-specific abundance data rather than density data (see Section 6.4.5.1 and Section 6.4.5.3, respectively).

### 3.3.2 Survey Efforts in the Vicinity of NBK at Bangor

Available data on marine mammal populations in Hood Canal are sparse, with the exception of surveys of harbor seal haul-outs (Jeffries et al. 2000) and recent surveys and monitoring efforts on NBK at Bangor (Agness and Tannenbaum 2009; Tannenbaum et al. 2009, 2011; HDR 2012; Navy 2013; Hart Crowser 2013), some of which covered a very limited area.

Beginning in April 2008, Navy personnel have recorded sightings of marine mammals including California sea lion, Steller sea lion, and harbor seal at known sea lion haul-outs along the Bangor waterfront on NBK, including submarines and the nearshore pontoons of the floating security fence. Sightings of marine mammals within the waters adjoining these locations were also recorded. Sightings were attempted during a typical work week (i.e., Monday through Friday), but inclement weather, holidays, or security constraints often precluded surveys. These sightings took place frequently (average 14 per month) although without a formal protocol. During the surveys, staff visited each of the above-mentioned locations and recorded observations of marine mammals on data collection forms, noting date, time, location, number, and species of marine mammals (by location), and other relevant notes. Surveys were conducted using binoculars and the naked eye from shoreline locations or the piers/wharves themselves. Data were compiled for the period from April 2008 through December 2013 for analysis in this IHA (Navy 2013).

Boat-based opportunistic sightings along portions of the Bangor waterfront on NBK during the course of beach seine fish surveys during the spring/summer of 2007 detected two marine mammal species (harbor seal and California sea lion) (Agness and Tannenbaum 2009). In these surveys, seals and sea lions were noted in a field notebook, as well as date, time, location, number of individuals, species, and other relevant notes.

Boat-based protocol marine wildlife surveys conducted during July through September 2008 (12 surveys) and November through May 2009/2010 (12 surveys) (Tannenbaum et al. 2009, 2011) detected four marine mammal species (harbor seal, California sea lion, harbor porpoise, and Dall's porpoise). These protocol surveys operated along pre-determined transects parallel to the shoreline from the nearshore out to approximately 1,800 feet from shoreline, at a spacing of 100 yards, and covered the entire Bangor waterfront on NBK (approximately 1.5 square miles) at a speed of 5 knots or less. Two observers recorded sightings of marine mammals both in the water and hauled out, including date, time, species, number of individuals, age (juvenile, adult), behavior (swimming, diving, hauled out, avoidance dive), and haul-out location. Positions of marine mammals were obtained by recording distance and bearing to the animal with a rangefinder and compass, noting the concurrent location of the boat with Global Positioning System (GPS), and, subsequently, analyzing these data with the coordinate geometry application available in ArcInfo to produce coordinates of the locations of all animals detected.

Marine mammal monitoring was conducted in the EHW-2 project area in late 2011 during the TPP as mitigation for pile driving noise (HDR 2012). In addition, on days where no pile driving activities occurred the Navy conducted vessel-based line transect surveys in Hood Canal and Dabob Bay to collect additional density data for species present in Hood Canal. The primary impetus for the Hood Canal/Dabob Bay surveys was that observational data during pile driving monitoring indicated an unexpected abundance of harbor porpoise within Hood Canal. The surveys in Hood Canal were conducted in September and October and detected three marine mammal species (harbor seal, California sea lion, and harbor porpoise). The surveys operated along pre-determined transects that followed a double saw-tooth pattern to achieve uniform coverage of the entire Bangor waterfront on NBK. The vessel traveled at a speed of approximately 5 knots when transiting along the transect lines. Two observers recorded sightings of marine mammals both in the water and hauled out, including the date, time, species, number of individuals, and behavior (swimming, diving, etc.). Positions of marine mammals were obtained by recording the distance and bearing to the animal(s), noting the concurrent location of the boat with GPS, and subsequently analyzing these data with the coordinate geometry application available in ArcInfo to produce coordinates of the locations of all animals detected. Distance sampling methodologies were used to estimate densities of animals.

### 3.3.3 Monitoring During EHW-2 Construction

Marine mammal monitoring was conducted during the first year of construction on the EHW-2 from late September 2012 to mid-February 2013 (Hart Crowser 2013). Monitoring was conducted in three areas: (1) Primary Surveys within the behavioral monitoring and shutdown zones in the waterfront restricted area (WRA) (464-meter radius of the driven pile), (2) Outside Boat Surveys within the larger Level B behavioral harassment zone due to vibratory pile driving but outside of the WRA, and (3) Delta Pier Surveys of marine mammals hauled out on submarines at Delta Pier. Monitoring of the first two areas was conducted in accordance with the approved Marine Mammal Monitoring Plan for the EHW-2 project, and consisted of placing marine mammal observers on construction barges, the construction pier, and vessels located in near-field (within the behavioral monitoring zone in the WRA) and far-field (outside the WRA but within the Level B harassment zone) locations. Marine mammal observers reported occurrences of marine mammals during actual construction (i.e., pile driving activity) and non-construction periods. Monitoring for the second year of construction was conducted from mid-July 2013 to mid-February 2014. The monitoring was conducted in the same manner as the first year, except that Primary Surveys within the behavioral monitoring and shutdown zones in the WRA extended at least to the PSBs, which are approximately 500 meters from the driven pile. Monitors are not able to easily see animals beyond the PSB.

The total number of marine mammals reported on construction days (including both pile-driving and non-pile-driving activities) in years 1 and 2 is summarized in Table 3–2 (Hart Crowser 2013).

A subset of all marine mammal observations consisting of sightings that occurred during pile installation and removal was also reported (Table 3–3). Two hundred nine sightings of 218 marine mammals were reported during primary surveys during construction monitoring of the buffer and shutdown zones (i.e., within a 464-meter radius) during impact and vibratory pile driving during the first in-water season (Table 3–3) (Hart Crowser 2013). Six hundred ninety-seven sightings of 723 marine mammals were reported during primary surveys during construction monitoring of the buffer and shutdown zones (i.e., within a 464-meter radius) during impact and vibratory pile driving during the second in-water season (Table 3–3) (Navy 2014b, in prep.). No observations were made at Delta Pier during pile installation or removal activities. During year 1 (but not year 2), additional sightings of marine mammals during pile installation and removal were reported from outside boat surveys (Table 3–3).

#### 3.3.4 Submergence

Cetaceans spend their entire lives in the water and spend most of their time (greater than 90 percent for most species) entirely submerged below the surface. When at the surface, cetacean bodies are almost entirely below the water's surface, with only the blowhole exposed to allow breathing. This makes cetaceans difficult to locate visually and also exposes them to underwater noise, both natural and anthropogenic, essentially 100 percent of the time because their ears are nearly always below the water's surface.

Seals and sea lions (pinnipeds) spend significant amounts of time out of the water during breeding, molting, and hauling out periods. Seals and sea lions have been sighted hauling out in the vicinity of NBK at Bangor. In the water, pinnipeds spend varying amounts of time underwater. California sea lions are known to rest at the surface in large groups for long amounts of time. When not actively diving, pinnipeds at the surface often orient their bodies vertically in the water column and hold their heads above the water surface. Consequently, pinnipeds may not be exposed to underwater sounds to the same extent as cetaceans.

**Table 3–2. Total Number of Unique Animals and Sightings by Species During EHW-2 Construction Days**

| Year | Species | Total # of Animals | Total # of Sightings | Mean Group Size | Min Group Size | Max Group Size |
|---|---|---|---|---|---|---|
| Year 1 | **Primary Surveys**[1] Total monitoring for year 1 included 530 hours, 50 minutes of marine mammal surveys on 80 construction days | | | | | |
| | California sea lion | 30 | 30 | 1 | 1 | 1 |
| | Harbor seal | 984 | 939 | 1.05 | 1 | 4 |
| | **Delta Pier Surveys**[2] | | | | | |
| | California sea lion | 385 | 30 | 12.8 | 1 | 40 |
| | Steller sea lion | 4 | 3 | 1.3 | 1 | 2 |
| | **Outside Boat Surveys**[3] | | | | | |
| | California sea lion | 126 | 21 | 6.0 | 1 | 20 |
| | Harbor seal | 76 | 73 | 1.0 | 1 | 2 |
| | Steller sea lion | 3 | 3 | 1.0 | 1 | 1 |
| | Harbor porpoise | 57 | 10 | 5.7 | 1 | 10 |
| | | | | | | |
| Year 2 | **Primary Surveys**[1] Total monitoring for year 2 included 1,247 hours, 27 minutes of marine mammal surveys on 162 construction days. | | | | | |
| | California sea lion | 83 | 77 | 1 | 1 | 3 |
| | Harbor seal | 3,229 | 3,046 | 1 | 1 | 5 |
| | **Non-Primary Surveys**[4] | | | | | |
| | California sea lion | 917 | 32 | 29 | 1 | 96 |
| | Harbor seal | 9 | 2 | 5 | 1 | 8 |
| | Steller sea lion | 36 | 9 | 4 | 1 | 11 |
| | Harbor porpoise | 0 | 0 | 0 | 0 | 0 |

**Source:** Hart Crowser 2013, Navy 2014b, in prep.

1. Primary Surveys occurred during monitoring of the shutdown zone and 464-meter buffer zone.
2. Delta Pier Surveys were sightings of animals hauled out on submarines at Delta Pier. These surveys typically occurred only at the end of daily construction monitoring.
3. Outside Boat Surveys were sightings of animals in the 41.4 sq km Level B harassment zone. These surveys occurred only during acoustic monitoring outside the WRA and, therefore, are a subset of all pile driving days.
4. Non-primary surveys were sightings of animals at Delta Pier, Marginal Wharf, and along the fence floats.

**Table 3–3. Summary of Unique Mammal Sightings During Pile Installation and Removal Activities**

| Year | Species | Total # of Animals | Total # of Sightings | Mean Group Size | Min Group Size | Max Group Size | Construction Type[1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SSV | V | SSI | I |
| Year 1 | **Primary Surveys**[2] Total monitoring for year 1 included 530 hours, 50 minutes of marine mammal surveys on 80 construction days | | | | | | | | | |
| | California sea lion | 4 | 4 | 1.0 | 1 | 1 | -- | 3 | --- | 1 |
| | Harbor seal | 214 | 205 | 1.06 | 1 | 3 | 19 | 179 | 5 | 11 |
| | Total | 218 | 209 | 1.03 | | | 19 | 182 | 5 | 12 |
| | **Outside Boat Surveys**[3] | | | | | | | | | |
| | California sea lion | 22 | 4 | 4.0 | 1 | 20 | -- | 21 | 1 | -- |
| | Harbor seal | 22 | 21 | 1 | 1 | 2 | 11 | 17 | 1 | 4 |
| | Harbor porpoise | 36 | 5 | 7.2 | 4 | 10 | -- | 36 | -- | -- |
| | | | | | | | | | | |
| Year 2 | **Primary Surveys**[2] Total monitoring for year 2 included 1,247 hours, 27 minutes of marine mammal surveys on 162 construction days. | | | | | | | | | |
| | California sea lion | 10 | 10 | 1.0 | 1 | 1 | -- | 8 | -- | 2 |
| | Harbor seal | 713 | 687 | 1.05 | 1 | 2 | -- | 304 | 30 | 379 |
| | Total | 723 | 697 | 1.02 | -- | -- | -- | 312 | 30 | 381 |

**Source:** Hart Crowser 2013, Navy 2014b, in prep.

1. SSV = Vibratory hammer soft start, V = Vibratory driving, SSI = Impact hammer soft start, I = impact hammer
2. Primary Surveys occurred during monitoring of the shutdown zone and 464-meter buffer zone.
3. Outside Boat Surveys were sightings of animals in the 41.4 sq km Level B harassment zone. These surveys occurred only during acoustic monitoring outside the WRA and therefore are a subset of all pile driving days. During year 2, no outside boat surveys took place during pile installation or removal activities.

For the purpose of assessing impacts from underwater sound on NBK at Bangor, the Navy assumed that all of the cetacean species and two of the pinniped species that may be found in the vicinity of NBK at Bangor (Steller sea lion, California sea lion, humpback whale, killer whale, Dall's porpoise, and harbor porpoise) spend 100 percent of the time underwater. This approach could be considered conservative because sea lions spend a portion of their time hauled out and therefore are expected to be exposed to less sound than is estimated by this approach. Exposures to underwater and airborne pile driving noise for harbor seals were calculated using a density derived from the number of harbor seals that may be present in the water at any one time in Hood Canal (approximately 381 individuals), divided by the area of Hood Canal (358.4 square kilometers) (Huber et al. 2001; Jeffries et al. 2003; Navy 2014a). The airborne exposure calculations assumed that 100 percent of the in-water injury exposures would be available at the surface to be exposed to airborne sound.

# 4 STATUS AND DISTRIBUTION OF MARINE MAMMAL SPECIES

*A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities.*

Eight marine mammal species within the marine waters adjacent to NBK at Bangor have confirmed or historic occurrence in the area of the projects. As discussed in Section 3, three of these species (humpback whale, gray whale, and Dall's porpoise) have few documented occurrences and are not included in this analysis. One of these rarely documented species, the humpback whale, is an ESA-listed species. The final rule for delisting the eastern DPS of the Steller sea lion was issued by NMFS on October 23, 2013, and published in the *Federal Register* on November 4, 2013 (NOAA Fisheries 2013a,b). The delisting of the eastern Steller sea lion took effect on December 4, 2013, 30 days after publication of the final rule in the Federal Register.

## 4.1 Steller Sea Lion (*Eumetopias jubatus*), Eastern Stock

ESA Status and Management

The Steller sea lion was originally listed as threatened under the ESA in 1990. In 1997, NMFS reclassified Steller sea lions as two subpopulations based on genetics and population trends, listing the western stock as endangered, and maintaining threatened status for the eastern stock (NMFS 1997a). The eastern stock, which occurs within the project area, includes the animals east of Cape Suckling, Alaska (144°W) (NMFS 1997a; Loughlin 2002; Angliss and Outlaw 2005). Steller sea lions west of 144°W longitude residing in the central and western Gulf of Alaska, Aleutian islands, as well as those that inhabit coastal waters and breed in Asia (e.g., Japan and Russia), are part of the western stock. The eastern stock breeds in rookeries located in southeast Alaska, British Columbia, Oregon, and California; there are no rookeries located in Washington. There is a final revised species recovery plan that addresses both stocks (NMFS 2008a). The eastern stock of Steller sea lion has been removed from listing under the ESA by NMFS (77 FR 23209) based in part on its consistent increase in abundance since the 1970s.

Critical habitat has been designated for the Steller sea lion (NMFS 1993). Critical habitat includes so-called "aquatic zones" that extend 3,000 feet seaward in state and federally managed waters from the baseline or basepoint of each major rookery in Oregon and California (NMFS 2008a). Three major rookery sites in Oregon (Rogue Reef, Pyramid Rock, and Long Brown Rock and Seal Rock on Orford Reef at Cape Blanco) and three rookery sites in California (Ano Nuevo Island, Southeast Farallon Island, and Sugarloaf Island and Cape Mendocino) are designated critical habitat (NMFS 1993). There is no designated critical habitat for the species in Washington.

Distribution

Eastern stock Steller sea lions are found year-round along the coasts of British Columbia, Washington, Oregon, and northern California where they occur at breeding rookeries and numerous haul-out locations along the outer coastline and Vancouver Island (Jeffries et al. 2000; Scordino 2006; Olesiuk 2008). Outside of the breeding season, male Steller sea lions often disperse widely from breeding rookeries in northern California (St. George Reef), southern Oregon (Rogue Reef), and the northern tip of Vancouver Island (COSEWIC 2003; Scordino 2006).

There are no known breeding rookeries in Washington State (NMFS 1992; Angliss and Outlaw 2005) but eastern stock Steller sea lions are present year-round along the outer coast of Washington at four major haul-out sites (NMFS 2008a). Both sexes are present in Washington waters; these animals are likely immature or non-breeding adults from rookeries in other areas (NMFS 2008a). In Washington, Steller sea lions primarily occur at haul-out sites along the outer coast from the Columbia River to Cape Flattery. In inland waters, Steller sea lions use haul-out sites along the Vancouver Island coastline of the Strait of Juan de Fuca (Jeffries et al. 2000; COSEWIC 2003; Olesiuk 2008). Numbers vary seasonally in Washington waters with peak numbers present during the fall and winter months (Jeffries et al. 2000). The highest breeding season Steller sea lion count at Washington haul-out sites was 847 individuals during the period from 1978 to 2001 (Pitcher et al. 2007). Non-breeding season surveys of Washington haul-out sites reported as many as 1,458 individuals between 1980 and 2001 (NMFS 2008a).

Steller sea lions are occasionally present at the Toliva Shoals haul-out site in south Puget Sound (Jeffries et al. 2000), a rock 3 miles south of Marrowstone Island (NMFS 2010), a net pen in Rich Passage, and navigation buoys in Puget Sound (Jeffries 2012, personal communication) (Figure 4–1). Other potential haul-out sites would include isolated islands, rocky shorelines, jetties, buoys, rafts, and floats (Jeffries et al. 2000). Steller sea lions likely utilize foraging habitats in Hood Canal similar to those of the California sea lion and harbor seal, which include marine nearshore and deeper water habitats. On NBK at Bangor, Steller sea lions have only been observed hauled out on submarines at Delta Pier. They have not been observed hauled out on any other natural or manmade structures along the Bangor waterfront. They were first detected in November 2008 and are currently present from September to May (Bhuthimethee 2008, personal communication; HDR 2012; Navy 2013; Hart Crowser 2013) (see detailed discussion in Section 6.5.1).

*Behavior and Ecology*

Steller sea lions are gregarious animals that often travel or haul out in large groups of up to 45 individuals (Keple 2002). At sea, groups usually consist of female and subadult males; adult males are usually solitary while at sea (Loughlin 2002). In the Pacific Northwest, breeding rookeries are located in British Columbia, Oregon, and northern California. Steller sea lions form large rookeries during late spring when adult males arrive and establish territories (Pitcher and Calkins 1981). Large males aggressively defend territories while non-breeding males remain at peripheral sites or haul-outs. Females arrive soon after and give birth. Most births occur from mid-May through mid-July, and breeding takes place shortly thereafter. Most pups are weaned within a year. Non-breeding individuals may not return to rookeries during the breeding season but remain at other coastal haul-outs (Scordino 2006).

Steller sea lions are opportunistic predators, feeding primarily on fish and cephalopods, and their diet varies geographically and seasonally (Bigg 1985; Merrick et al. 1997; Bredesen et al. 2006; Guénette et al. 2006). Foraging habitat is primarily shallow, nearshore and continental shelf waters; freshwater rivers; and also deep waters (Reeves et al. 2008; Scordino 2010). Their prey in inland Washington waters is not well documented, but studies in British Columbia and Alaska suggest their prey would include schooling fish such as herring, hake, sand lance, salmon, flounder, rockfish, squid, and octopus (Bigg 1985; Merrick and Loughlin 1997). Prey in Hood Canal would likely include large fall chum salmon runs. Foraging habitats in Hood Canal would likely include nearshore and deeper waters.

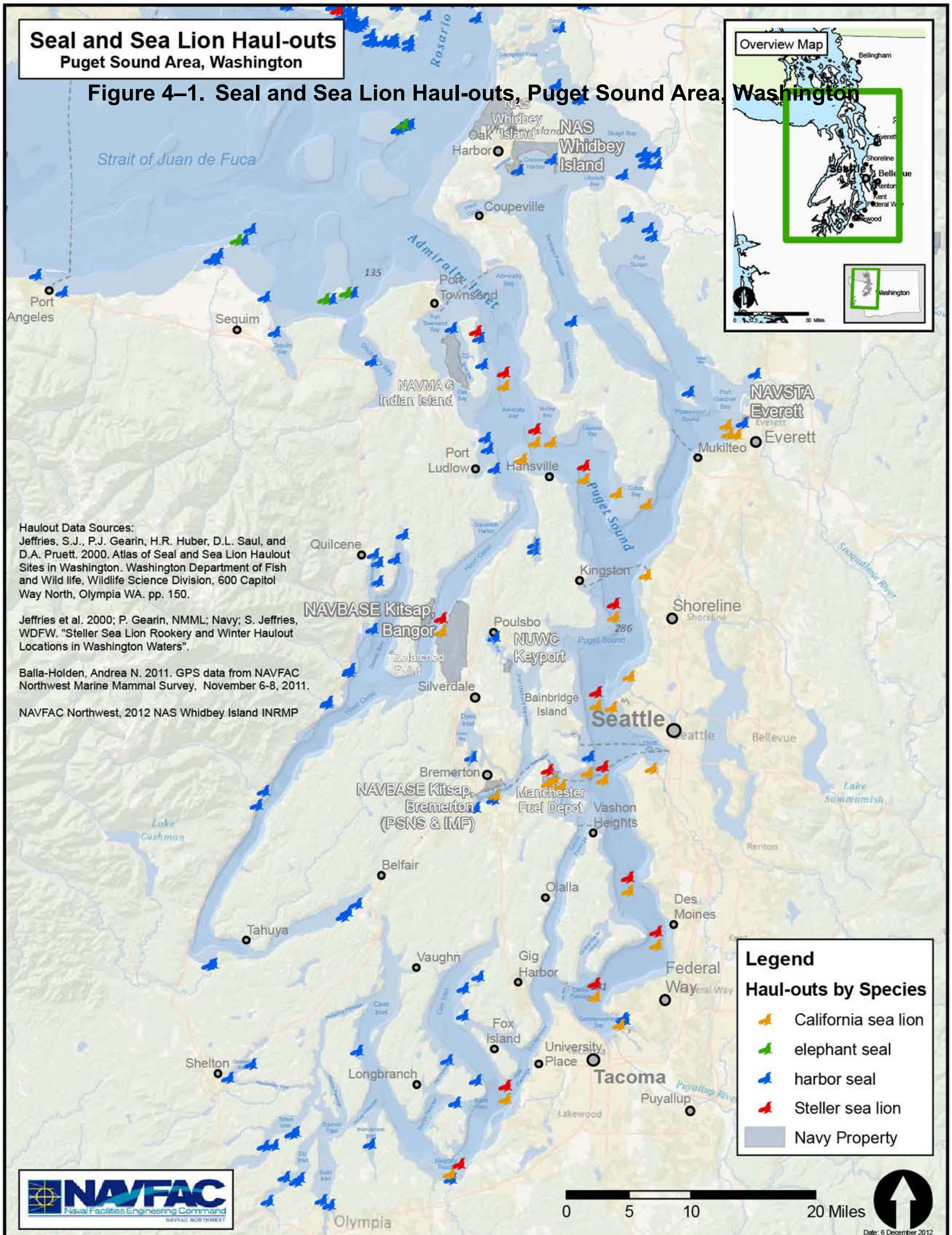


Figure 4–1. Seal and Sea Lion Haul-outs, Puget Sound Area, Washington

## 4.2 California Sea Lion (*Zalophus californianus*), U.S. Stock

*Distribution*

The geographic distribution of California sea lions includes a breeding range from Baja California to southern California. During the summer, California sea lions breed at rookeries on islands from the Gulf of California to the Channel Islands and seldom travel more than about 50 kilometers from the islands (Bonnell et al. 1983).

The non-breeding distribution extends from Baja California north to Alaska for males, and encompasses the waters of California and Baja California for females (Maniscalco et al. 2004; Reeves et al. 2008). In the non-breeding season, an estimated 3,000 to 5,000 adult and sub-adult males migrate northward along the coast to central and northern California, Oregon, Washington, and Vancouver Island from September to May (Jeffries et al. 2000) and return south the following spring (Mate 1975; Bonnell et al. 1983). Along their migration, they are occasionally sighted hundreds of miles offshore (Jefferson et al. 1993). Females and juveniles tend to stay closer to the breeding rookeries (Bonnell et al. 1983).

Peak abundance in Puget Sound occurs September to May. California sea lions are known to haul out on manmade structures, such as piers, jetties, offshore buoys, and oil platforms (Riedman 1990; Jeffries et al. 2000). As many as 122 California sea lions have hauled out daily from late August through early June on pontoons of the port security barrier (PSB) and submarines docked at NBK at Bangor in Hood Canal (Figure 4–1) (Agness and Tannenbaum 2009; Tannenbaum et al. 2009; HDR 2012; Navy 2013; Hart Crowser 2013). California sea lions were also observed swimming near the EHW-1 on several occasions, and they likely forage in nearshore and deep-water marine habitats within the vicinity.

*Behavior and Ecology*

California sea lions are gregarious during the breeding season and social at haul-out sites during other times. They prefer to breed on sandy, remote beaches (Le Boeuf 2002) near productive upwelling zones where prey is easily available to lactating females (Heath 2002). Females give birth in May and June, and mating follows. Within their geographic range, California sea lions have been known to utilize manmade structures such as piers, jetties, offshore buoys, oil platforms, and navigational buoys (Jeffries et al. 2000).

California sea lions are opportunistic foragers whose diet varies by season and location. The diet throughout their range includes a wide variety of prey, including many species of fish and squid (Everitt et al. 1981; Roffe and Mate 1984; Antonelis et al. 1990; Lowry et al. 1991). In the Puget Sound region, they feed primarily on Pacific hake and Pacific herring (Everitt et al. 1981; Olesiuk et al. 1993; London 2006). In some locations, California sea lions feed on returning adult and out-migrating juvenile salmonids (review in London 2006; Scordino 2010).

## 4.3 Harbor Seal (*Phoca vitulina*), Washington Inland Waters Stock

*Distribution*

The geographic distribution of harbor seals includes the U.S. west coast from Baja California north to British Columbia and coastal Alaska, including southeast Alaska, the Aleutian Islands, the Bering Sea, and the Pribilof Islands (Carretta et al. 2013). The harbor seal is the only pinniped species that breeds in inland Washington waters, including Hood Canal, and is consistently abundant and widespread (Jeffries et al. 2003). The population of harbor seals in Hood Canal is a closed population, meaning they do not have much movement outside of Hood Canal (London 2006). The abundance of harbor seals in Hood Canal has stabilized, and the population may have reached carrying capacity in the mid-1990s (approximate abundance in Hood Canal is 1,000 harbor seals) (Jeffries et al. 2003). The mean population size in 1999 for harbor seals in all inland waters of Washington was estimated from 9,550 to 14,612 harbor seals (Jeffries et al. 2003). Thus, up to 10 percent of the Puget Sound harbor seal population occurs in Hood Canal.

The most frequently used haul-out sites for harbor seals in Hood Canal (Figure 4–1) are located on river deltas and tidal exposed areas at Quilcene, Dosewallips, Duckabush, Hamma Hamma, and Skokomish River mouths, with the closest haul-out area 10 miles southwest of NBK at the Dosewallips River mouth (London 2006) (Figure 4–1).

Harbor seals have been observed swimming in the waters along NBK at Bangor in every month of surveys conducted from 2007 to 2013 (Agness and Tannenbaum 2009; Tannenbaum et al. 2009, 2011; HDR 2012; Hart Crowser 2013). Harbor seals have not been observed hauled out along the shoreline of NBK at Bangor, but have historically and occasionally been observed hauled out on manmade structures such as the floating security fences, wavescreen at Carderock Pier, buoys, barges, and logs (Agness and Tannenbaum 2009; Tannenbaum et al. 2009, 2011). In addition, harbor seals were occasionally seen hauled out on opportunistic and temporary manmade floating structures near K/B Dock and Delta Pier. On two occasions, the group size was four to six individuals near Delta Pier.

*Behavior and Ecology*

Although generally solitary in the water, harbor seals come ashore at communal haul-out sites for resting, thermoregulation, birthing, and nursing pups. Major haul-out sites are relatively consistent from year to year. Haul-out areas can include intertidal and subtidal rock outcrops, mudflats, sandbars, sandy beaches, peat banks in salt marshes, and manmade structures such as log booms, docks, and recreational floats (Wilson 1978; Prescott 1982; Gilbert and Guldager 1998; Jeffries et al. 2000). Harbor seals mate at sea and females in most areas give birth during the spring and summer, although the "pupping season" varies considerably in the Pacific Northwest. The Hood Canal population has the latest pupping season in the region: pupping typically extends from mid-July through December (Ferrero and Fowler 1992). Suckling harbor seal pups spend as much as 40 percent of their time in the water (Bowen et al. 1999). Vessel crews reported that harbor seal pupping has occurred on a section of the Service Pier (over a mile south of the EHW-2 project site). Navy biologists will confirm these observations in 2014. On August 5, 2011, a harbor seal gave birth on the wavescreen dock at Carderock Pier, just south of the Service Pier. A harbor seal neonate was documented on a small floating dock at the EHW-2 project site in Fall 2013.

Harbor seals are opportunistic feeders that adjust their patterns to take advantage of locally and seasonally abundant prey (Payne and Selzer 1989; Baird 2001; Bjørge et al. 2002). Their diet consists of fish and invertebrates (Bigg 1981; Roffe and Mate 1984; Orr et al. 2004). In the Puget Sound region, the diet is diverse but primarily consists of Pacific hake, walleye pollock, and Pacific herring (Lance and Jeffries 2006, 2007; London 2006; Luxa 2008). In some locations harbor seals feed on returning adult and out-migrating juvenile salmonids (London et al. 2002; Lance and Jeffries 2006, 2007; London 2006; Scordino 2010). Harbor seals in Hood Canal feed on returning adult salmon, including threatened summer-run chum salmon (London et al. 2002); the other top prey species found in Hood Canal harbor seal scats were Pacific hake and Pacific herring (London 2006). Telemetry studies in the San Juan Islands showed no consistent diurnal or nocturnal pattern for foraging behavior (Suryan and Harvey 1998), and observations in Hood Canal at river mouths indicated that feeding on fish occurred during both day and night, and was most influenced by tidal stage (London 2006).

## 4.4 Killer whale (*Orcinus orca*), West Coast Transient Stock

*Distribution*

The geographical range of West Coast stock transient killer whales includes the northeast Pacific, with a preference for coastal waters of southern Alaska and British Columbia. Groups of West Coast stock transients regularly visit waters off the coast of central California (Krahn et al. 2002; Black 2011). Transient killer whales in the Pacific Northwest spend most of their time along the outer coast of British Columbia and Washington, but visit inland waters in search of harbor seals, sea lions, and other prey. Transients may occur in inland waters in any month (Orca Network 2010), but several studies have shown peaks in occurrences: Morton (1990) found bimodal peaks in spring (March) and fall (September to November) for transients on the northeastern coast of British Columbia. Baird and Dill (1995) found some transient groups frequenting the vicinity of harbor seal haul-outs around southern Vancouver Island during August and September, which is the peak period for pupping through post-weaning of harbor seal pups. However, not all transient groups were seasonal in these studies, and their movements appear to be unpredictable. In 2003 and 2005, small groups of transient killer whales (11 and 6 individuals, respectively) entered Hood Canal to feed on harbor seals and remained in the area for significant periods of time (59 and 172 days, respectively) between the months of January and July. Killer whales have not had a significant presence in Hood Canal within the past 30 years, although both mammal-eating and fish-eating killer whales have been observed previously in Hood Canal (London 2006). For both types, occurrences have been extremely rare and most last less than one or two days (London 2006).

*Behavior and Ecology*

Transient killer whales show great variability in habitat use, with some groups spending most of their time foraging in shallow waters close to shore while others hunt almost entirely in open water (Felleman et al. 1991; Baird and Dill 1995; Matkin and Saulitis 1997). West Coast transient killer whales feed on marine mammals and some seabirds, and do not consume fish (Morton 1990; Baird and Dill 1996; Ford et al. 1998, 2005; Ford and Ellis 1999). While present in Hood Canal in 2003 and 2005, transient killer whales preyed on harbor seals in the subtidal zone of the nearshore marine and inland marine deeper water habitats (London 2006). Other observations of foraging transient killer whales indicate they prefer to forage on pinnipeds in shallow, protected waters (Heimlich-Boran 1988; Saulitis et al. 2000). Transient killer whales travel in small matrilineal groups, and their social organization generally is more fluid than the resident killer whale (Morton 1990; Ford and Ellis 1999). Differences in social organization may be adaptations to differences in feeding specializations (Ford and Ellis 1999; Baird and Whitehead 2000). There is no information on the reproductive behavior of transient killer whales in this area.

## 4.5 Harbor Porpoise (*Phocoena phocoena*), Washington Inland Waters Stock

*Distribution*

Harbor porpoises are generally found in cool temperature to subarctic waters over the continental shelf in both the North Atlantic and North Pacific (Read 1999). This species is seldom found in waters warmer than 17°C (Gaskin et al. 1993) or south of Point Conception in southern California (Barlow and Hanan 1995). Harbor porpoises can be found year-round, primarily in the shallow coastal waters including harbors, bays, and river mouths (Green et al. 1992). Along the Pacific coast, harbor porpoises occur from Monterey Bay, California, to the Aleutian Islands and west to Japan (Reeves et al. 2008). Harbor porpoises are known to occur in Puget Sound year-round (Osmek et al. 1996, 1998; Carretta et al. 2012); indeed, harbor porpoise observations in Puget Sound including northern Hood Canal have increased in recent years (Calambokidis 2010, personal communication). A harbor porpoise was seen in deeper water on NBK at Bangor during 2010 field observations (Tannenbaum et al. 2011). Line transect surveys conducted as part of the TPP detected harbor porpoises in the deeper waters of Hood Canal adjacent to NBK at Bangor (HDR 2012).

*Behavior and Ecology*

Harbor porpoises are usually seen in small groups of two to five animals. Little is known about their social behavior. Studies of harbor porpoises in the Gulf of Maine showed that they mature at an earlier age, reproduce more frequently, and live for shorter periods than other toothed whales (Read and Hohn 1995). Females reach sexual maturity at 3 to 4 years and may give birth every year for several years in a row. Calves are born in late spring (Read 1990; Read and Hohn 1995). Dall's and harbor porpoises appear to hybridize relatively frequently in the Puget Sound area (Willis et al. 2004).

Harbor porpoises can be opportunistic foragers but primarily consume schooling forage fish (Osmek et al. 1996; Bowen and Siniff 1999; Reeves et al. 2008). Along the coast of Washington, harbor porpoises primarily feed on Pacific herring (C*lupea pallasii*), market squid, and smelts (Gearin et al. 1994).

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# 5 HARASSMENT AUTHORIZATION REQUESTED

*The type of incidental taking authorization that is being requested (i.e., takes by harassment only, takes by harassment, injury and/or death), and the method of incidental taking.*

Under Section 101 (a)(5)(D) of the MMPA, the Navy requests an IHA for the take of marine mammals incidental to construction of a second EHW on NBK at Bangor, Washington. The Navy requests an IHA for the incidental take described in this application for the third year of construction: July 16, 2014, through February 15, 2015, for pile-driving. The Navy previously submitted IHA applications for the first and second years of construction, which were granted by NMFS.

Except with respect to certain activities not pertinent here, the MMPA defines ‘‘harassment’’ as: any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild [Level A harassment]; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering [Level B harassment] (50 CFR, Part 216, Subpart A, Section 216.3-Definitions).

Level A is the more severe form of harassment because it may result in injury, whereas Level B only results in disturbance without the potential for injury (Norberg 2007a, personal communication).

## 5.1 Take Authorization Request

Under Section 101 (a)(5)(D) of the MMPA, the Navy requests an IHA from NMFS for: Level B harassment (behavioral harassment) of marine mammals described within this application as a result of in-water pile driving activities. The Navy requests the IHA to begin coverage on July 16, 2014, and extend through February 15, 2015.

The exposure assessment methodology taken in this IHA request attempts to quantify potential exposures to marine mammals resulting from pile driving. Section 6 presents a detailed description of the acoustic exposure assessment methodology. Results from this approach tend to provide an overestimation of exposures because all animals are assumed to be available to be exposed 100 percent of the time, and the formulas used to estimate transmission loss used idealized parameters, which are unrealistic in nature. Densities of marine mammals in Hood Canal vary throughout the year due to seasonal migrations of several species. Modeling was conducted for the seven months in the proposed construction season (July 16 through February 15). The modeling estimated exposures based on the densities of marine mammal species and the expected number of pile driving days for each month over the projected maximum of 195 days of pile driving for the third year of construction.

The proposed action may affect the prey of marine mammals and may represent a partial barrier to the movement of marine mammals. However, none of these effects is expected to rise to the level of take.

The modeling results for the EHW-2 predict 16,755 potential exposures (see Section 6, Table 6–14 for estimates of exposures by species and season) from pile driving for the third year of construction (maximum of 195 pile driving days) that could be classified as Level B harassment as defined under the MMPA. The Navy’s mitigation procedures, presented in Section 11, include monitoring to ensure that marine mammals are not present in injury zones during pile driving, implementation of pile driving shutdown in the event that marine mammals appear in injury zones, the use of a soft start for impact pile driving, and the use of noise attenuating devices (e.g., bubble curtain) on all impact driven piles.

The Navy does not anticipate that 16,755 actual harassment incidents will result from pile driving activities within Hood Canal. However, to allow for scientific uncertainty regarding the exact mechanisms of the physical and behavioral effects, and as a conservative approach, the Navy is requesting authorization for behavioral disturbance (Level B harassment) of 16,755 marine mammals over the third year of construction covered by this IHA application.

## 5.2 Method of Incidental Taking

Although the proposed action may affect the prey and other habitat features of marine mammals, none of these effects is expected to rise to the level of take. Pile driving activities associated with construction of the EHW-2 as outlined in Sections 1 and 2 have the potential to disturb or displace marine mammals. Specifically, the proposed activities may result in Level B harassment (behavioral disturbance) only from airborne or underwater sounds generated from pile driving. Level A harassment is not anticipated given the methods of installation and measures designed to minimize the possibility of injury to marine mammals. Specifically, vibratory pile drivers will be the primary method of installation, which are not expected to cause injury to marine mammals due to the relatively low source levels (<190 dB). Also, impact pile driving will not occur without a noise attenuation measure (such as a bubble curtain or other attenuating device) in place, and pile driving will either not start or be halted if marine mammals approach the shutdown zone. See Section 11 for more details on the impact reduction and mitigation measures proposed.

# 6 NUMBERS AND SPECIES EXPOSED

*By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in [Section 5], and the number of times such takings by each type of taking are likely to occur.*

## 6.1 Introduction

The NMFS application for an IHA requires applicants to determine the number of marine mammals that are expected to be incidentally harassed by an action and the nature of the harassment (Level A or Level B). Section 5 defines MMPA Level A and Level B. The project construction and operation as outlined in Sections 1 and 2 have the potential to affect marine mammals by behavioral harassment only, primarily through noise generated by in-water pile driving. Section 6 below presents how these definitions were relied on to develop the quantitative acoustic analysis methodologies used to assess the potential for the proposed action to affect marine mammals. Analytical methods are summarized in this section and described fully in Appendix B. The Navy recently developed draft recommendations for pile driving noise source levels to be used in the Navy's permit applications for in-water construction projects beginning in 2013. In support of this effort, the Navy reviewed available pile driving noise data in Puget Sound, including data that were not available at the time the EHW-2 noise analysis was developed. However, this application for the third year of EHW-2 construction uses the earlier analysis methods and source levels presented in the IHA applications for the first and second years of EHW-2 construction. This was done to maintain consistency with the EHW-2 National Environmental Policy Act (NEPA) Record of Decision (77 FR 29620). Also, the analytical method used for EHW-2 differs from analysis of acoustic impacts from a single pile driver used in other waterfront construction projects because it involves modeling underwater sound propagation from multiple concurrent pile drivers, as described below and in Appendix B. Up to three vibratory pile drivers and one impact pile driver may be in use at a time on the EHW-2 project. The assumption that four pile drivers will be operating concurrently throughout the construction day is a worst-case scenario; modeling based on this assumption resulted in highly conservative noise propagation distances. Source levels used in the multiple concurrent pile driver analysis are conservative values for the pile sizes in this project and are consistent with recently available data from pile driving projects on the NBK at Bangor waterfront (Illingworth & Rodkin 2012, 2013).

In-water pile driving will temporarily increase the local underwater and airborne noise environment in the vicinity of the project area. Research suggests that increased noise may impact marine mammals in several ways and depends on many factors. This is discussed in more detail in Section 7. Section 6 provides a summary of noise sources in the area of the projects, applicable criteria related to underwater and airborne noise, and the basis for the calculation of Level B harassment exposures for marine mammal species in the area of the projects. Detailed information on fundamentals of underwater and airborne sound, descriptions of noise sources, and noise analysis methods for impact and vibratory pile driving are provided in Appendix B. Level A harassment of cetaceans and pinnipeds for this project is not expected to occur; therefore, the noise-related impacts discussed in this IHA are entirely Level B harassment. Other project activities are not expected to result in take as defined under the MMPA. Effects of these activities are discussed in Section 7.

## 6.2 Vocalizations and Hearing of Marine Mammals

Marine mammals produce sounds that are linked to their peak hearing capabilities in order to interact with one another, but their hearing sensitivity extends beyond that peak range to allow them to detect acoustic cues from their environment (Ketten 2004). They use sound to navigate in limited visibility conditions, detect prey, and detect and respond to predators. Manmade sound in the marine environment that is in excess of certain levels can affect marine mammals behaviorally and physiologically. Measurements of marine mammal sound production and hearing capabilities provide some basis for assessing whether exposure to a particular sound source may affect a marine mammal behaviorally or physiologically. Marine mammal hearing abilities have been quantified using live subjects either via behavioral audiometry or electrophysiology (review in Southall et al. 2007). An auditory threshold, estimated either way, is the level of the quietest sound audible for a given frequency. For all marine mammal species measured, hearing response in relation to frequency is a generalized U-shaped curve (audiogram) showing the frequency range of best sensitivity (lowest hearing threshold). Marine mammals have poorer sensitivity (higher threshold values) to frequencies above and below this range.

Audiograms of marine mammals are difficult to obtain because many species are too large, too rare, and too difficult to acquire and train for experiments in captivity. In many cases, our understanding of a species' hearing ability may be based on the audiograms of a single individual or small group of animals. For species not available in captive or stranded settings (including large whales and rare species), estimates of hearing capabilities are extrapolated from cochlear morphology, body size, vocalization frequencies, and behavioral responses (or lack thereof) to sounds at various frequencies.

Direct measurement of hearing sensitivity exists for approximately 20 of the nearly 130 species of marine mammals (Southall et al. 2007). Species differ in absolute sensitivity and functional frequency bandwidth (i.e., the frequency range of best hearing sensitivity). In general, marine mammals are arranged into the following functional hearing groups based on their generalized hearing sensitivities: high-frequency cetaceans, mid-frequency cetaceans, low-frequency cetaceans (mysticetes), phocid pinnipeds (true seals), and otariid pinnipeds (sea lions and fur seals) (Southall et al. 2007; NOAA Fisheries 2013c). Table 6–1 summarizes sound production and hearing capabilities for marine mammal species in the project area. The estimated auditory bandwidth is the lower to upper frequency hearing cut-off. The bandwidth of best hearing sensitivity is the portion of this range with lowest hearing thresholds measured in laboratory studies.

### 6.2.1 Pinnipeds

Pinnipeds are amphibious, meaning that all foraging activity takes place in the water, but offspring are born on land at coastal rookeries (Mulsow and Reichmuth 2008). Thus, underwater and in-air frequency ranges for hearing and vocalizations are relevant to these species. On land, territorial male Steller sea lions regularly use loud, relatively low-frequency calls/roars to establish breeding territories (Schusterman et al. 1970; Loughlin et al. 1987). Individually distinct vocalizations exchanged between mothers and pups are thought to be the main way in which mothers reunite with their pups after returning to crowded rookeries following foraging at sea (Mulsow and Reichmuth 2008). On land, California sea lions make raucous barking sounds, with most of the sound energy occurring at less than 2 kHz (Schusterman 1974). As amphibious mammals, pinniped hearing differs in air and in water (Kastak and Schusterman 1998), and separate auditory ranges have been measured in each medium. Phocid species have demonstrated an extended underwater frequency range of hearing, especially in the higher frequencies (Hemilä et al. 2006; Kastelein et al. 2009; Reichmuth et al. 2013), compared to the otariid species. Phocid ears have anatomical features that appear to adapt them better to hearing underwater than otariids (Hemila et al. 2006). Harbor seals hear almost equally as well in air as underwater and have lower underwater sound detection thresholds at lower frequencies (below 64 kHz) than California sea lions (Kastak and Schusterman 1998). This difference is thought to make harbor seals more vulnerable to low-frequency manmade sounds such as ships and oil platforms.

### 6.2.2 Transient Killer Whale (Mid-Frequency Cetaceans)

Killer whales produce several types of underwater sounds, including: (1) clicks used for echolocation, (2) highly variable whistles produced while whales socialize, and (3) pulsed signals generated at high repetition rates (Ford 1987). Both behavioral and auditory brainstem response measurements indicate they can hear in a frequency range of 1 to 100 kHz and are most sensitive at 20 kHz. This is one of the lowest maximum-sensitivity frequencies known among toothed whales (Szymanski et al. 1999).

Killer whales are “mid-frequency” cetaceans; that is, their echolocation signals use a frequency range that is somewhat lower than some of the other toothed whales, such as Dall’s porpoise and harbor porpoise. Social signals generally involve a lower frequency range. The most abundant and characteristic sound type produced by killer whales is pulsed signals, which are highly repetitive and fall into distinctive structural categories (Ford 1987). These are referred to as discrete calls, and one of their potential functions may be to help whales maintain contact while they are out of sight of each other (Ford and Ellis 1999).

The discrete call repertoire of Pacific Northwest transients is smaller than that of resident whales, with only four to six calls, none of which is used by resident whales. Moreover, transients are far quieter than residents when foraging, suggesting that they must remain relatively silent to avoid alerting their prey because marine mammals such as pinnipeds are highly sensitive to sounds in the frequency range of sonar clicks (Barrett-Lennard et al. 1996).

### 6.2.3 High-Frequency Cetaceans

The harbor porpoise is a “high-frequency” cetacean; that is, its auditory range includes very high frequencies (estimated auditory bandwidth for this category is 200 to 180 kHz) (Southall et al. 2007). Harbor porpoises use very high-frequency sounds for echolocation and lower frequency signals for social interactions (Southall et al. 2007).

**Table 6–1. Hearing and Vocalization Ranges for Marine Mammal Functional Hearing Groups and Species Present Within the Project Area**

| Functional Hearing Group[1] | Functional Hearing Group – Estimated Auditory Bandwidth[1] | Species Represented in Project Area | Vocalization Dominant Frequencies (citation) | Best Hearing Sensitivity Range (citation) |
|---|---|---|---|---|
| **High-Frequency Cetaceans** | 200 Hz to 180 kHz[2] | Harbor Porpoise | 120 to 140 kHz (pulses; Tyack and Clark 2000; Hansen et al. 2008);<br>110 to 150 kHz (Ketten 1998) | 16 to 140 kHz (bimodal; reduced sensitivity at 64 kHz; maximum sensitivity 100 to 140 kHz; Kastelein et al. 2002) |
| **Mid-Frequency Cetaceans** | 150 Hz to 160 kHz[2] | Killer Whale | 1.5 to 6 kHz (pulses; Richardson et al. 1995)<br>35 to 50 kHz (echolocation; Au et al. 2004)<br>6 to 12 kHz (whistles; Richardson et al.1995) | 18 to 42 kHz<br>(Szymanski et al. 1999) |
| **Phocid Pinnipeds (true seals)** | In-water: 75 Hz to 100 kHz[3]<br>In-air: 75 Hz to 30 kHz | Harbor Seal | In-water: 250 Hz to 4 kHz (males: grunts, growls, roars; Hanggi and Schusterman 1994)<br>In-air: 100 Hz to 1 kHz (males: snorts, grunts, growls; Richardson et al. 1995) | In-water: 1 to 50 kHz (Southall et al. 2007)<br>In-air: 6 to 16 kHz (Richardson et al. 1995; Wolski et al. 2003) |
| **Otariid Pinnipeds (true seals)** | In-water: 100 Hz to 40 kHz[3]<br>In-air: 25 Hz to 30 kHz[3] | Steller Sea Lion | In-water: <1 kHz (males: pulses; Schusterman et al. 1970)<br>In-air: 150 Hz to 1 kHz (females; Campbell et al. 2002) | In-water: 1 to 16 kHz (males; Kastelein et al. 2005)<br>16 to 25 kHz (females; Kastelein et al. 2005)<br>In-air: 5 to 14 kHz (Schusterman 1974; Mulsow & Reichmuth 2008; Mulsow & Reichmuth 2010) |
| | | California Sea Lion | In-water: 500 Hz to 4 kHz (clicks, pulses, barks; Schusterman et al. 1966, 1967; Schusterman & Balliet 1969)<br>In-air: 250 to 5 kHz (barks; Schusterman 1974) | In-water: 1 to 28 kHz (Schusterman et al. 1972)<br>In-air: 4 to 16 kHz (Mulsow et al. 2011a,b) |

Hz = hertz; kHz = kilohertz

1. Source: Southall et al. 2007.
2. Source: NOAA Fisheries (2013c).
3. Source: Mulsow and Reichmuth (2010).

## 6.3 Sound Exposure Criteria and Thresholds

Under the MMPA, NMFS has defined levels of harassment for marine mammals. Level A harassment is defined as "Any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild." Level B harassment is defined as "Any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to migration, breathing, nursing, breeding, feeding or sheltering."

NMFS uses generic sound exposure thresholds to determine when an activity in the ocean that produces sound might result in impacts to a marine mammal such that a take by harassment might occur (NMFS 2005). To date, no studies have been conducted that examine impacts to marine mammals from pile driving sounds from which empirical noise thresholds have been established. Current NMFS practice regarding exposure of marine mammals to high underwater level sounds is that cetaceans and pinnipeds exposed to impulsive sounds equal to or greater than 180 and 190 dB RMS, respectively, are considered to have been taken by Level A (i.e., injurious) harassment. Level A injury thresholds have not been established for continuous sounds such as vibratory pile driving, but the Navy has applied the threshold values for impulsive sounds to vibratory sound in this analysis (Table 6–2).

Behavioral harassment (Level B) is considered to have occurred when marine mammals are exposed to underwater sounds equal to or greater than 160 dB RMS for impulse sounds (e.g., impact pile driving) and 120 dB RMS for continuous noise (e.g., vibratory pile driving), but below injurious thresholds. Level A (injury) and Level B (disturbance) thresholds are provided in Table 6–2.

**Table 6–2. Injury and Disturbance Thresholds for Underwater and Airborne Sounds**

| Marine Mammals | Airborne Marine Construction Criteria (impact and vibratory pile driving) (re 20 µPa)[1] | Underwater Vibratory Pile Driving Criteria (non-pulsed/continuous sounds) (re 1 µPa) | | Underwater Impact Pile Driving Criteria (pulsed sounds) (re 1 µPa) | |
|---|---|---|---|---|---|
| | Disturbance Guideline Threshold (haul-out)[2] | Level A Injury Threshold | Level B Disturbance Threshold | Level A Injury Threshold | Level B Disturbance Threshold |
| **Cetaceans** (whales, dolphins, porpoises) | Not applicable | 180 dB RMS | 120 dB RMS | 180 dB RMS | 160 dB RMS |
| **Pinnipeds** (seals, sea lions, walrus, except harbor seal) | 100 dB RMS (unweighted) | 190 dB RMS | 120 dB RMS | 190 dB RMS | 160 dB RMS |
| Harbor seal | 90 dB RMS (unweighted) | 190 dB RMS | 120 dB RMS | 190 dB RMS | 160 dB RMS |

dB = decibel; µPa = micropascal; RMS = root-mean-square

1. Airborne disturbance thresholds do not specify pile driver type.
2. Sound level at which pinniped haul-out disturbance has been documented. Not an official threshold, but used as a guideline.

As described above for underwater sound injury and harassment thresholds, NMFS uses generic sound exposure thresholds to determine when an activity in the ocean that produces airborne sound might result in impacts to a marine mammal (70 FR 1871). Construction-period airborne noise would have little impact to cetaceans because noise from airborne sources would not transmit as well underwater (Richardson et al. 1995); thus, noise would primarily be a problem for hauled-out pinnipeds near the EHW-2 project site. NMFS has identified behavioral harassment threshold criteria for airborne noise generated by pile driving for pinnipeds regulated under the MMPA. Level A injury threshold criteria for airborne noise have not been established. The Level B behavioral harassment threshold for harbor seals is 90 dB RMS (unweighted) and for all other pinnipeds is 100 dB RMS (unweighted).

#### 6.3.1 Limitations of Existing Noise Criteria

The application of the 120 dB RMS threshold can sometimes be problematic because this threshold level can be either at or below the ambient noise level of certain locations. As a result, this threshold level is subject to ongoing discussion (NMFS 2009 74 FR 41684). NMFS is developing new science-based thresholds to improve and replace the current generic exposure level thresholds, but the criteria have not been finalized (Southall et al. 2007). The 120 dB RMS threshold level for continuous noise originated from research conducted by Malme et al. (1984, 1988) for California gray whale response to continuous industrial sounds such as drilling operations. (The 120 dB *continuous* sound threshold should not be confused with the 120 dB *pulsed* sound criterion established for migrating bowhead whales in the Arctic as a result of research in the Beaufort Sea [Richardson et al. 1995; Miller et al. 1999]).

To date, there is no research or data supporting a response by pinnipeds or odontocetes to continuous sounds from vibratory pile driving as low as the 120 dB threshold. Southall et al. (2007) reviewed studies conducted to document behavioral responses of harbor seals and northern elephant seals to continuous sounds under various conditions, and concluded that those limited studies suggest that exposures between 90 and 140 dB RMS generally do not appear to induce strong behavioral responses.

### 6.4 Noise Exposure Analysis

#### 6.4.1 Distance to Underwater Sound Thresholds

Pile driving will generate underwater noise that potentially could result in disturbance to marine mammals swimming by the project area. Transmission loss (TL) underwater is the decrease in acoustic intensity as an acoustic pressure wave propagates out from a source. TL parameters vary with frequency, temperature, sea conditions, current, source and receiver depth, water depth, water chemistry, and bottom composition and topography. The degree to which underwater noise propagates away from a noise source is dependent on a variety of factors, most notably the underwater bathymetry and presence or absence of reflective or absorptive conditions including in-water structures and sediments. In a perfectly unobstructed (free-field) environment not limited by depth or water surface, noise follows the spherical spreading law, resulting in a 6 dB reduction in noise level for each doubling of distance from the source [20*log(range)]. Cylindrical spreading occurs in an environment wherein noise propagation is bounded by the water surface and sea bottom. In this case, a 3 dB reduction in noise level is observed for each doubling of distance from the source [10*log(range)]. The propagation environment along the Bangor waterfront on NBK is neither free-field nor cylindrical; as the receiver moves away from the shoreline, the water increases in depth, resulting in an expected propagation environment that would lie between spherical and cylindrical spreading loss conditions. At the time of the original IHA application, no empirical propagation loss studies had been conducted along the Bangor waterfront on NBK, and a practical spreading loss model was adopted to approximate the environment for noise propagation between the cylindrical and spherical methods. The practical spreading loss method uses a 4.5 dB reduction in noise level for each doubling of distance from the source , i.e.:

$TL = 15 * \log_{10}(R_1/R_2)$, where
$R_1$ = the distance of the modeled sound pressure level from the driven pile, and
$R_2$ = the distance from the driven pile of the initial measurement.

The practical spreading loss method has been accepted by NMFS and USFWS.

Monitoring results from the TPP and the first year of EHW-2 construction conducted on NBK at Bangor in late 2011 and 2012 support the use of the practical spreading model for estimating acoustic propagation in the project area (Illingworth and Rodkin 2012a, 2013). RMS transmission loss values measured during the TPP averaged 14 $\log_{10}$ (R) for impact pile driving and 16 $\log_{10}$ (R) for vibratory pile driving of 36-inch piles. Transmission loss measured during the first year of EHW-2 construction averaged 14.9 $\log_{10}$ (R) for impact pile driving of 36-inch piles and 16 $\log_{10}$ (R) for vibratory pile driving. The approach for estimating noise levels generated by pile driving for the EHW-2 is described in detail in Appendix B.

### 6.4.2 Underwater Noise from Pile Driving

#### *6.4.2.1 Source Levels*

The intensity of pile driving sounds is greatly influenced by factors such as the type and size of piles, type of pile driver, and the physical environment in which the activity takes place. In order to determine reasonable SPLs and their associated effects on marine mammals that are likely to result from pile driving on NBK at Bangor, studies with similar properties to the proposed action were evaluated as described in Appendix B. Studies that met the following parameters were considered:

1. Pile materials: steel pipe piles (30–72-inch diameter);
2. Pile driver type: vibratory and impact; and
3. Physical environment: shallow depth (<30 meters).

Tables 6–3 and 6–4 detail representative pile driving activities (impact hammer and vibratory driver, respectively) that have occurred in recent years, including pile driving projects on NBK at Bangor. Due to the similarity of these actions and the Navy's proposed action, they represent reasonable SPLs that could be anticipated. For the impact hammer, a source value of 195 dB RMS at 10 meters was the average value reported from the listed studies (Table 6–3). This value matches the values from the larger sized pile projects including values obtained during the TPP and Carderock Pier pile driving projects on the Bangor waterfront on NBK, which had similar pile materials (48 and 42-inch hollow steel piles, respectively), water depth, and substrate type as the EHW-2 project site. For the vibratory driver source level, the Navy selected the most conservative value (72-inch piles) available at the time of the first IHA application for the EHW-2 project (Table 6–4): 180 dB RMS at 10 meters, Subsequently, data became available for the TPP that indicated, on average, a lower source level for vibratory pile driving (172 dB RMS for 48-inch steel piles). However, the Navy has selected the 180 dB RMS source level as the worst-case condition in order to maintain a consistent approach with the first IHA application for the EHW-2 project.

Underwater noise levels during the worst-case multiple-rig scenario (up to three vibratory and one impact hammer rig concurrently) would be higher than those observed with a single rig operating due to the additive effects of multiple noise sources. Noise from multiple simultaneous sources produces an increase in the overall noise field.

**Table 6–3. Sound Pressure Levels from Pile Driving Studies Using Impact Hammers**

| Project | Location | Pile Type | Hammer Type | Water Depth | Distance | Measured Sound Levels (RMS) |
|---|---|---|---|---|---|---|
| Eagle Harbor Maintenance Facility[1] | Bainbridge Island, WA | Steel Pipe/ 30-inch | Diesel Hammer | 10 m | 10 m | 192 dB re 1 μPa |
| Friday Harbor Ferry Terminal[2] | Friday Harbor, WA | Steel Pipe/ 30-inch | Diesel Hammer | 10 m | 10 m | 196 dB re 1 μPa |
| Humboldt Bay Bridges[3] | CA | CISS Steel Pipe/ 36-inch | Diesel Impact Hammer | 10 m | 10 m | 193 dB re 1 μPa |
| Mukilteo Test Piles[4] | WA | Steel Pipe/ 36-inch | Impact | 7.3 m | 10 m | 195 dB re 1 μPa |
| Anacortes Ferry[5] | WA | Steel Pipe/ 36-inch | Impact | 12.8 m | 10 m | 199 dB re 1 μPa |
| Test Pile Program, NBK at Bangor[6] | Hood Canal, WA | Steel Pipe/ 36-inch | Diesel | 13.7 to 26.8 m | 10 m | 196 dB re 1 μPa |
| EHW-2 First Year, NBK at Bangor[7] | Hood Canal, WA | Steel Pipe/ 36-inch | Impact | 0 to 30 m | 10 m | 191 dB re 1 μPa[8] |
| Carderock Pier, NBK at Bangor[9] | Hood Canal, WA | Steel Pipe/ 42-inch | Impact | 14.6 to 21.3 m | 10 m | 195 dB re 1 μPa |
| Test Pile Program, NBK at Bangor[6] | Hood Canal, WA | Steel Pipe/ 48-inch | Diesel | 26.2 to 28 m | 10 m | 194 dB re 1 μPa |
| EHW-2 First Year, NBK at Bangor[7] | Hood Canal, WA | Steel Pipe/ 48-inch | Impact | 13.7 to 26.8 m | 10 m | 194 dB re 1 μPa[8] |
| Russian River[3] | Russian River, CA | CISS Steel Pipe/ 48-inch | Diesel Impact | 2 m | 10 m<br>20 m<br>45 m<br>65 m | 195 dB re 1 μPa<br>190 dB re 1 μPa<br>185 dB re 1 μPa<br>175 dB re 1 μPa |
| Unknown[3,10] | CA | Steel CISS/ 60-inch | Impact | ~10 m | 10 m | 195 dB re 1 μPa |
| Richmond-San Rafael Bridge[3] | San Francisco Bay, CA | CIDH Steel Pipe/ 66-inch | Diesel Impact | 4 m | 4 m<br>10 m<br>20 m<br>30 m<br>40 m<br>60 m<br>80 m | 202 dB re 1 μPa<br>195 dB re 1 μPa<br>189 dB re 1 μPa<br>185 dB re 1 μPa<br>180 dB re 1 μPa<br>169 dB re 1 μPa<br>170 dB re 1 μPa |

**Sources:**
1. JASCO Research Ltd. 2005
2. Laughlin 2005b
3. Illingworth & Rodkin 2007 and 2012b
4. WSDOT 2007a
5. WSDOT 2007b
6. Illingworth & Rodkin 2012a
7. Illingworth & Rodkin 2013. During year 1 EHW-2 construction, only one 48-inch pile was driven.
8. Bubble curtain was in place for all measurements.
9. Navy 2009. Source level at 10 meters (m) estimated based on measurements at distances of 48 to 387 m.
10. Summary value possibly comprising multiple events rather than a single event.

CA = California; CIDH = cast-in-drilled hole; CISS = cast-in-steel-shell; dB = decibel; μPa = micropascal; m = meter; RMS = root-mean-square; WA = Washington

**Table 6–4. Sound Pressure Levels from Pile Driving Studies Using Vibratory Drivers**

| Project | Location | Pile Type | Hammer Type | Water Depth | Distance | Measured Sound Levels (RMS) |
|---|---|---|---|---|---|---|
| Vashon Terminal[1] | WA | Steel Pipe/30-inch | Vibratory | ~6 m | 11 m | 165 dB re 1 μPa |
| Keystone Terminal[2] | WA | Steel Pipe/30-inch | Vibratory | ~5 m | 10 m | 164 dB re 1 μPa |
| Keystone Terminal[2] | WA | Steel Pipe/30-inch | Vibratory | ~8 m | 10 m | 165 dB re 1 μPa |
| Edmonds Ferry Terminal[3] | WA | Steel Pipe/36 inch | Vibratory | 5.8 m | 11 m | 162 to 163 dB re 1 μPa[6] |
| Anacortes Ferry Terminal[4] | WA | Steel Pipe/36-inch | Vibratory | 12.7 m | 11 m | 168 to 170 dB re 1 μPa[6] |
| Test Pile Program (TPP), NBK at Bangor[5] | Hood Canal, WA | Steel Pipe/36-inch | Vibratory | 13.7 to 26.8 m | 10 m | 154 to 169 dB re 1 μPa[6] |
| Unknown[7,8] | CA | Steel Pipe/36-inch | Vibratory * | ~5 m | 10 m | 170 dB re 1 μPa |
| Unknown[7,8] | CA | Steel Pipe/36-inch | Vibratory ** | ~5 m | 10 m | 175 dB re 1 μPa |
| EHW-2 First Year, NBK at Bangor[9] | Hood Canal, WA | Steel Pipe/ 36-inch | Vibratory | Average of mid-depth and bottom hydro-phones | 10 m | 169 dB re 1 μPa |
| Test Pile Program (TPP), NBK at Bangor[5] | Hood Canal, WA | Steel Pipe/48-inch | Vibratory | 13.7 to 26.8 m | 10 m | 172 dB re 1 μPa[6] |
| Unknown[7] | CA | Steel Pipe/72-inch | Vibratory * | ~5 m | 10 m | 170 dB re 1 μPa |
| Unknown[7] | CA | Steel Pipe/72-inch | Vibratory ** | ~5 m | 10 m | 180 dB re 1 μPa |

**Sources:**

1. Laughlin 2010a; RMS noise levels reported in terms of the 30-second average continuous sound level and computed from the Fourier transform of pressure waveforms in 30-second time intervals. Average of measured values at 11 meters.
2. Laughlin 2010b; RMS noise levels reported in terms of the 30-second average continuous sound level and computed from the Fourier transform of pressure waveforms in 30-second time intervals.
3. WSDOT 2011
4. WSDOT 2012
5. Illingworth & Rodkin 2012a. RMS duration was 10 seconds and arithmetically averaged over the duration of the driving event.
6. Maximum of averages
7. Adapted from *Compendium of Pile Driving Data* report to the California Department of Transportation - Illingworth & Rodkin 2007; *RMS impulse level used duration of (35 msec), typical. **RMS impulse level used duration of (35 msec), loudest.
8. Summary value possibly comprising multiple events rather than a single event.
9. Illingworth & Rodkin 2013. Note: during first year of EHW-2 construction, only one 48-inch pile was driven.

CA = California; dB = decibel; μPa = micropascal; m = meter; msec = millisecond; RMS = root-mean-square; WA = Washington

#### *6.4.2.2 Noise Attenuation*

A bubble curtain will be used to minimize the noise levels generated by driving steel piles with an impact hammer. The Navy intends to use an unconfined bubble curtain. Unconfined bubble curtain attenuators (Type I) emit a series of bubbles around a pile to introduce a high-impedance boundary through which pile driving noise is attenuated. Published noise reduction results using an unconfined bubble curtain from several projects indicate a wide variance, with very little measurable attenuation in some cases (less than 6 dB) and high attenuation in other cases (greater than 15 dB) (Illingworth and Rodkin 2001; CALTRANS 2009; WSDOT 2014). Variability in performance of the bubble curtain can be due to multiple factors, including not seating on the bottom substrate or inadequate air pressure or inadequate distribution of air pressure to the curtain rings. CALTRANS (2009) noted noise reduction may be more difficult to achieve in harder substrates, which may transmit ground-borne noise and propagate it into the water column, while softer substrate may allow for a better seal of the curtain on the substrate. WSDOT (2013) provided a summary of unconfined bubble curtain performance for its projects in Washington (Table 6–5).

**Table 6–5. Average Noise Reduction Values for WSDOT Projects from 2005 to 2009 for Steel Piles Using an Unconfined Bubble Curtain. All values are dB re 1 μPa.**

| Location | Pile Diameter (inches) | Substrate Type | Hammer Energy Rating (ft-lbs) | Average Noise Reduction per Pile (range) | Standard Deviation (dB) |
|---|---|---|---|---|---|
| Friday Harbor Ferry Terminal[1] | 24<br>30 | Silty sand with hard clay layer | 60,000 | 2 dB (0 to 5) | 2.2 |
| Bainbridge Island Ferry Terminal[1] | 24 | Sand and fist-sized rocks to 1-foot rocks | 55,000 | 7 dB (3 to 14) | 4.7 |
| Mukilteo Test Pile Project[1] | 36 | Sand and silt | 164,000 | 15 dB (7 to 22) | 10.6 |
| Anacortes Ferry Terminal[1] | 36 | Sand and silt mix | 165,000 | 8 dB (3 to 11) | 3.1 |
| SR 520 Test Pile Project[2] (Lake Washington) | 24<br>30 | Very loose unconsolidated silt over glacial till | 20,100 | 20 dB (3 to 32) | 11.1 |
| SR-529[3] | 72 | "soft" substrate | APE D100 diesel hammer[4] | 22 dB (16 to 26) | 4.3 |

**Source:** WSDOT 2014. See also WSDOT individual reports, available at http://wsdot.wa.gov/environment/air/piledrivingreports.htm.

dB = decibel; ft-lbs = foot-pounds

1. Project located in Puget Sound Region (marine water environment).
2. Project located in Puget Sound Region (freshwater environment).
3. Project located in Puget Sound Region (estuarine environment subject to 4-foot tidal flux over test period).
4. APE D100 single-acting diesel impact hammer rated from 158,760 to 248,063 ft-lbs. Setting not specified in project report.

At the time the Navy evaluated bubble curtain attenuation performance for projects in Puget Sound, the TPP had not yet occurred, and a 10 dB reduction (CALTRANS 2009) was assumed in the analysis of pile driving noise with multiple concurrent pile drivers for the EIS and the first IHA application for the EHW-2 project. The TPP on NBK at Bangor reported a range of measured values, mostly within 6 to 12 dB reduction, with the use of a bubble curtain (Illingworth & Rodkin 2012a) (Tables 6–6 and 6–7). The sample set is limited with regard to the number of piles of various sizes and the strikes evaluated. The sole 24-inch pile in this project was struck a total of 10 times, 3 of which were attenuated, and the results are unlikely to be indicative of values that would be obtained on this site with more extensive measurements. Therefore, data for 24-inch piles are not considered further in this review. For 36-inch piles, the average RMS reduction with use of the bubble curtain was 8 dB, where the averages of all bubble-on and bubble-off data were compared (Table 6–6). For 48-inch piles, the average RMS reduction with use of the bubble curtain was 5 dB (Table 6–7).

**Table 6–6. Average Noise Reduction Values for Impact Pile Driving of 36-inch Steel Piles with a Bubble Curtain. Measured at 10 meters (dB re 1 μPa) combining mid-depth and deep-depth data. Measurements obtained during NBK at Bangor Test Pile Program.**

| | Sound Level (RMS)[1] | Sound Level (Peak)[2] | Sound Level (SEL)[3] |
|---|---|---|---|
| **Bubble Curtain On** | | | |
| Maximum | 190 | 208 | 180 |
| Average | 181 | 195 | 172 |
| Standard deviation | 5.45 | 6.09 | 5.07 |
| **Bubble Curtain Off** | | | |
| Maximum | 196 | 210 | 184 |
| Average | 189 | 203 | 177 |
| Standard deviation | 4.71 | 5.82 | 4.57 |

**Source:** Illingworth & Rodkin 2012a

RMS = root-mean-square; SEL = sound exposure level

1. Values are the averages of all bubble-on data and the averages of all bubble-off data, based on the average impulse RMS ($RMS_{imp}$) levels over the entire pile driving event.
2. Values are average peak levels of all bubble-on data and all bubble-off data.
3. Values are the average single strike SEL of all bubble-on data and all bubble-off data.

**Table 6–7. Average Noise Reduction Values for Impact Pile Driving of 48-inch Steel Piles with a Bubble Curtain. Measured at 10 meters (dB re 1 μPa) combining mid-depth and deep-depth data. Measurements obtained during NBK at Bangor Test Pile Program.**

| | Sound Level (RMS)[1] | Sound Level (Peak)[2] | Sound Level (SEL)[3] |
|---|---|---|---|
| **Bubble Curtain On** | | | |
| Maximum | 191 | 209 | 181 |
| Average | 187 | 201 | 177 |
| Standard deviation | 4.43 | 5.90 | 4.17 |
| **Bubble Curtain Off** | | | |
| Maximum | 194 | 209 | 181 |
| Average | 192 | 207 | 180 |
| Standard deviation | 1.83 | 1.71 | 1.41 |

**Source:** Illingworth & Rodkin 2012a

RMS = root-mean-square; SEL = sound exposure level

1. Values are the averages of all bubble-on data and the averages of all bubble-off data, based on the average impulse RMS ($RMS_{imp}$) levels over the entire pile driving event.
2. Values are average peak levels of all bubble-on data and all bubble-off data.
3. Values are the average single strike SEL of all bubble-on data and all bubble-off data.

There was no provision for acoustic monitoring with the bubble curtain off during the first year of EHW-2 construction (Illingworth & Rodkin 2013). Therefore, bubble curtain performance cannot be verified except by comparison with the attenuation expected with the 10 dB attenuation factor assumed prior to EHW-2 and based on the distances to injury and behavioral threshold levels measured during the TPP project. Monitoring results during TPP and the first year of EHW-2 construction indicate that distances to the injury thresholds for marine mammals were greater than the modeled distances for multiple pile driving rigs reported in the first IHA (Table 6–8) (Illingworth & Rodkin 2012a, 2013). The modeled distances for the 180 dB and 190 dB thresholds were 22 meters and 4.9 meters, respectively, whereas the distances calculated from pile driving noise levels recorded during the first year of EHW-2 were approximately double the modeled distances for the 180 dB and 190 dB thresholds. In contrast, the average calculated distance to the 160 dB threshold for impact pile driving of 36-inch piles with the bubble curtain on was 425 meters during TPP (Illingworth and Rodkin 2012a) and 670 meters during EHW-2 Year 1 (Illingworth and Rodkin 2013), compared to the modeled distance of 464 meters reported in the first IHA. At times during the first year of EHW-2 it appeared the bubble curtain achieved close to 10 dB of attenuation and other times it did not (Illingworth & Rodkin 2013). A number of sources of variability can influence variability in bubble curtain performance, including air flow and proper seating of the bubble curtain rings around the piles.

**Table 6–8. Distances to Pile Driving Noise Thresholds for Test Pile Project and EHW-2 and Monitoring Zones for EHW-2**

| Source | RMS Source Level | Threshold Distances | | | |
|---|---|---|---|---|---|
| | | 120 dB | 160 dB | 180 dB | 190 dB |
| **Calculated Distances to Thresholds** | | | | | |
| EIS and Year 1 IHA Application Modeled Distances | Multi-Rig Model (1 Impact and 3 vibratory drivers) Assumes 10 dB attenuation | 13.8 km[1] | See footnote 1 | 22 m | 4.9 m |
| **Test Pile Program** Measured Near-Field Source Level and Calculated distances to thresholds for 36-inch piles[2] | Spreading Loss Model = 16.43 $Log_{10}R$<br>Impact hammer with bubble curtain<br>Average = 181 dB (max 183 dB) | -- | 425 m | 35 m | <10 m |
| **Test Pile Program** Measured Near-Field Source Level and Calculated distances to thresholds for 48-inch piles[2] | Spreading Loss Model = 13.35 $Log_{10}R$<br>Impact hammer with bubble curtain<br>Average = 187 dB (max 188 dB) | -- | 1,300 m | 60 m | 15 m |
| **Test Pile Program** Estimated ranges based on measured data, 36-inch and 48-inch piles[3] | Day-to-day estimated range | 1,200 to 8,000+ m | - | - | - |
| **EHW-2 Year 1** Measured Near-Field Source Level and Calculated distances to thresholds for 36-inch piles[4] | Spreading Loss Model = 14.9 $Log_{10}R$<br>Impact Hammer with bubble curtain<br>Average = 188 dB (max = 191 dB) | -- | 670 m | 45 m | 12 m |
| **EHW-2 Year 1** 36-inch piles[5] | Distance to the 120 dB isopleth ranged from 300 m to 10,250 m | Average 4,400 m | - | - | - |
| **EHW-2 Monitoring Zones** | | | | | |
| **EHW-2 Year 1 IHA Application** Monitoring Zones[6] | Impact Hammer | -- | 464 m | Shutdown: 25 m | Shutdown: 10 m |
| | Vibratory Driver | 464 m | -- | Shutdown: 10 m | Shutdown: 10 m |
| **EHW-2 Years 2 and 3 IHA Applications** Monitoring Zones[8] | Impact Hammer | -- | Approx 500 m[7] | Shutdown: 85 m | Shutdown: 20 m |
| | Vibratory Driver | Approx 500 m | -- | Shutdown: 10 m | Shutdown: 10 m |

dB = decibel; km = kilometer; m = meter

**Table 6-8. Distances to Pile Driving Noise Thresholds for Test Pile Project and EHW-2 and Monitoring Zones for EHW-2 (continued)**

1. Distance to the 160 dB RMS behavioral harassment zone for impulsive noise is combined with distance to the 120 dB behavioral harassment zone for continuous noise.
2. Illingworth & Rodkin 2012a, Table 27
3. Illingworth & Rodkin 2012a
4. Illingworth & Rodkin 2013
5. The distance to the 120 dB isopleth ranged from 300 m to 10,250 m from the pile for 36-inch piles (Hart Crowser (2013).
6. The modeled injury threshold distance for pinnipeds for one impact pile driver is approximately 5 meters, and for cetaceans is approximately 22 meters, but the Navy conservatively increased the monitoring distances up to 10 meters and 25 meters, respectively, for Year 1 construction.
7. As discussed in Section 11.1.1, observers cannot easily see animals beyond the PSB, which is at least 500 meters from the driven piles.
8. The Navy increased monitoring distances for Year 2 and 3 construction based on in-situ recorded sound pressure levels during the Test Pile Program and Year 1 construction, which indicated the pinniped injury zone more consistently extended up to 12 meters from the pile and the cetacean injury zone more consistently extended up to 45 meters from the pile. The monitoring distances were conservatively adjusted upward in recognition of the uncertainties associated with bubble curtain performance.

#### *6.4.2.3 Concurrent Multiple Pile Driver Analysis*

For the multiple-source analysis, a two-dimensional grid of closely spaced points was created, and noise levels were computed from individual sources at each grid point, then incoherently summed together to estimate the combined noise field. This analysis provides a robust means to estimate the additive effects of noise levels with multiple pile drivers simultaneously operating. RMS calculations were made for both equivalent continuous sound and impulsive sound. In order to evaluate the contribution of the impact rig to the vibratory rigs, the impulsive wave form was converted to an equivalent continuous sound. Since the impulsive noise only exists for a short duration, a time-weighting factor was calculated to determine the effective continuous sound level to apply to the impulsive source level.

For the case of continuous underwater noise, the effects of impulsive impact noise were added to continuous vibratory piling noise to provide the most conservative estimate of the equivalent continuous sound field. This process involved converting the impact noise to an equivalent continuous RMS noise level by computing a time-weighting factor account for the ratio of time duration the noise persisted compared to the time it was silent. Using this methodology, the equivalent continuous noise level from the impact driving is computed as the SPL of a steady sound source containing the same energy as the impact driver. Calculations for this assumed that the impact noise persisted for 100 milliseconds, which is representative of the longest duration impact waveforms (ICF Jones and Stokes and Illingworth and Rodkin 2009) reported for impact driving waveforms. Furthermore, it was assumed that the pile driving rate was one hammer impact per second. The equivalent continuous noise factor was then computed as the ratio of “on” time vs. “total” time, or 10*log10(on/total), or 10*log10(100msec/1sec), resulting in a 10 dB reduction in the intensity of the impact pile driving sound when converted to an equivalent continuous waveform.

The use of a bubble curtain or other noise attenuating device during all impact driving was assumed to result in an additional reduction in the source level by another 10 decibels. Therefore, the initial source level for an impulsive sound of 195 dB RMS at 10 meters is equivalent to 185 dB RMS, assuming the application of noise attenuation measures. This was summed with the continuous noise levels from the vibratory drivers (180 dB at 10 meters) to establish the combined equivalent continuous noise level.

In order to evaluate the contribution of the three vibratory rigs to the impulsive waveform produced by the impact rig, vibratory RMS levels were added directly to the impulsive RMS SPLs of the impact driver. The maximum impulsive noise was computed as the additive sum of continuous vibratory energy and the impulsive RMS energy over the duration of the impact strike. Since this is only computed over the duration of each pile strike, the impulsive RMS SPL for multiple rigs operating are always higher than continuous equivalent RMS SPLs.

All noise exposure modeling for impact pile driving used the distances calculated assuming a bubble curtain or similar noise attenuating device was in place. Calculations for the marine mammal noise criteria for vibratory pile driving were done based on in-situ recordings of vibratory installation/extraction data from Illingworth and Rodkin (2007), which indicated an SPL of 180 dB at 10 meters. This concurred with published literature from other studies (Table 6–4). Worst-case scenario calculations assuming one impact pile driver and three vibratory drivers simultaneously operated are presented in this analysis. This analysis is conservative because it incorporates all sound energy at a given sensitive receptor location when all of the pile drivers are operating concurrently. All calculated distances to underwater marine mammal noise thresholds are provided in Table 6–9.

**Table 6–9. Calculated Distance(s) to Underwater Marine Mammal Noise Thresholds due to Pile Driving and Areas Encompassed by Noise Thresholds**

| | Injury Pinnipeds (190 dB RMS)[2] | Injury Cetaceans (180 dB RMS)[2] | Behavioral Harassment Cetaceans & Pinnipeds (160 dB RMS and 120 dB RMS)[2,3] |
|---|---|---|---|
| Distance to Threshold[1] | 4.9 meters (impulsive)[4]<br>2.1 meters (continuous)[5] | 22 meters (impulsive)[4]<br>10 meters (continuous)[5] | 13.8 km[6] |
| Area Encompassed by Threshold | 0.0001 sq km | 0.002 sq km | 41.4 sq km |

dB = decibel; km = kilometer; μPa = micropascal; RMS = root-mean-square; sq km = square kilometer

1. Distance to threshold calculation is based on concurrent operation of one impact hammer and three vibratory drivers.
2. Bubble curtain or other sound attenuating device assumed to achieve 10 dB reduction in sound pressure levels. Sound pressure levels used for calculations were: 185 dB re 1 μPa at 10 meters for impact hammer with noise attenuator and 180 dB re 1 μPa for vibratory driver for 48-inch hollow steel pile. All sound levels are expressed in dB RMS re 1 μPa (see Section 3.4.2.1).
3. Distance to the 160 dB RMS behavioral harassment zone for impulsive noise is combined with distance to the 120 dB RMS behavioral harassment zone for continuous noise.
4. Threshold distance for noise produced by multiple pile driving rigs treated as impulsive noise.
5. Threshold distance for noise produced by multiple pile driving rigs treated as continuous noise.
6. Calculated range (over 222 km) is greater than actual sound propagation through Hood Canal due to intervening land masses. 13.8 km is the greatest line-of-sight distance from pile driving locations unimpeded by land masses, which would block further propagation of sound.

The 120 dB RMS threshold in Table 6–9 is shorter than the distance actually calculated using the practical spreading formula due to the irregular contour of the waterfront, the narrowness of the canal, and the maximum fetch (furthest distance sound waves travel without obstruction [i.e., line of site]) at the project area. For this reason, the maximum affected range at the 120 dB RMS threshold would be approximately 13.8 kilometers from the driven pile, which is bounded by the farthest line-of-sight distance from the EHW-2 location to the northern shore of Squamish Harbor. Further propagation is limited by land mass. Figure 6–1 depicts the effect of land masses on sound propagation for the 120 dB RMS threshold.

For the analysis of injury-level noise exposure of marine mammals, the combined sounds of the two pile driver types were treated as impulsive noise, because noise generated by the impact hammer this close to the pile driving activity would dominate over noise produced by the vibratory hammers. Using this approach, when multiple pile-driving rigs are operating concurrently, and assuming a properly functioning bubble curtain or other noise attenuating device is in place on the impact hammer rig, then construction of the EHW-2 would likely result in noise-related injury to pinnipeds and cetaceans within 4.9 meters and 22 meters from an impact-driven pile, respectively (Table 6–9). A representative scenario of areas affected by above-threshold noise levels for multiple pile driving rigs is shown in Figure 6–1. The analysis modeled the expected sound field of spatially separated sources because it is not realistic to locate all pile drivers at a single physical point. The larger injury threshold circle shown in Figure 6–1 represents the threshold around the impact pile driver, which is expected to be larger than the area around the vibratory drivers, even in a concurrent multiple pile driving rig analysis.

Placement of pile driving rigs at other locations on the EHW-2 would generate above-threshold noise levels in other portions of the project area. Marine mammals are unlikely to be injured by pile driving noise at these short distances because the high level of human activity and vessel traffic would cause them to avoid the immediate construction area. Cetaceans in particular are unlikely to swim this close to manmade structures. Marine mammal monitoring during construction would further serve to render exposure to injury from pile driving noise very unlikely.

For the analysis of behavioral harassment of marine mammals due to construction of the EHW-2, combined sounds of the two pile driver types would be dominated by impulsive noise from the impact pile hammer at locations closer to the pile driving activity, but the contribution of vibratory drivers would increase with increasing distance. At the 160 dB behavioral harassment threshold (approximately 724 meters from the source) the influence of vibratory drivers would roughly equal the influence of the impact hammer. Beyond this distance, noise from the vibratory drivers would dominate out to the 120 dB RMS threshold. Since the 160 dB threshold and the 120 dB threshold both indicate behavioral harassment, pile driving effects in the two zones can be combined to estimate exposures of marine mammals to behavioral harassment.

Using this approach, when multiple pile-driving rigs are operating concurrently, assuming a properly functioning bubble curtain or other noise attenuating device is in place on the impact driver, then construction of the EHW-2 would likely result in behavioral harassment to pinnipeds and cetaceans within 13.8 kilometers (Table 6–9). The calculated distance is much greater than 13.8 kilometers (Table 6–9), but this is not realistic because intervening land masses would truncate the propagation of underwater pile driving sound (Figure 6–1). The area encompassed by the truncated threshold distance is approximately 41.4 square kilometers around the pile drivers (Table 6–9). Marine mammals within this area would be susceptible to behavioral harassment due to pile driving operations.

**Figure 6–1. Representative View of Affected Areas for Marine Mammals Due to Underwater Pile Driving Noise**

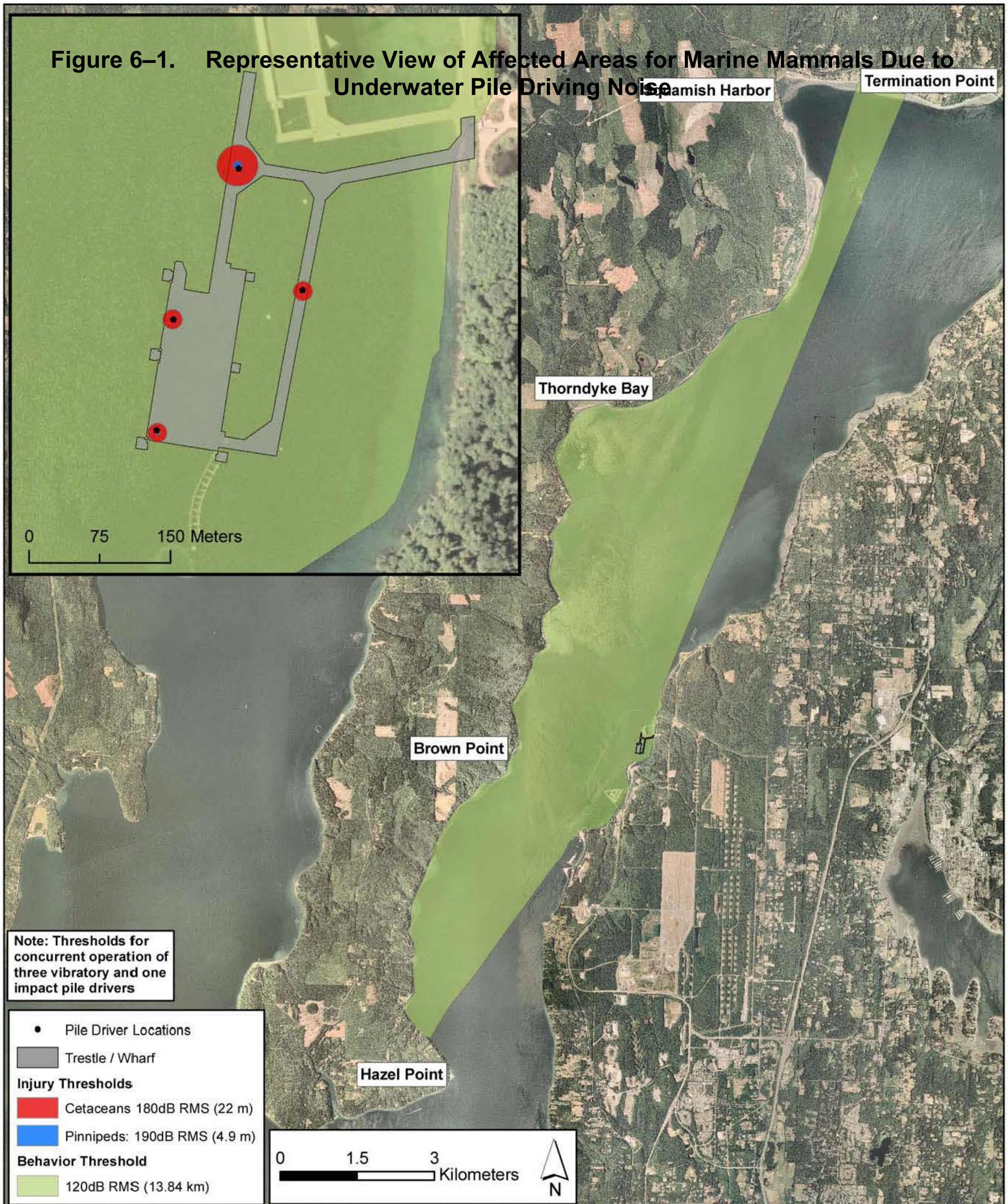


**Figure 6−1. Representative View of Affected Areas for Marine Mammals Due to Underwater Pile Driving Noise**

Pile driving can generate airborne noise that could potentially result in disturbance to marine mammals (pinnipeds) that are hauled out or at the water's surface. As a result, the Navy analyzed the potential for pinnipeds hauled out or swimming at the surface near NBK at Bangor to be exposed to airborne SPLs that could result in Level B behavioral harassment. The appropriate airborne noise thresholds for behavioral harassment for all pinnipeds except harbor seals is 100 dB RMS (unweighted) and for harbor seals is 90 dB RMS (unweighted) (see Table 6–2). Per WSDOT (2013), construction noise behaves as point-source, and thus propagates in a spherical manner, with a 6 dB decrease in SPL over water ("hard-site" condition) per doubling of distance. A spherical spreading loss model, assuming average atmospheric conditions, was used to estimate the distance to the 100 dB and 90 dB RMS (unweighted) airborne thresholds. The formula for calculating spherical spreading loss is:

$$TL = 20 * \log_{10}(R1/R2),$$

where

TL = Transmission loss,
R1 = the distance of the modeled sound pressure level from the source,
R2 = the distance from the source of the initial measurement.

### 6.4.3 Airborne Sound from Pile Driving

The intensity of pile driving sounds is greatly influenced by factors such as the type of piles, hammers, and the physical environment in which the activity takes place. In order to determine reasonable airborne SPLs and their associated effects on marine mammals that are likely to result from pile driving on NBK at Bangor, studies with similar properties to the proposed action were evaluated. Studies that met the following parameters were considered:

1. Pile materials: steel pipe piles (30–66-inch diameter);
2. Pile driver type: vibratory and impact; and
3. Physical environment: shallow depth (less than 33 meters).

Table 6–10 details representative pile driving activities that have occurred in recent years. Due to the similarity of these actions and the Navy's proposed action, they represent reasonable SPLs that could be anticipated.

Noise from multiple simultaneous sources produces an increase in the overall noise field. For the multiple-source analysis, a two-dimensional grid of closely spaced points was created, and noise levels were computed from individual sources at each grid point, then incoherently summed together to estimate the combined noise field. A-weighted and unweighted values were computed for each multiple-rig scenario analyzed. RMS calculations were made for both equivalent continuous sound and impulsive sound. In order to evaluate the contribution of the impact rig to the vibratory rigs, the impulsive wave form was converted to an equivalent continuous sound. Since the impulsive noise only exists for a short duration, a time-weighting factor was calculated to determine the effective continuous sound level to apply to the impulsive source level. This was done by taking the energy encompassed within an impulsive strike (assumed to be ~125 msec in duration in-air) and spreading it over the time for a continuous wave form (assumed to be 1 sec long).

**Table 6–10. Airborne Sound Pressure Levels from Similar In-situ Monitored Construction Activities**

| Project and Location | Pile Size and Type | Installation Method | Water Depth | Measured Sound Pressure Levels |
|---|---|---|---|---|
| Northstar Island, AK | 42-inch steel pipe pile | Impact | 40 feet | 97 dB RMS re 20 μPa at 525 feet (160 m) |
| Keystone Ferry Terminal, WA | 30-inch steel pipe pile | Vibratory | 30 feet | 98 dB RMS re 20 μPa at 36 feet (11 m) |
| EHW-2 First Year, Bangor, WA | 24-inch | Impact[1] | NA | 111 dB (109 dBA) Lmax at 50 feet (15 m) |
| EHW-2 First Year, Bangor, WA | 24-inch | Vibratory[1] | NA | 95 dB (89 dBA) Leq at 50 feet (15 m)<br>102 dB (96 dBA) Lmax at 50 feet (15 m) |
| EHW-2 First Year, Bangor, WA | 36-inch | Impact[1] | NA | 111 dB (108 dBA) at 50 feet (15 m) |
| EHW-2 First Year, Bangor, WA | 36-inch | Vibratory[1] | NA | 103 dB (96 dBA) Leq at 50 feet (15 m)<br>100 dB (89 dBA) Lmax at 50 feet (15 m) |
| Test Pile Program (TPP), Bangor, WA | 36-inch | Impact[2,3] | NA | 109 dB (107 dBA) Lmax at 50 feet (15 m)<br>Drop off at 15 Log (distance) from 50 to 1,000 feet (15 to 305 m) |
| TPP, Bangor, WA | 36-inch | Vibratory[4] | NA | 93 dB (87 dBA) Leq at 50 feet (15 m)<br>102 dB (97 dBA) Lmax at 50 feet (15 m)<br>Drop off at 16 Log (distance) from 50 to 1,000 feet (15 m) |
| TPP, Bangor, WA | 48-inch | Impact[2,3] | NA | 107 dB (105 dBA) at 50 feet (15 m)<br>Drop off at 15 Log (distance) from 50 to 1,000 feet (15 to 305 m) |
| TPP, Bangor, WA | 48-inch | Vibratory[4] | NA | 94 dB (87 dBA) Leq at 50 feet (15 m)<br>104 dB (98 dBA) Lmax at 50 feet (15 m)<br>Drop off at 16 Log (distance) from 50 to 1,000 feet (15 to 305 m) |

**Sources:** Blackwell et al. 2004; Laughlin 2010b, Illingworth & Rodkin 2012a

dB = decibel; dBA = A-weighted decibel; Leq = equivalent level; Lmax = maximum level; μPa = micropascal; RMS = root-mean-square

1. Illingworth & Rodkin 2013, Tables 23 and 24
2. Table 30 of the TPP Acoustic Monitoring Report. These are the average of the maximum levels for all pile driving events measured. The maximum levels were 2 to 3 dB higher. Only Lmax levels reported for impact pile driving. Note that the Leq measured for impact pile driving reported in Table 29 included time when there was no pile driving, because the events were so short and the minimum measurements period was 1 minute. Typically, the Leq for impact pile driving is 8 to 10 dB (or dBA) lower than the Lmax level. Note that the sound levels from impact pile driving propagate at a rate of 15 times the Log10 of the distance. This lower rate reflects the complexity of the source and the near-field measurements.
3. Note that this RMS for impact pile driving is based on a maximum level from a continuous measurement of sound pressure levels averaged over 1/8th of a second (125 milliseconds). The Leq during a pile-driving event is typically 7 to 10 dB or dBA lower.
4. Table 29 of the TPP Acoustic Monitoring Report. These are the average of the maximum levels for all pile driving events measured. The maximum levels were 3 to 7 dB higher. Note that the sound levels from vibratory pile driving propagate at a rate of 15 times the Log10 of the distance. This lower rate reflects the complexity of the source and the near-field measurements.

Using the time-weighting factor computed as 10 log 10 [125 msec/1 sec], this results in a reduction in the intensity of the impulsive source level by 9 dB. This result was summed with continuous RMS noise levels from the vibratory drivers to establish the combined equivalent continuous noise level for both A-weighted and unweighted airborne noise sources.

In order to evaluate the contribution of the three vibratory rigs to the impulsive waveform produced by the impact rig, vibratory RMS levels were added directly to the impulsive RMS SPLs of the impact driver. The maximum impulsive noise was computed as the sum of continuous vibratory energy and the impulsive RMS energy over the duration of the impact strike. Since this is only computed over the duration of each pile strike, the impulsive RMS SPL for multiple rigs operating would always be higher than continuous equivalent RMS SPLs.

For this analysis, it was assumed that all rigs were operating simultaneously, and the noise was incoherently summed to produce the expected noise field.

Based on in-situ recordings from similar construction activities, the maximum airborne noise levels that would result from impact and vibratory pile driving are estimated to be 97 dB RMS at 160 meters and 98 dB RMS at 11 meters, respectively (Blackwell et al. 2004; Laughlin 2010b). The distances to the airborne harassment thresholds were calculated with the airborne transmission loss formula presented in Section 6.4.2.3. All calculated distances to marine mammal airborne noise thresholds as well as the areas encompassed by these threshold distances are shown in Table 6–11.

**Table 6–11. Calculated[1] Maximum Distances in Air to Marine Mammal Noise Thresholds due to Pile Driving and Areas Encompassed by Noise Thresholds**

| | Harbor seal (90 dB RMS)[2] | Pinnipeds (seals, sea lions, except harbor seal) (100 dB RMS)[2] |
|---|---|---|
| Distance to Threshold[1] | 361 meters | 114 meters |
| Area Encompassed by Threshold | 0.07 sq km | 0.005 sq km |

dB = decibel; RMS = root-mean-square; sq km = square kilometer

1. Distance to threshold calculation is based on concurrent operation of one impact hammer and three vibratory drivers.
2. Sound pressure levels used for calculations were: 97 dB RMS re 20 μPa at 160 meters (Blackwell et al. 2004) for impact hammer for 42-inch steel pile, and 98 dB RMS re 20 μPa at 11 meters for vibratory driver, for 30-inch steel pile (Laughlin 2010b). All sound levels expressed in dB RMS re 20 μPa. All distances calculated over water.

For the analysis of behavioral harassment of pinnipeds due to construction of the EHW-2, combined sounds of the two pile driver types would be dominated by impulsive noise from the impact pile hammer. Treating the combined noise from both types of pile driver as impulsive noise, when multiple pile driving rigs are operating concurrently, construction of the EHW-2 would likely result in noise-related behavioral harassment to harbor seals at a distance of 361 meters, and to other pinnipeds (California sea lion and Steller sea lion) at a distance of 114 meters (Table 6–11).

The areas encompassed by these threshold distances are shown in Table 6–11 and a representative scenario of areas affected by above-threshold noise levels for multiple pile driving rigs is shown in Figure 6–2. Other areas would be included in the above-threshold noise areas if the analysis was performed for pile driving rigs at other locations on the EHW-2.

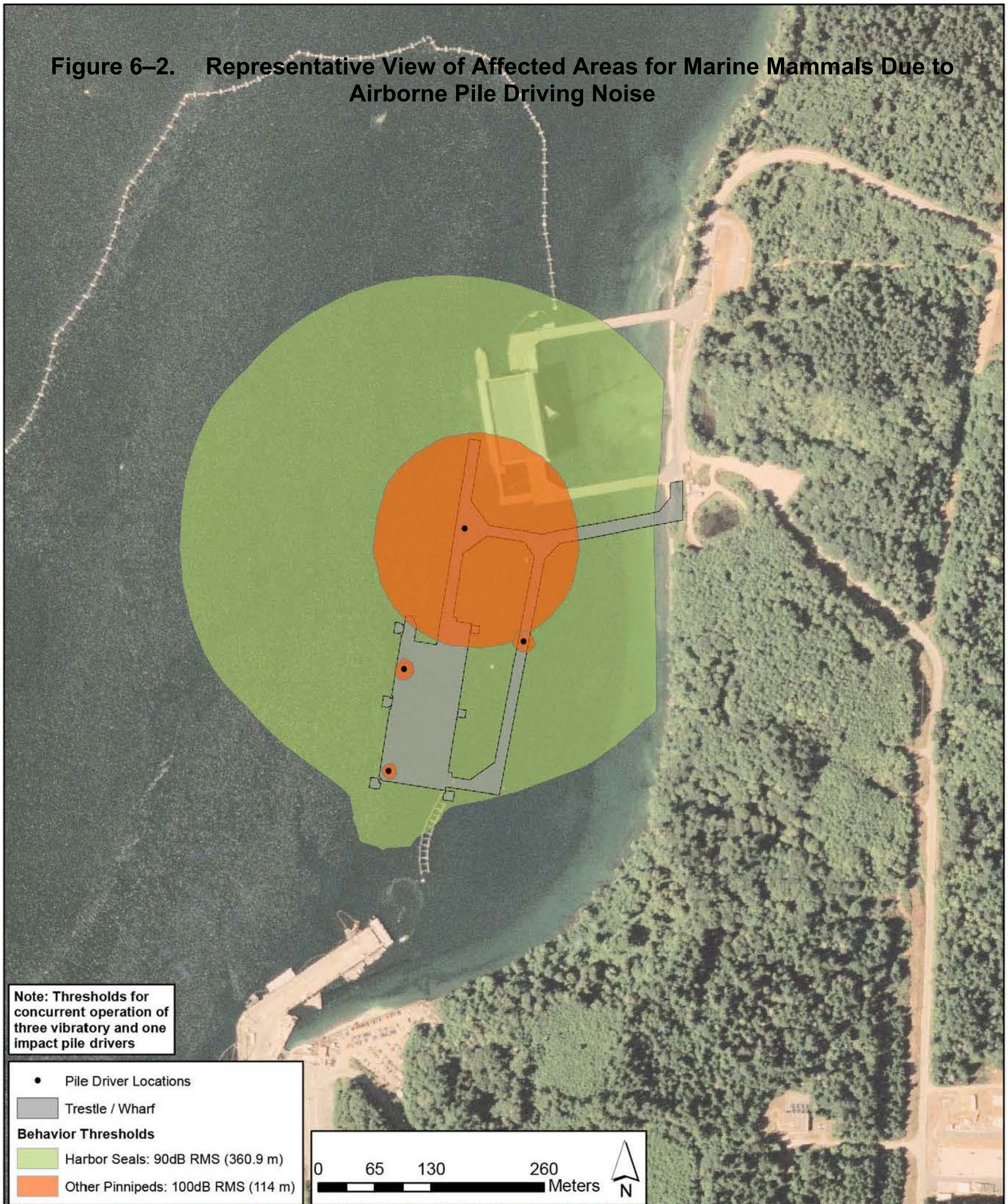


**Figure 6−2. Representative View of Affected Areas for Marine Mammals Due to Airborne Pile Driving Noise**

### 6.4.4 Auditory Masking

Natural and artificial sounds can disrupt behavior by auditory masking, or interfering with a marine mammal's ability to hear other relevant sounds, such as communication and echolocation signals (Wartzok et al. 2003/04). Masking occurs when both the signal and masking sound have similar frequencies and either overlap or occur very close to each other in time. Noise can only mask a signal if it is within a certain "critical band" around the signal's frequency and its energy level is similar or higher (Holt 2008).

Noise within the critical band of a marine mammal signal will show increased interference with detection of the signal as the level of the noise increases (Wartzok et al. 2003/04). In delphinid subjects, for example, relevant signals needed to be 17 to 20 dB louder than masking noise at frequencies below 1 kHz in order to be detected and 40 dB greater at approximately 100 kHz (Richardson et al. 1995).

If the masking sound is manmade, it could be potentially harassing (as defined by the MMPA) if it disrupts hearing-dependent behavior such as communications or echolocation. The most intense underwater sounds in the proposed action are those produced by impact pile driving. Given that the energy distribution of pile driving covers a broad frequency spectrum, with greatest amplitude typically from 50 to 1,000 Hz (WSDOT 2014), pile driving sound would be primarily within the lower audible range of the pinniped and cetacean species likely to occur in the project area. There may be some overlap of frequencies used for social signals by the marine mammal species with pile driving frequencies, especially by pinnipeds which use and are more sensitive to lower frequencies than the cetaceans that may occur in the project area (see Section 4.0, Status and Distribution of Marine Mammal Species).

Impact pile driving noise levels may exceed the levels of social signals within an unknown range of the driven pile, but impact pile driving activity would be relatively short-term. For each of the selected piles that will be proofed, actual pile driving is expected to last approximately 15 minutes per pile (Illingworth & Rodkin 2013). Therefore, the likelihood that impact pile driving for this short duration would mask acoustic signals important to the behavior and survival of marine mammal species is negligible.

Vibratory pile driving produces frequencies from 1.25 to 2 kHz, which would be at the lower range of audible sound for most marine mammals that may occur in the project area. Given that the energy level of vibratory pile driving is less than half that of impact pile driving, the potential for masking noise would be limited to a very small radius around the given pile. The likelihood that vibratory pile driving would mask relevant acoustic signals for marine mammals is negligible. Any masking event that could possibly rise to Level B harassment under the MMPA would occur concurrently within the zones of behavioral harassment estimated for vibratory and impact pile driving (see Section 6.4.2, Underwater Noise from Pile Driving) and which are taken into account in the exposure analysis (see Section 6.5, Description of Exposure Calculation). Therefore, masking effects are not considered as separately contributing to exposure estimates in this IHA application.

### 6.4.5 Basis for Estimating Harassment Exposures

The U.S. Navy is seeking authorization for the potential taking of Steller sea lions, California sea lions, harbor seals, transient killer whales, and harbor porpoises in Hood Canal that may result from pile driving during construction of the EHW-2. The exposures requested are expected to have no more than a minor effect on individual animals and no effect on the populations of these species. Any effects experienced by individual marine mammals are anticipated to be limited to short-term disturbance of normal behavior or temporary displacement of animals near the source of the noise.

#### 6.4.6 Steller Sea Lion

Steller sea lions are occasionally present in Hood Canal from late September through May (Navy 2013; HDR 2013).

Navy personnel recorded sightings of pinnipeds at known haul-outs along the Bangor waterfront on NBK from April 2008 through December 2013 (Navy 2013). Through 2012, these surveys took place frequently (average 14 per month) and only include known haul-outs (Table 6–12). Surveys were minimal in early 2013 due to budget reductions. The earliest documented arrival of Steller sea lions along NBK at Bangor was reported in the last IHA application as September 30, 2010. However, Navy biologists observed four Steller sea lions at Delta Pier on September 26, 2013. During TPP monitoring, Steller sea lions were documented arriving on October 8, 2011, and were seen during surveys on each of the remaining 12 days of the project (HDR 2012). Steller sea lions have only been observed hauled out on submarines docked at Delta Pier. Delta Pier and other docks on NBK at Bangor are not accessible to pinnipeds. One to four animals are typically seen hauled out with California sea lions; the maximum Steller sea lion group size seen at any given time was 11 individuals. Only adult and sub-adult males are likely to be present; female Steller sea lions have not been observed in the project area. Since there are no known breeding rookeries in the vicinity of the project site, Steller sea lion pups are not expected to be present. By the end of May, Steller sea lions have left inland waters and returned to their rookeries to mate. Occasionally, sub-adult individuals (immature or pre-breeding animals) will remain in Puget Sound over the summer. These sightings are summarized in Table 6–12 and used to estimate the density of Steller sea lions on NBK at Bangor.

Based on observations in recent years on NBK at Bangor, Steller sea lions may occasionally be present in the project area during the in-water pile driving period (mid-July through mid-February). Steller sea lions hauled out on submarines at Delta Pier would be beyond the area encompassed by the airborne noise behavioral harassment threshold (Figure 6–2) and are unlikely to be affected by construction activities. When pile driving is under way, exposure to construction activity would likely involve sea lions that are moving through the area en route to Delta Pier or during the return trip to Puget Sound. Steller sea lions that are exposed to elevated noise levels could exhibit behavioral changes such as increased swimming speed, increased surfacing time, or decreased foraging. Pile driving will occur only during daylight hours, and therefore will not affect nocturnal movements of Steller sea lions in the water. Most likely, Steller sea lions affected by elevated underwater or airborne noise would move away from the sound source and be temporarily displaced from the affected areas. Given the absence of any rookeries, only one haul-out area near the project site (i.e., submarines docked at Delta Pier), and infrequent attendance by a small number of individuals at this site, potential disturbance exposures will have a negligible effect on individual Steller sea lions and would not result in population-level impacts.

**Table 6–12. Steller Sea Lions Observed on NBK at Bangor, April 2008–December 2013**

| | Number of Surveys with SSL Present | Number of Surveys | Frequency of SSL Occurrence at Survey Sites[1] | Daily Maximum Number | Monthly Average of Maximum Number Observed per Survey |
|---|---|---|---|---|---|
| January | 12 | 47 | 0.26 | 3 | 1.5 |
| February | 7 | 51 | 0.14 | 2 | 1.4 |
| March | 12 | 47 | 0.26 | 3 | 1.8 |
| April | 21 | 69 | 0.30 | 6 | 2.3 |
| May | 6 | 73 | 0.08 | 6 | 1.5 |
| June | 0 | 73 | 0.00 | 0 | 0.0 |
| July | 0 | 67 | 0.00 | 0 | 0.0 |
| August | 0 | 67 | 0.00 | 0 | 0.0 |
| September | 2 | 58 | 0.03 | 5 | 0.8 |
| October | 30 | 69 | 0.43 | 9 | 3.7 |
| November | 37 | 65 | 0.57 | 11 | 5.7 |
| December | 18 | 54 | 0.33 | 4 | 2.6 |
| Totals | 145 | 740 | Average 0.20 | N/A | 3 |

**Source:** Navy 2013

SSL = Steller sea lion

1. Frequency of occurrence is defined as the number of surveys with Steller sea lions present divided by the number of surveys conducted.

### 6.4.7 California Sea Lion

California sea lions may be present from August to mid-June in Hood Canal, although the highest likelihood of their presence is October through May based on haul-out counts from April 2008 through December 2013 (Table 6–13) (Navy 2013). Considering the project ends in mid-February, the highest potential for overlap between the species and the project is therefore October to mid-February.

The largest daily number of California sea lions hauled out along the Bangor waterfront on NBK during the survey period summarized in Table 6–13 was 122 in a November 2013 survey. During the in-water construction period (mid-July to mid-February) the largest daily attendance averaged for each month ranged up to 93 individuals. Additionally, five navigational buoys near the entrance to Hood Canal were documented as potential haul-outs, each capable of supporting three adult California sea lions (Jeffries et al. 2000).

Breeding rookeries are in California; therefore, pups are not expected to be present in Hood Canal (NMFS 2008b). Female California sea lions are rarely observed north of the California/ Oregon border; therefore, only adult and sub-adult males are expected to be exposed to project impacts.

**Table 6–13. California Sea Lions Observed on NBK at Bangor, April 2008–December 2013**

| | Number of Surveys with CSL Present | Number of Surveys | Frequency of CSL Occurrence at Survey Sites[1] | Daily Maximum Number | Monthly Average of Maximum Number Observed per Survey |
|---|---|---|---|---|---|
| January | 36 | 47 | 0.77 | 44 | 31.0 |
| February | 44 | 51 | 0.86 | 48 | 39.2 |
| March | 45 | 47 | 0.96 | 82 | 53.3 |
| April | 57 | 69 | 0.83 | 66 | 43.2 |
| May | 58 | 73 | 0.79 | 54 | 24.5 |
| June | 17 | 73 | 0.23 | 17 | 7.4 |
| July | 1 | 67 | 0.01 | 3 | 0.5 |
| August | 12 | 67 | 0.18 | 5 | 2.2 |
| September | 34 | 58 | 0.59 | 35 | 22.8 |
| October | 65 | 69 | 0.94 | 88 | 57.8 |
| November | 65 | 65 | 1.00 | 122 | 70.5 |
| December | 44 | 54 | 0.81 | 69 | 49.6 |
| Totals | 478 | 740 | Average 0.65 | N/A | 34 (in-water work window only, 2008–2012) |

**Source:** Navy 2013

CSL = California sea lion

1. Frequency of occurrence is defined as the number of surveys with California sea lions present divided by the number of surveys conducted.

When pile driving is under way, exposure to construction activity would likely involve sea lions that are moving through the area en route to a haul-out site at Delta Pier or during the return trip to Puget Sound. California sea lions that are exposed to elevated noise levels could exhibit behavioral changes such as increased swimming speeds, increased surfacing time, or decreased foraging. Most likely, California sea lions affected by elevated underwater or airborne noise would move away from the sound source and be temporarily displaced from the affected areas. Pile driving will occur only during daylight hours, and therefore will not affect nocturnal movements of California sea lions in the water. Given the absence of any breeding rookeries and only one haul-out area near the project site, potential disturbance exposures will have a minor effect on individual California sea lions and would not result in population-level impacts.

#### 6.4.8 Harbor Seal

Harbor seals are the most abundant marine mammal in Hood Canal, where they can occur anywhere in Hood Canal waters year-round. Jeffries et al. (2003) assessed the harbor seal population in Hood Canal in 1999 and estimated 1,088 harbor seals. The Navy detected harbor seals during marine mammal boat surveys of the waterfront area from July to September 2008 (Tannenbaum et al. 2009) and November to May 2010 (Tannenbaum et al. 2011), and during monitoring for the TPP project and the first year of EHW-2 construction (HDR 2012; Hart Crowser 2013), as described in Section 3.3.2. Harbor seals were sighted during every survey and were found in all marine habitats, including nearshore waters and deeper water, and hauled out on manmade objects such as piers and buoys. From 3 to 5 individuals were detected in most boat surveys, which encompassed the entire Bangor waterfront on NBK out to a distance of at least 1,800 feet from shore. Neonates have been observed at NBK at Bangor, as described in Section 4.3. Thus, all age and sex classes could occur in the project area throughout the period of construction activity.

Potential exposures during pile driving would likely involve seals that are present in the area on foraging trips or in transit through the area. Harbor seals that are exposed could exhibit behavioral changes such as increased swimming speeds, increased surfacing time, or decreased foraging. Most likely, harbor seals affected by elevated underwater or airborne noise would move away from the sound source and be temporarily displaced from the affected areas. With the absence of any breeding rookeries and only a few small haul-out sites (primarily buoys and pontoons of the floating security barrier) near the project site, and the small number of individuals that frequent the project area, potential disturbance exposures will have a minor short-term effect on individual harbor seals and would not result in population-level impacts.

#### 6.4.9 Transient Killer Whales

Transient killer whales in the Pacific Northwest spend most of their time along the outer coast of British Columbia and Washington, but visit inland marine waters in search of harbor seal, harbor porpoises, and other prey. Transients may occur in inland waters in any month (Orca Network 2012), but there are peaks in occurrences: Morton (1990) found bimodal peaks in spring (March) and fall (September to November). Baird and Dill (1995) found some transient groups frequenting the vicinity of harbor seal haul-outs around southern Vancouver Island during August and September, which is the peak period for pupping through post-weaning of harbor seal pups. However, not all transient groups were seasonal in these studies, and their movements appear to be unpredictable.

Recent research suggests that transient killer whales' use of inland waters from 2004 through 2010 has increased (Houghton et al. in progress). Transient killer whales in the Salish Sea most often travel in small pods of up to four individuals (Baird and Dill 1996). However, Houghton (2012, personal communication) reported that the most commonly observed group size in Puget Sound from 2004–2010 was 6 whales. Occasionally larger groups may occur (OrcaNetwork 2012). A group of up to 27 animals was observed in Puget Sound in 2010 (Houghton 2012, personal communication). Transient killer whales are uncommon visitors to Hood Canal, but they may potentially be present anywhere in Hood Canal anytime during the year. Resident killer whales have not been documented in Hood Canal since 1995 (NMFS 2008c), but transient pods were observed in Hood Canal for lengthy periods of time in 2003 (January–March) and 2005 (February–June), feeding on harbor seals (London 2006). Transient killer whales are not considered regular or seasonal visitors to Hood Canal.

Potential exposures due to pile driving would likely involve transient killer whales that are moving through the area on foraging trips. Killer whales that are exposed to elevated noise levels could exhibit behavioral changes such as increased swimming speeds, increased surfacing time, or decreased foraging. Most likely, killer whales that are affected by elevated noise levels would move away from the sound source and be temporarily displaced from the affected areas. With the absence of any regular occurrence in Hood Canal, potential disturbance exposures will have a negligible short-term effect on individual killer whales and would not result in population-level impacts.

#### 6.4.10 Harbor Porpoise

Harbor porpoises may be present anywhere in Hood Canal year-round. The Navy conducted nearshore marine mammal boat surveys of the Bangor waterfront area on NBK from July to September 2008 (Tannenbaum et al. 2009) and from November 2009 to May 2010 (Tannenbaum et al. 2011), as described in Section 3.3.2. During one of these surveys a harbor porpoise was sighted in May in the deeper waters within the WRA in the vicinity of the existing EHW. Overall, these nearshore surveys indicated a low occurrence of harbor porpoise within the waters adjacent to the base. Surveys conducted during the TPP indicate that the abundance of harbor porpoises within Hood Canal in the vicinity of NBK at Bangor is greater than anticipated from earlier surveys and anecdotal evidence (HDR 2012). During these surveys, while harbor porpoise presence in the immediate vicinity of the base (i.e., within 1 kilometer) remained low, harbor porpoises were frequently sighted within several kilometers of the base, mostly to the north or south of the project area, but occasionally directly across from the proposed EHW-2 project site on the far side of Toandos Peninsula. During the TPP projects a total of 941 sightings (i.e., detections of one or more marine mammals) of 1,665 individual marine mammals were documented during surveys. These observations include those made during pile driving activities and those made during non-construction periods on work days for a total of 149 hours of observation. Sixty-eight of the sightings (125 individuals) were harbor porpoise. The maximum group size per sighting was 6 individuals (mean 1.8) (HDR 2012).

Potential exposures during pile driving would likely involve harbor porpoises that are present in the area on foraging trips or in transit through the area. Harbor porpoises that are exposed to elevated noise levels could exhibit behavioral changes such as increased swimming speeds, increased surfacing time, or decreased foraging. Most likely, harbor porpoises that are affected by elevated noise levels would move away from the sound source and be temporarily displaced from the affected areas. Since their occurrence immediately adjacent to the project site remains low, exposures would likely be at very low SPLs. Therefore, potential takes by disturbance will have a negligible short-term effect on individual harbor porpoises. Given the abundance of these animals in Hood Canal and other inland waters and the proportion of harbor porpoises that may experience effects relative to the entire stock, the proposed action would not result in population-level impacts.

## 6.5 Description of Exposure Calculation

The exposure calculations presented here relied on the best data currently available for marine mammal populations in Hood Canal.

As described in Section 3.3, the calculations presented here rely on the Navy's marine species database (NMSDD) (Navy 2014a) for all marine mammals that occur in Hood Canal (Table 3-1), with the exception of Steller sea lion and California sea lion, for which site-specific abundances are available.

Successful implementation of mitigation measures (visual monitoring and the use of shutdown zones) will preclude injury exposures for marine mammals. Results of noise effects exposure assessments should be regarded as conservative overestimates that are influenced by limited occurrence data and the assumption that individuals may be present every day of pile driving.

The method for calculating potential exposures to impact and vibratory pile driving noise includes the following assumptions:

- Each species' population is at least as large as any previously documented highest population estimate.
- Each species would be present in the project area during construction at the start of each day, based on observed patterns of occurrence in the absence of construction. The timeframe for takings would be 1 potential taking per individual per 24 hours.
- All pilings to be installed would have a noise disturbance distance equal to the noise disturbance distance (Zone of Influence[7] [ZOI]) from the pile that would cause the greatest noise disturbance (i.e., the piling furthest from shore).
- Pile driving will occur up to 195 days during the in-water work window.
- Sound attenuation modeling assumes three vibratory rigs and one impact rig may be in operation at the same time.
- Some type of mitigation (i.e., bubble curtain) will be utilized, as discussed previously.

For species with density estimates (e.g., cetacean species), exposures are estimated by:

Exposure estimate = (n * ZOI)* X days of pile driving activity, where:

n = density estimate used for each species, ZOI = noise threshold ZOI impact area, and

X = number of days of pile driving estimated based on the total number of piles and the estimated number of piles installed per day.

The ZOI impact area is the estimated range of impact on the noise criteria thresholds for both underwater and airborne noise. The distances specified in Tables 6–9 and 6–11 were used to calculate the areas that would be encompassed within the threshold distances for injury or behavioral harassment. All calculations were based on the estimated threshold ranges and modeled distances for multiple pile driving rigs that incorporated an assumption of 10 dB of attenuation from a bubble curtain implemented during impact pile driving. As discussed in Section 6.4.2.2, the 10 dB assumption was used in the EIS and the first IHA application. Based on acoustic monitoring results from the first year of EHW-2, overall bubble curtain performance did not achieve 10 dB of attenuation. Discussion of the 10 dB assumption in this application does not imply that it is supported by empirical evidence from recent pile-driving activities at the Bangor waterfront. However, based on the measured source levels and calculated distances to thresholds shown in Table 6-8, shutdown and monitoring zones for the second and third construction years are based on in situ measurements rather than the original modeling that assumed 10 dB attenuation from a bubble curtain.

The ZOIs for each threshold are not necessarily spherical and would be truncated by land masses, such as points of land on the Bangor shoreline on NBK and the Toandos Peninsula on the opposite shoreline, which would dissipate sound pressure waves.

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[7] Zone of Influence (ZOI) is the area encompassed by all locations where the sound pressure levels equal or exceed the threshold being evaluated.

The product of n*ZOI was rounded to the nearest whole number before multiplying by the number of pile driving days. If the product of n*ZOI rounds to zero, the number of exposures calculated is zero regardless of the number of pile driving days. The exposure assessment methodology is an estimate of the numbers of individuals exposed to the effects of pile driving activities exceeding NMFS-established thresholds. Of significant note is that successful implementation of mitigation methods (i.e., visual monitoring and the use of shutdown zones) results in no Level A exposure. Results from acoustic impact exposure assessments should be regarded as conservative overestimates that are strongly influenced by limited marine mammal occurrence data, the assumption that marine mammals will be present every day of pile driving, and the assumption that the maximum number of piles will be extracted or installed.

For species with counts of animals in the project area (Steller and California sea lions) available, exposures are estimated by:

> Exposure estimate = (Abundance) * X days of pile driving activity, where:
>
> Abundance = average monthly maximum counts during the months when pile driving will occur.

#### 6.5.1 Steller Sea Lion

Steller sea lions may be present in Washington inland waters, but they have only been detected in Hood Canal during the period from late September to May, primarily during the course of the Navy's monitoring of sea lions at haul-out sites along the Bangor waterfront on NBK, as described in detail in Section 6.4.6. They have been present along the Bangor waterfront on NBK in less than 57 percent of surveys during any month since the survey effort began in April 2008 (Navy 2013) (Table 6–12).

Although the Navy has determined a density for Steller sea lions in Hood Canal (Navy 2013; Table 3–1), when more site-specific data are available it is preferable to determine the abundance of individuals that may be exposed to noise effects. This is because a density analysis assumes an even distribution of animals, whereas Steller sea lion distribution within the project area actually is concentrated at Delta Pier. Therefore, the noise exposure calculation for Steller sea lions uses the average daily abundance of the species during the in-water work window, defined as the average of the monthly maximum number of individuals present during surveys at Delta Pier from July 2011 to February 2013 (Table 6–12). The abundance trend for Steller sea lions at Delta Pier has increased since they were first detected in November 2008, and in 2011 and 2012 the average of the monthly maximum number present during the in-water work window was approximately three animals. The average of the monthly maximum number present during the in-water work window from 2008 through 2013 was approximately two animals (Table 6–13). To be consistent with the previous IHAs, a daily abundance of three animals was assumed for this analysis.

Exposures to underwater pile driving noise were calculated using the abundance-based formula presented above. Table 6–14 depicts the number of potential behavioral harassment exposures that are estimated from underwater vibratory and impact pile driving. Using the most conservative criterion for behavioral harassment (the 120 dB continuous noise harassment threshold) and an average daily abundance of 3 individual Steller sea lions, the noise exposure formula above predicts 585 exposures to underwater noise within the behavioral harassment threshold for vibratory pile installation over the 195 days of pile driving.

Steller sea lions are unlikely to be injured by pile driving noise because they are unlikely to be within the injury threshold distance for pile driving noise (5 meters] from the driven pile). Marine mammal observers will monitor shutdown and disturbance zones during pile driving activities (see Section 11 for a detailed discussion of mitigation measures) for the presence of marine mammals, and they will alert work crews when to begin or stop work due to the presence of sea lions in or near the shutdown zones, thereby avoiding the potential for injury.

The airborne exposure calculations assumed that 100 percent of the in-water animals would be available at the surface to be exposed to airborne sound. Sea lions hauled out on submarines at Delta Pier would be beyond the areas encompassed by the airborne noise behavioral harassment threshold for EHW-2 (Figure 6–2) and are unlikely to be affected by construction activities. Animals swimming with their heads above the water would potentially be affected by elevated airborne pile driving noise within a small ZOI (114 meters). Given that both the vibratory and impact airborne ZOI is encompassed within the larger underwater disturbance ZOIs, pinniped takes would occur as a result of underwater rather than in-air exposures. Therefore, zero exposure to airborne pile driving noise was estimated for Steller sea lions, and the total number of behavioral harassment exposures over the entire pile driving period is estimated to be 585 (all underwater) (Table 6–14).

### 6.5.2 California Sea Lion

No regular haul-outs were documented during aerial survey population counts of California sea lions within Hood Canal (Jeffries et al. 2000). However, the Navy's observations of animals hauled out on submarines and the PSB pontoons on NBK at Bangor indicate that California sea lions are present in Hood Canal during much of the year with the exception of mid-June through August (Table 6–13). The Navy has conducted waterfront surveys beginning in April 2008, and results were compiled through December 2013 for the analysis in this IHA (Navy 2013), as described in Section 6.4.6. These surveys, which are summarized in Table 6–13, represent the best available data for California sea lion abundance within Hood Canal.

During the in-water construction period (mid-July to mid-February), the attendance averaged for each month ranged from 3 to 71 individuals. The largest daily count (122 animals) was recorded in November 2013 (Navy 2013). The likelihood of California sea lions being present at the Bangor waterfront on NBK was greatest from October through May, when the frequency of occurrence in surveys was at least 0.8 (i.e., 80 percent of surveys had California sea lions present).

**Table 6–14. Number of Authorized/Observed Exposures, First and Second In-Water Construction Seasons, and Estimated Exposures of Marine Mammals, Third Year**

| Species | Year 1 Authorized and Observed Takes | | | Year 2 Authorized and Observed Takes through end of November 2013 | | Year 3 Estimated Takes | |
|---|---|---|---|---|---|---|---|
| | Underwater and Airborne | | | Underwater and Airborne | | Underwater | Airborne |
| | Authorized Behavioral Harassment Exposures[1] | Total Number of Unique Animals Sighted[2,3] | Observed and Extrapolated Behavioral Harassment Exposures[2,4] | Authorized Behavioral Harassment Exposures[1] | Observed and Extrapolated Behavioral Harassment Exposures[5] | Estimated Behavioral Harassment Exposures, All Species (120 dB RMS) | Estimated Behavioral Harassment Exposures, Harbor Seal (100 dB RMS), Other Pinnipeds (90 dB RMS) |
| Steller sea lion | 390 | 4 | 2 | 390 | 106 | 585 | 0 |
| California sea lion | 5,070 | 541 | 167 | 6,045 | 1,273 | 6,630 | 0 |
| Harbor seal | 10,530 | 1060 | 368 | 10,530 | 5,631 | 8,580 | 0 |
| Harbor porpoise | 1,950 | 57 | 109 | 1,950 | 665 | 1,170 | N/A |
| Transient killer whale | 90 | 0 | 0 | 180 | 13 | 180[6,7] | N/A |
| Dall's Porpoise[6] | 195 | 0 | 0 | 195 | 0 | -- | N/A |
| Total | 18,225 | | 646 | 19,290 | 7,688 | 16,755 | 0 |

dB = decibels; RMS = root-mean-square

1. Authorized takes from Year 1 IHA dated 11 July 2012 and Year 2 IHA dated 19 July 2013, based on 195 days of pile driving.
2. Source: Hart Crowser (2013). Year 1 results based on 80 days of pile driving.
3. Includes primary surveys within injury and behavioral harassment zones, Delta Pier surveys, and outside (WRA) boat surveys.
4. Exposures in the unmonitored behavioral harassment zone were calculated as the area encompassed by the average distance to the 120 dB isopleth (4,400 meters) (Hart Crowser 2013) minus the 464-meter radius monitored zone. Density estimates for the extrapolation calculation were derived from TPP density estimates expressed at total sightings per $km^2$ per hour (Hart Crowser 2013).
5. Source: Navy 2014b, in prep. Year 2 preliminary results based on 162 days of pile driving.
6. As discussed in Section 3, Dall's porpoise has only been documented once in Hood Canal; therefore, it was not included in the take request for the third year of construction.
7. The calculated number of potential exposures using the density formula was zero for underwater behavioral harassment. However, transient killer whales remain in Hood Canal for extended periods on the rare occasions when they are present. Therefore, the Navy estimates that harassment exposures may occur due to underwater vibratory pile driving based on possible exposure of six transient killer whales during 30 days of pile driving.

The noise exposure analysis for California sea lions is similar to the analysis described above for Steller sea lions. The Navy used the average daily abundance of the species during the in-water work window, defined as the average of the monthly maximum number of individual present during surveys at Delta Pier from mid-July to mid-February. The average of the monthly maximum number present during the in-water work window from 2008 through 2013 was approximately 34 animals (Table 6–13). Using the abundance-based analysis and the most conservative criterion for behavioral harassment (the 120 dB continuous noise harassment threshold), an average of 34 individual California sea lions may experience underwater SPLs that would qualify as behavioral harassment on a given day. Over the 195 days of pile driving, the noise exposure formula predicts 6,630 exposures to underwater noise within the behavioral harassment threshold for vibratory pile installation. Zero exposure to airborne pile driving noise was estimated for California sea lions, and the total number of exposures over the entire pile driving period is estimated to be 6,630 (all underwater) (Table 6–14). Sea lions are unlikely to be injured by pile driving noise because they are unlikely to be within the injury threshold distance for pile driving noise (5 meters from the driven pile). Marine mammal observers will monitor shutdown and disturbance zones during pile driving activities (see Section 11 for a detailed discussion of mitigation measures) for the presence of marine mammals, and they will alert work crews when to begin or stop work due to the presence of sea lions in or near the shutdown zones, thereby avoiding the potential for injury.

### 6.5.3 Harbor Seal

Harbor seals are the most abundant marine mammal in Hood Canal. Jeffries et al. (2003) provided a population estimate of 1,088 harbor seals in Hood Canal based on aerial survey data that focused on Hood Canal haul-outs and data obtained from tagged animals (Huber et al. 2001). These data suggest that on a daily basis harbor seals spend an average of 35 percent of their time in the water versus hauled out. In order to estimate the underwater exposures from pile driving operations, the Navy estimated the proportion of the Hood Canal population that could be in the water and susceptible to exposure on a daily basis. The Navy assumed that the proportion of the population susceptible to this exposure was 35 percent of the total population (35 percent of 1,088 animals, or approximately 381 individuals). The Navy recognizes that over the course of the day, while the proportion of animals in the water may not vary significantly, different individuals may enter and exit the water. However, fine-scale data on harbor seal movements within the project area on time durations of less than a day are not available to support this analysis.

Exposures to underwater and airborne pile driving noise were calculated using a density derived from the number of harbor seals that may be present in the water at any one time (approximately 381 individuals), divided by the area of Hood Canal (358.4 square kilometers) (Huber et al. 2001; Jeffries et al. 2003; Navy 2014a).[8] The density of harbor seals calculated in this manner is

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[8] The density used in the past two IHA applications was based upon the area of Hood Canal just south of Hood Canal Bridge. Subsequently, the Navy refined estimates of marine mammal densities in Washington inland waters with regional marine mammal expert participation and developed the Navy Marine Species Density Database (Navy 2014a). Based on further analysis, the Navy now defines the area of Hood Canal as extending just north of Hood Canal Bridge.

1.06/square kilometer (Appendix A). The airborne exposure calculations assumed that 100 percent of the in-water injury exposures would be available at the surface to be exposed to airborne sound. Exposures to underwater noise were calculated with the formula above, and the ZOI in Table 6–9. Table 6–14 depicts the number of behavioral harassment exposures that are estimated from vibratory and impact pile driving both underwater and in-air.

Multiplying the stated density by the 41.4 square mile behavioral disturbance area (120 dB vibratory harassment threshold), up to 44 individual harbor seals may experience SPLs on a given day that would qualify as behavioral harassment. Over the 195 days of pile driving, the noise exposure formula above predicts zero exposures to underwater noise within the injury threshold and 8,580 exposures to noise within the behavioral harassment threshold for vibratory pile driving. Zero exposures to airborne pile driving noise were calculated by the formula above. Therefore, the total number of exposures to potential behavioral harassment over the entire pile driving period is estimated to be 8,580 (all underwater) (Table 6–14).

#### 6.5.4 Transient Killer Whale

Transient killer whales are rarely present in Hood Canal. In 2003 and 2005, small groups of transient killer whales (6 to 11 individuals per event) visited Hood Canal to feed on harbor seals and remained in the area for significant periods of time (59 to 172 days) between the months of January and July (London 2006). These whales used the entire expanse of Hood Canal for feeding. No other confirmed sightings of transient killer whales in Hood Canal were found. It is assumed conservatively for the exposure analysis that transient killer whales could occur in Hood Canal, including the project area, at any time during the in-water work season.

The density used in the underwater sound exposure analysis was 0.0038 animals/square kilometer (Navy 2014a and Appendix A). Exposures to underwater and airborne pile driving noise were calculated using the formula in Section 6.5, and the ZOI in Table 6–9. Table 6–14 depicts the number of potential behavioral harassment and injury exposures that are estimated from underwater vibratory and impact pile driving.

Based on the density analysis (Navy 2014a) and using the most conservative criterion for behavioral disturbance (the 120 dB vibratory harassment threshold), the formula above calculates zero exposures to underwater noise within the behavioral harassment threshold. However, the Navy is requesting incidental takes for the third year IHA for the EHW-2 project using the method established during consultation for the second year IHA for the EHW-2 project. Assuming a pod size of 6 transient killer whales (as discussed in Section 6.4.9) with a minimum residence time in Hood Canal of 59 days (as observed during the 2003 and 2005 events), NMFS concluded that the whales could be exposed to behavioral disturbance due to pile driving noise for 30 days (NMFS 2013). This conclusion reasonably assumes that the whales would not remain in the area for the typical residence time due to the harassing stimuli. Multiplying 6 animals by 30 days of exposure would result in a request for 180 exposures to behavioral harassment due to underwater vibratory pile driving (Table 6–14).

#### 6.5.5 Harbor Porpoise

Harbor porpoises may be occasionally present in Hood Canal year round and conservatively are assumed to use the entire area. The Navy conducted boat surveys of the waterfront area from July to September 2008 (Tannenbaum et al. 2009) and November 2009 to May 2010 (Tannenbaum et al. 2011). During one of the surveys a single harbor porpoise was sighted in

May 2010 in deeper waters in the vicinity of the existing EHW. Overall, these nearshore surveys indicated a low occurrence of harbor porpoise within waters adjacent to the base. Surveys conducted during the TPP indicate that the abundance of harbor porpoises within Hood Canal in the vicinity of NBK at Bangor is greater than anticipated from earlier surveys and anecdotal evidence (HDR 2012). Authorization for the second construction year included TPP data, but the data were unavailable to include in the authorization for the first construction year. During these surveys, while harbor porpoise presence in the immediate vicinity of the base (i.e., within 1 kilometer) remained low, harbor porpoises were frequently sighted within several kilometers of the base, mostly to the north or south of the project area, but occasionally directly across from the EHW-2 project site on the far side of Toandos Peninsula. These surveys reported 38 individual harbor porpoise sightings on tracklines of specified length and width, resulting in a density of 0.149 individuals/square kilometer.

The density used in the underwater sound exposure analysis was 0.149 animals/square kilometer (Navy 2014a). Exposures to underwater and airborne pile driving noise were calculated using the formula above and the ZOI in Table 6–9. Table 6–14 depicts the number of potential behavioral harassment exposures that are estimated from underwater vibratory and impact pile driving.

Based on the density analysis (Navy 2014a) and using the most conservative criterion for behavioral disturbance (the 120 dB vibratory harassment threshold), the formula above calculates zero exposures to underwater noise within the injury threshold and 6 exposures per day to behavioral harassment due to vibratory pile driving. The total number of exposures to potential behavioral harassment over the entire pile driving period is estimated to be 1,170 over the estimated 195 days of pile driving. (Table 6–14).

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# 7 IMPACTS TO MARINE MAMMAL SPECIES OR STOCKS

*The anticipated impact of the activity upon the species or stock of marine mammals.*

## 7.1 Potential Effects of Pile Driving on Marine Mammals

### 7.1.1 Underwater Noise Effects

The effects of pile driving on marine mammals are dependent on several factors, including the species, size, and depth of the animal; the depth, intensity, and duration of the pile driving sound; the depth of the water column; the substrate of the habitat; the distance between the pile and the animal; and the sound propagation properties of the environment. Impacts to marine mammals from pile driving activities are expected to result primarily from acoustic pathways. As such, the degree of effect is intrinsically related to the received level and duration of the sound exposure, which are in turn influenced by the distance between the animal and the source. The farther away from the source, the less intense the exposure should be. The substrate and depth of the habitat affect the sound propagation properties of the environment. Shallow environments are typically more structurally complex, which leads to rapid sound attenuation. In addition, substrates that are soft (i.e., sand) will absorb or attenuate the sound more readily than hard substrates (rock), which may reflect the acoustic wave. Soft porous substrates would also likely require less time to drive the pile, and possibly less forceful equipment, which would ultimately decrease the intensity of the acoustic source.

Impacts to marine species are expected to be the result of physiological responses to both the type and strength of the acoustic signature (Viada et al. 2008). Behavioral impacts are also expected, though the type and severity of these effects are more difficult to define due to limited studies addressing the behavioral effects of impulsive sounds on marine mammals. Potential effects from impulsive sound sources can range from brief acoustic effects such as behavioral disturbance, tactile perception, physical discomfort, slight injury of the internal organs and the auditory system, to death of the animal (Yelverton et al. 1973; O'Keefe and Young 1984; Ketten 1995; Navy 2001).

*Physiological Responses*

Direct tissue responses to impact/impulsive sound stimulation may range from mechanical vibration or compression with no resulting injury, to tissue trauma (injury). Because the ears are the most sensitive organ to pressure, they are the organs most sensitive to injury (Ketten 2000). Sound-related trauma can be lethal or sub-lethal. Lethal impacts are those that result in immediate death or serious debilitation in or near an intense source (Ketten 1995). Sub-lethal damage to the ear from a pressure wave can rupture the tympanum, fracture the ossicles, damage the cochlea, and cause hemorrhage and leakage of cerebrospinal fluid into the middle ear (Ketten 2004). Sub-lethal impacts also include hearing loss, which is caused by exposure to perceptible sounds. Moderate injury implies partial hearing loss. Permanent hearing loss (also called permanent threshold shift or PTS) can occur when the hair cells of the ear are damaged by a very loud event, as well as prolonged exposure to noise. Instances of temporary threshold shifts (TTS) and/or auditory fatigue are well documented in marine mammal literature as being one of the primary avenues of acoustic impact. Temporary loss of hearing sensitivity (TTS) has been documented in controlled settings using captive marine mammals exposed to strong sound exposure levels at various frequencies (Ridgway et al. 1997; Kastak et al. 1999; Finneran et al.

2005). While injuries to other sensitive organs are possible, they are less likely since pile driving impacts are almost entirely acoustically mediated, versus explosive sounds which also include a shock wave that can result in damage.

No physiological responses are expected from pile driving operations occurring during construction of the EHW-2, for several reasons. First, vibratory pile driving, which is being utilized as the primary installation method, does not generate high enough peak SPLs that are commonly associated with physiological damage. Additionally, the Navy will employ noise attenuating devices (see Section 11) that will greatly reduce the chance that a marine mammal may be exposed to SPLs that could cause physical harm. Furthermore, the Navy will have trained biologists monitoring a shutdown zone equivalent to the Level A harassment zone (inclusive of the 180 dB (cetaceans) and 190 dB (pinnipeds) isopleths) to reduce the potential for injury of marine mammals.

*Behavioral Responses*

Behavioral responses to sound are highly variable and context specific. For each potential behavioral change, the magnitude of the change ultimately determines the severity of the response. A number of factors may influence an animal's response to noise, including its previous experience, its auditory sensitivity, its biological and social status (including age and sex), and its behavioral state and activity at the time of exposure. Habituation occurs when an animal's response to a stimulus wanes with repeated exposure, usually in the absence of unpleasant associated events (Wartzok et al. 2003/04). Animals are most likely to habituate to sounds that are predictable and unvarying. The opposite process is sensitization, when an unpleasant experience leads to subsequent responses, often in the form of avoidance, at a lower level of exposure. Behavioral state or differences in individual tolerance levels may affect the type of response as well. For example, animals that are resting may show greater behavioral change in response to disturbing noise levels than animals that are highly motivated to remain in an area for feeding (Richardson et al. 1995; NRC 2003; Wartzok et al. 2003/04). Indicators of disturbance may include sudden changes in the animal's behavior or avoidance of the affected area. A marine mammal may show signs that it is startled by the noise and/or it may swim away from the sound source and avoid the area. Increased swimming speed, increased surfacing time, and cessation of foraging in the affected area would indicate disturbance or discomfort. Pinnipeds may increase their haul-out time, possibly to avoid in-water disturbance.

Controlled experiments with captive marine mammals showed pronounced behavioral reactions, including avoidance of loud sound sources (Ridgway et al. 1997; Finneran et al. 2003). Observed responses of wild marine mammals to loud pulsed sound sources (typically seismic guns or acoustic harassment devices, and also including pile driving) have been varied but often consist of avoidance behavior or other behavioral changes suggesting discomfort (Morton and Symonds 2002; also see reviews in Gordon et al. 2004; Wartzok et al. 2003/04; and Nowacek et al. 2007). Some studies of acoustic harassment and acoustic deterrence devices have found habituation in resident populations of seals and harbor porpoises (see review in Southall et al. 2007). Blackwell et al. (2004) found that ringed seals exposed to underwater pile driving sounds in the 153–160 dB RMS range tolerated this noise level and did not seem unwilling to dive. One individual was as close as 63 meters from the pile driving. Responses of two pinniped species to impact pile driving at the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project were mixed (CALTRANS 2001, 2006, 2010). Harbor seals were observed in the water at distances of approximately 400 to 500 meters from the pile driving activity and exhibited no alarm responses, although several showed alert reactions, and none of the seals appeared to remain in the area. One of these harbor seals was even seen to swim to within 150 meters of the pile driving barge during pile driving. Several sea lions, however, were observed at distances of 500 to 1,000 meters swimming rapidly and porpoising away from pile driving activities. The reasons for these differences are not known, although Kastak and Schusterman (1998) reported that sea lions are more sensitive than harbor seals to underwater noise at low frequencies.

Observations of marine mammals on NBK at Bangor during the TPP project concluded that pinniped (harbor seal and California sea lion) foraging behaviors decreased slightly during construction periods involving impact and vibratory pile driving, and both pinnipeds and harbor porpoise were more likely to change direction while traveling during construction (HDR 2012). Pinnipeds were more likely to dive and sink when closer to pile driving activity, and a greater variety of other behaviors (including fighting, foraging, hauling out, milling, playing, and vocalizing) were observed with increasing distance from pile driving. Relatively few observations of cetacean behaviors were obtained during pile driving, and all were outside the WRA. Most harbor porpoises were observed swimming or traveling through the project area and no obvious behavioral changes were associated with pile driving.

During the first year of EHW-2 construction monitoring, only California sea lions and harbor seals were detected within the shutdown and behavioral disturbance zones (Primary Surveys) and outside the WRA (Outside Boat Surveys). The sample size for California sea lions was too small during pile driving to identify any trends in responses to construction (Hart Crowser 2013). Harbor seals engaged in a variety of behaviors during pile driving, including swimming, diving, sinking, and looking. They were equally likely to swim, dive, or sink as their ultimate behavior if they were inside the 464-meter behavioral disturbance zone and most likely to dive if they were outside the WRA. However, observation effort within the WRA was more intense than effort outside the WRA (as explained in Section 11.1.1). Harbor porpoises were only observed outside the WRA, where the predominant behavior during construction (vibratory pile driving) was swimming or traveling through the project area. During pre-construction monitoring, marine mammal observers also reported harbor porpoise foraging. Marine mammal observers did not detect adverse reactions to TPP or EHW-2 construction activities consistent with distress, injury, or high speed withdrawal from the area, nor did they report obvious changes in less acute behaviors.

Similarly, marine mammal monitoring at the Port of Anchorage marine terminal redevelopment project found no response by marine mammals swimming within the threshold distances to noise impacts from construction activities including pile driving (both impact hammer and vibratory driving) (Integrated Concepts & Research Corporation 2009). Most marine mammals observed during the two lengthy construction seasons were beluga whales; harbor seals, harbor porpoises, and Steller sea lions were observed in smaller numbers. Background noise levels at this port are typically at 125 dB.

A comprehensive review of acoustic and behavioral responses to noise exposure by Nowacek et al. (2007) concluded that one of the most common behavioral responses is displacement. To assess the significance of displacements, it is necessary to know the areas to which the animals relocate, the quality of that habitat, and the duration of the displacement in the event that they return to the pre-disturbance area. Short-term displacement may not be of great concern unless the disturbance happens repeatedly. Similarly, long-term displacement may not be of concern if adequate replacement habitat is available.

Steller sea lions and California sea lions would most likely avoid waters within the areas affected by above-threshold noise levels during impact pile driving around the EHW-2 project. Steller sea lions and California sea lions exposed to elevated noise levels could exhibit behavioral changes such as avoidance of the affected area, increased swimming speed, increased surfacing time, or decreased foraging activity. Pile driving will occur only during daylight hours and, therefore, will not affect nocturnal movements of Steller sea lions and California sea lions in the water. Most likely, Steller sea lions and California sea lions affected by elevated underwater or airborne noise would move away from the sound source and be temporarily displaced from the affected areas. Steller sea lions and California sea lions continued to haul out on Delta Pier during the first year of in-water construction, although Delta Pier was not monitored during pile installation. However, California sea lions would likely continue using submarines and PSB pontoons at Delta Pier as haul-out sites during pile driving, based on evidence cited above regarding responses of pinnipeds to construction noise including pile driving. Given the absence of any rookeries and only one haul-out area near the project site (i.e., submarines docked at Delta Pier and PSB pontoons), and infrequent attendance by a small number of individuals at this site, potential disturbance exposures would have a negligible effect on individual Steller sea lions and California sea lions and would not result in population-level impacts.

Harbor seals were by far the most frequently sighted species within the shutdown and behavioral harassment (464-meter) monitoring zones during the first year of EHW-2 construction (Hart Crowser 2013). A total of 984 animals were detected within the WRA during the year 1 and a total of 3,229 animals during the year 2 construction monitoring periods (Table 3-2). During year 1 impact and vibratory pile driving (a portion of the total construction monitoring periods), 214 harbor seals were detected within the shutdown and behavioral harassment (464-meter) monitoring zones (Hart Crowser 2013). During year 2 impact and vibratory pile driving, 713 harbor seals were detected within the shutdown and behavioral harassment (464-meter) monitoring zones (Navy 2014b, in prep.). The marine mammal observers did not observe flight behaviors during impact driving, but anecdotally it appeared that marine mammals were more likely to leave the construction area and monitoring zone during impact pile driving than during vibratory pile driving. Marine mammal observers will continue to monitor shutdown and disturbance zones during pile driving activities (see Section 11 for a detailed discussion of mitigation measures) for the presence of marine mammals, and they will alert work crews when to begin or stop work due to the presence of harbor seals in or near the shutdown zones, thereby reducing the potential for injury.

Transient killer whales that are exposed to pile driving noise could exhibit behavioral reactions such as avoidance of the affected area. Harassment from underwater noise impacts is not expected to be significant because it is estimated that only a small number of transient killer whales would ever be present in the project area. Marine mammal observers will monitor shutdown and disturbance zones during pile driving activities (see Section 11 for a detailed discussion of mitigation measures) for the presence of marine mammals, and they will alert work crews when to begin or stop work due to the presence of transient killer whales in or near the shutdown zones, thereby precluding the potential for injury.

Harbor porpoises that are exposed to pile driving noise could exhibit behavioral reactions such as avoidance of the affected area. Harassment from underwater noise impacts is not expected to be significant because it is estimated that only a small number of harbor porpoises would ever be present in the project area. Marine mammal observers will monitor shutdown and disturbance zones during pile driving activities (see Section 11 for a detailed discussion of mitigation measures) for the presence of marine mammals, and they will alert work crews when to begin or stop work due to the presence of harbor porpoises in or near the shutdown zones, thereby precluding the potential for injury.

Marine mammals encountering pile driving operations over the three project construction seasons would likely avoid affected areas in which they experience noise-related discomfort, limiting their ability to forage or rest there. As described in the section above, individual responses to pile driving noise are expected to be variable: some individuals may occupy the project area during pile driving without apparent discomfort, but others may be displaced with undetermined long-term effects. Avoidance of the affected area during pile driving operations would eliminate the likelihood of injury impacts but would reduce access to foraging areas in nearshore and deeper waters of Hood Canal. Noise-related disturbance across the 1.4-mile width of Hood Canal may inhibit some marine mammals from transiting the area. Given the long duration of the project (200 to 400 days of pile driving over three construction seasons), there is a potential for displacement of marine mammals from the affected area due to these behavioral disturbances during the in-water construction season. However, habituation over time may occur, along with a decrease in the severity of responses. Also, since pile driving will only occur during daylight hours, marine mammals transiting the project area or foraging or resting in the project area at night will not be affected. Effects of pile driving activities would be experienced by individual marine mammals, but would not cause population level impacts or affect the continued survival of the species.

#### 7.1.2 Airborne Noise Effects

Marine mammals that occur in the project area could be exposed to airborne sounds associated with pile driving that have the potential to cause behavioral harassment, depending on their distance from pile driving activities. Airborne pile driving noise would have less impact to cetaceans than pinnipeds because noise from atmospheric sources does not transmit well through the air-water interface (Richardson et al. 1995); thus, airborne noise would primarily be an issue for pinnipeds that are swimming or hauled out in the project area. In general, pinnipeds are less sensitive to airborne sound than are most terrestrial carnivores and less sensitive to underwater sound than strictly aquatic mammals (e.g., cetaceans), within the range of best sensitivity (Kastak and Schusterman 1998). Pinnipeds' hearing represents a compromise between aerial and aquatic adaptations, but the extent of adaptation for underwater hearing varies among pinniped families. California sea lions (members of the Otariidae, or eared seal family) appear to be better adapted to in-air hearing than underwater hearing in comparison to harbor seals (members of the Phocidae, or hair seal family), which are better adapted to hearing underwater (Richardson et al. 1995; Kastak and Schusterman 1998). Within the range of 100 Hz to 1.6 kHz, harbor seals hear nearly as well in air as underwater and had lower thresholds (i.e., greater sensitivity) than California sea lions (Kastak and Schusterman 1998). In air, harbor seals are most sensitive to frequencies between 6 and 16 kHz (Richardson et al. 1995; Wolski et al. 2003) but have functional hearing between 100 Hz and 30 kHz (Richardson et al. 1995; Kastak and Schusterman 1998). Thus, construction noise such as pile driving is well within the low-frequency range for this species. California sea lions are most sensitive at frequencies between 2 and 16 kHz (Schusterman 1974) and thus have functional hearing that includes lower-frequency construction noise (Kastak and Schusterman 1998).

Most likely, airborne sound would cause behavioral responses similar to those discussed above in relation to underwater noise. For instance, anthropogenic sound could cause hauled-out pinnipeds to exhibit changes in their normal behavior, such as reduction in vocalizations, or cause them to temporarily abandon their usual or preferred locations and move farther from the noise source. Pinnipeds swimming in the vicinity of pile driving may avoid or withdraw from the area, or show increased alertness or alarm (e.g., head out of the water, and looking around). However, studies of ringed seals by Blackwell et al. (2004) and Moulton et al. (2005) indicate a tolerance or lack of response to unweighted airborne sounds as high as 112 dB peak and 96 dB RMS, which suggests that habituation occurred.

Based on these observations, marine mammals on NBK at Bangor may exhibit temporary behavioral reactions to airborne pile driving noise, but the effect would be largely limited to the unlikely situation where animals are swimming in the areas encompassed by the airborne noise thresholds (90 dB for harbor seals, 361 meters from the driven pile; and 100 dB for other pinnipeds, 114 meters from the driven pile). Pinnipeds have habituated to existing airborne noise levels at Delta Pier on NBK at Bangor, where they regularly haul out on submarines and the floating security fences. The distance between the EHW-2 project site and haul-out sites is 1 kilometer or greater, which is beyond the airborne behavioral harassment threshold for pinnipeds that frequent the Bangor waterfront on NBK. The exposure modeling results (Section 6.5) indicate that no hauled-out pinnipeds would be exposed to airborne noise levels at sound levels that would constitute Level B behavioral harassment during either impact or vibratory pile driving (see Section 6 for modeling results). In conclusion, airborne noise may have a temporary minor effect on a few individuals, but this level of exposure is not likely to result in population level impacts.

#### 7.1.3 Non-Pile Driving Noise Effects

Under existing conditions, the Bangor waterfront on NBK produces an environment of complex and highly variable noise that could affect marine mammals. Existing underwater noise levels primarily due to industrial activity and small vessel traffic measured along the Bangor waterfront on NBK were measured at 114 dB between 100 Hz and 20 kHz (Slater 2009). As discussed in Section 2.2.8, Ambient Underwater Sound, peak spectral noise from industrial activity was noted below the 300 Hz frequency, with maximum levels of 110 dB noted in the 125 Hz band. In the 300 Hz to 5 kHz range, average levels ranged between 83 and 99 dB. These frequencies are in the lowest portion of the functional hearing ranges of marine mammals that occur on NBK at Bangor.

During construction of the EHW-2, noise will be generated by barge-mounted equipment such as cranes and generators, but this noise would typically not exceed existing underwater noise levels resulting from existing routine waterfront operations on NBK at Bangor, including Delta Pier, Marginal Wharf, and the existing EHW facility.

Existing airborne noise levels at developed wharfs and piers on NBK at Bangor result from vehicle traffic and operation of equipment such as forklifts, generators, pumps, and cranes. Noise is estimated to range from 70 to 90 dBA and may peak at 99 dBA for short durations (Slater 2009). Construction of the EHW-2 will increase vehicle traffic and use of construction equipment at the EHW-2 project site, with similar noise levels expected. With the exception of occasional noise peaks, most airborne construction equipment noise would be lower than MMPA threshold criteria for Level B disturbance harassment (Table 6–2), and the effects on marine mammals would be negligible.

## 7.2 Other Effects on Marine Mammals

Construction period effects on marine mammals may result from water quality changes, increased vessel activity and human presence in the project area, collisions with vessels, and changes in prey availability (see Section 9).

### 7.2.1 Water Quality

Water quality will be impacted as a result of spud use and barge anchoring and installation of piles because bottom sediments will be temporarily re-suspended. Turbidity plumes will be generated periodically in relation to the level of in-water construction activities. The quantity and settling speed of resuspended sediments reflect the composition of sediments; in general, sediments at the EHW-2 project site are coarse-grained and are more resistant to resuspension and have a higher settling speed than fine-grained sediments. Calculations of sediment dispersion distance, using worst-case current velocity and residence time of sediment particles, indicate a likely spread up to approximately 130 feet (Morris et al 2008).

Re-suspended sediments could potentially re-suspend metals and organic contaminants that may be present in marine sediments. Sediment quality sampling was conducted at the EHW-2 project site during 2007 pursuant to guidelines established by the Washington State Sediment Management Standards (SMS) (Washington Administrative Code [WAC] 173-204) (Hammermeister and Hafner 2009). Sediments sampled included a large number of contaminants that are ubiquitous in Puget Sound, including heavy metals, polycyclic aromatic hydrocarbons, chlorinated pesticides, polychlorinated biphenyls (PCBs), and other compounds listed under the SMS. However, their concentrations were below levels of concern as defined by the Washington State SMS. The marine Sediment Quality Standards (SQS) established by the SMS include numeric criteria using bulk contaminant concentrations and biological impacts criteria based on sediment bioassays that define the lower limit of sediment quality expected to cause no adverse impacts to biological resources in Puget Sound. Sediment sampling at the EHW-2 project site indicated that sediment quality at the project site is generally good; that is, levels of contaminants meet applicable state standards (Hammermeister and Hafner 2009). Thus, marine mammals exposed to resuspended sediments resulting from EHW-2 in-water construction are not likely to be impacted by contaminants.

The activities that generate suspended sediments will be short-term and localized and suspended sediments would disperse and/or settle rapidly. Moreover, marine mammals are expected to avoid the immediate construction area due to increased vessel traffic, noise and human activity, and possibly reduced prey abundance. Therefore, no direct impacts to marine mammals are expected due to water quality effects during construction.

### 7.2.2 Vessel Traffic

Marine mammals on NBK at Bangor encounter vessel traffic associated with daily operations, maintenance, and security monitoring along the waterfront. Vessel movements have the potential to affect marine mammals by directly striking or disturbing individuals, as evidenced by behavioral changes. For example, several studies have linked vessels with behavioral changes in killer whales in Pacific Northwest inland waters (Kruse 1991; Kriete 2002;

Williams et al. 2002; Bain et al. 2006), although it is not well understood whether the presence and activity of the vessel, the vessel noise, or a combination of these factors produces the changes. The probability and significance of vessel and marine mammal interactions is dependent upon several factors including numbers, types, and speeds of vessels; the regularity, duration, and spatial extent of activities; and the presence/absence and density of marine mammals.

Behavioral changes in response to vessel presence include avoidance reactions, alarm/startle responses, temporary abandonment of haul outs by pinnipeds, and other behavioral and stress-related changes (such as altered swimming speed, direction of travel, resting behavior, vocalizations, diving activity, and respiration rate) (Watkins 1986; Würsig et al 1998; Terhune and Verboom 1999; Ng and Leung 2003; Foote et al. 2004; Mocklin 2005; Bejder et al. 2006; Nowacek et al. 2007). Some dolphin species approach vessels and are observed bow riding or jumping in the wake of a vessel (Norris and Prescott 1961; Shane et al 1986; Würsig et al. 1998; Ritter 2002). In other cases neutral behavior (i.e., no obvious avoidance or attraction) has been reported (review in Nowacek et al. 2007). Little is known about the biological importance of changes in marine mammal behavior under prolonged or repeated exposure to high levels of vessel traffic, such as increased energetic expenditure or chronic stress, which can produce adverse hormonal or nervous system effects (Reeder and Kramer 2005).

During construction of the EHW-2, several additional vessels will operate in the project area, including one derrick barge and one pile barge for pile driving, and one derrick barge and two material barges for deck construction, tug boats that will move barges into position, and small supporting boats. At any given time, there will be no more than two tugs and six smaller boats, plus barges, present in the construction area. Harbor seals Steller sea lions, and California sea lions are expected to alter foraging activities along the Bangor waterfront on NBK to avoid boats but may remain in the area, as these marine mammals have become habituated to an industrial waterfront with substantial boat activity. These vessels will operate at low speeds within the relatively limited construction zone and access routes during the in-water construction period. Low speeds are expected to reduce the impact of boat movements in the construction zone during this period. Marine vessel traffic will potentially pass near marine mammals on an incidental basis, but short-term behavioral reactions to vessels are not expected to result in long-term impacts to individuals, or to marine mammal populations in Hood Canal.

#### 7.2.3 Collisions with Vessels

Collisions of vessels and marine mammals, primarily cetaceans, are not expected during construction because vessel speeds will be low. All of the cetaceans likely to be present in the project area are fast-moving odontocete species that tend to surface at relatively short, regular intervals allowing for increased detectability and avoidance. Vessel impacts are more frequently documented in slower-moving cetaceans or those that spend extended periods of time at the surface, but these species do not occur in Hood Canal. Although boat traffic in the localized EHW-2 area will increase, once construction is completed, overall vessel traffic along the Bangor waterfront on NBK is not expected to increase above current vessel traffic.

## 7.3 Conclusions Regarding Impacts to Species or Stocks

Individual marine mammals may be exposed to SPLs during pile driving operations on NBK at Bangor, which may result in Level B Behavioral harassment. Any marine mammals that are exposed (harassed) may change their normal behavior patterns (i.e., swimming speed, foraging habits, etc.) or be temporarily displaced from the area of construction. Any exposures would likely have only a minor effect on individuals and no effect on the population. The sound generated from vibratory pile driving is non-pulsed (e.g., continuous), which is not known to cause injury to marine mammals. Mitigation is likely to avoid most potential adverse underwater impacts to marine mammals from impact pile driving. Nevertheless, some level of impact is unavoidable. The expected level of unavoidable impact (defined as an acoustic or harassment exposure) is described in Sections 6 and 7. This level of effect is not anticipated to have any detectable adverse impact to population recruitment, survival, or recovery (i.e., no more than a negligible adverse effect).

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# 8 IMPACT TO SUBSISTENCE USE

*The anticipated impact of the activity on the availability of the species or stock of marine mammals for subsistence uses.*

## 8.1 Subsistence Harvests by Northwest Treaty Indian Tribes

Historically, Pacific Northwest treaty Indian tribes were known to utilize several species of marine mammals including, but not limited to harbor seals, Steller sea lions, northern fur seals, gray whales, and humpback whales (Norberg 2007a, personal communication). Recently, several Pacific Northwest treaty Indian tribes have promulgated[9] tribal regulations allowing tribal members to exercise treaty rights for subsistence harvest of California sea lions and harbor seals (Carretta et al. 2007).[10] The Makah Indian Tribe (Makah) has specifically passed hunting regulations for gray whales (Norberg 2007b, personal communication). However, the directed take of marine mammals (not just gray whales) for ceremonial and/or subsistence purposes was enjoined by the Ninth Circuit Court of Appeals in a ruling against the Makah in 2002, 2003, and 2004 (Norberg 2007b, personal communication; NMFS 2008d). The court ruled that a National Environmental Policy Act Environmental Impact Statement (EIS) should be prepared and that the Makah, to pursue any treaty rights for whaling, must comply with MMPA processes. The National Oceanic and Atmospheric Administration (NOAA) initiated a draft EIS but terminated it in 2012 and began a new draft EIS, following new findings regarding the population structure of eastern North Pacific gray whales. Presently, there are no known active ceremonial and/or subsistence hunts for marine mammals in Puget Sound or the San Juan Islands.

## 8.2 Summary

Potential impacts resulting from the proposed action will be limited to individuals of marine mammal species located in the marine waters near NBK at Bangor and will be limited to Level B harassment. Therefore, no impacts to the availability of species or stocks for subsistence use were found.

[9] To make known by open declaration; publish; proclaim formally or put into operation (a law, decree of a court, etc.).

[10] Some coastal tribes also have regulations that allow their fishermen to protect their life, gear, and catch from seals and California sea lions by lethal means. These rare takes, which are not for subsistence or ceremonial needs, are reported annually to NMFS by each tribe (Wright 2007, personal communication).

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# 9 IMPACTS TO THE MARINE MAMMAL HABITAT AND THE LIKELIHOOD OF RESTORATION

*The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.*

The construction of the EHW-2 would not result in permanent impacts to habitats used directly by marine mammals, such as haul-out sites, but would affect the prey base such as forage fish and salmonids. There are no rookeries or major haul-out sites within 10 kilometers, or other ocean bottom structure of significant biological importance to marine mammals that may be present in the marine waters in the vicinity of the project area. The main impact issue associated with the EHW-2 would be elevated noise levels and the associated direct effects on marine mammals, as discussed in Sections 6 and 7. The most likely impact to marine mammal habitat would result from pile driving effects on likely marine mammal prey (i.e., fish).

## 9.1 Effects on Potential Prey (Fish)

Construction would impact marine habitats used by fish. Marine habitats used by fish species that occur along the Bangor waterfront on NBK include offshore (deeper) habitat, nearshore habitats (intertidal zone and shallow subtidal zone), and other habitats, including piles used for structure and cover. The greatest impacts to prey species during construction would result from benthic habitat displacement, resuspension of sediments, and behavioral disturbance due to pile driving noise. The prey base for the most common marine mammal species (harbor seal and California sea lion) in the project area includes a wide variety of small fish such as Pacific hake, Pacific herring, and juvenile salmonids, as well as adult salmonids, when available. The prey base of Steller sea lions and California sea lions includes forage fish, which potentially would be less available for predators within the fish injury exposure and behavioral harassment zones during the 7-month, in-water construction window. Steller sea lions in the project area probably consume pelagic and bottom fish. The prey base of harbor seals includes forage fish and juvenile salmonids, which would be less available for predators within the fish injury exposure and behavioral harassment zones during the 7-month, in-water construction window. Dall's porpoise and harbor porpoise are also occasionally seen in Hood Canal, where they probably feed on schooling forage fishes, such as Pacific herring, smelts, and squid. Transient killer whales consume marine mammals; in Hood Canal they prey on harbor seals. Southern Resident killer whales do not occur in Hood Canal, but consume salmonids (with a strong preference for Chinook salmon) that originate in Hood Canal tributaries.

### 9.1.1 Underwater Noise Effects on Fish

The greatest impact to marine fish during construction would occur during impact pile driving because pile driving would exceed the established underwater noise thresholds for fish, for both behavior and injury. The applicable criterion for injury to fish would be 187 dB sound exposure level (SEL) for a fish greater than 2 grams in weight and 183 dB SEL for a fish less than 2 grams in weight (Fisheries Hydroacoustic Working Group 2008) (Table 9–1). No injury threshold for fish has been identified for vibratory pile driving. In addition to injury thresholds, the Fisheries Hydroacoustic Working Group (2008) established underwater noise threshold criteria for behavioral impacts to fish, including startle response, at a level of 150 dB RMS. This behavioral threshold applies to both impact and vibratory pile driving.

**Table 9–1. Estimated Distances to Underwater Noise Thresholds, One Impact and Three Vibratory Pile Drivers, Peak, RMS, and SEL**

| Functional Hearing Group | Underwater Threshold | With Noise Attenuator Distance to Threshold (meters) |
|---|---|---|
| **Fish ≥ 2 grams (based on 6,400 impact pile strikes)** | | |
| Injury | 187 dB SEL | 464[1] |
| **Fish < 2 grams (based on 6,400 impact pile strikes)** | | |
| Injury | 183 dB SEL | 464[2] |
| **Fish all sizes** | | |
| Injury | 206 dB peak | 4 |
| Behavior | 150 dB RMS | 2,224 (continuous)<br>3,361 (impulsive) |

dB = decibel; RMS = root-mean-square; SEL = sound exposure level

1. Distances shown are limited by effective quiet; calculated distance is 546 meters.
2. Distances shown are limited by effective quiet; calculated distance is 1,009 meters.

During pile driving, the associated underwater noise levels would have the potential to cause injury and would result in behavioral response, including project area avoidance. Average underwater baseline noise levels acquired along the waterfront were measured at a level of 114 dB (Slater 2009).

Sound during impact pile driving would be detected above the average background noise levels at any nearby location in Hood Canal with a direct acoustic path (e.g., line-of-sight from the driven pile to the receiver location). To reduce the underwater noise levels and associated impacts to underwater organisms during active impact pile driving, a bubble curtain or other noise attenuating device will be deployed that should reduce sound levels by 10 dB. To further minimize the underwater noise impacts during pile driving, vibratory pile drivers will be used to the maximum extent practicable for structural integrity to drive piles; an impact hammer will be primarily used to proof load the piles to verify load bearing capacity, and not as the primary means to drive piles.

For the concurrent operation of one impact and three vibratory pile drivers averaging 6,400 daily strikes, a fish less than 2 grams could be injured by noise levels from pile driving if it occurred within 464 meters (Table 9–1). Any fish greater than or equal to 2 grams could also be injured by noise levels from pile driving if it occurred within 464 meters under a 6,400 daily strike scenario (Table 9–1). The reason for identical distances for different SEL thresholds is that the NMFS SEL model methodology includes a factor that adjusts the maximum affected area to exclude single strike values less than 150 dB SEL, which are assumed to not accumulate to cause injury (WSDOT 2009). This factor ("effective quiet") has the effect of fixing the maximum distance at which injury is expected to occur, regardless of the number of hammer strikes used in the model calculation. For these assumed conditions, both 187 and 183 dB SEL threshold values will be limited to 464 meters for 6,400 pile strikes.

Behavioral disturbance of fish of all sizes was evaluated at the 150 dB RMS threshold for multiple pile driver scenarios where all sound sources were treated as continuous in nature, and where all sound sources were treated as impulsive in nature. The distance out to the behavioral disturbance threshold was greatest when all sound sources were treated as impulsive sounds. Under this scenario, the threshold would be exceeded within a circle centered at the location of the driven pile out to a distance of approximately 3,361 meters (in a direct line-of-sight) (Table 9–1).

Fish in the 150 dB range may display a startle response during initial stages of pile driving, and would likely avoid the immediate project vicinity during construction activities, including pile driving. However, field investigations of Puget Sound salmonid behavior, when occurring near pile driving projects (Feist 1991; Feist et al. 1992), found little evidence that normally nearshore migrating juvenile salmonids move farther offshore to avoid the general project area. In fact, some studies indicate that construction site behavioral responses, including site avoidance, may be as strongly tied to visual stimuli as to underwater sound (Feist 1991; Feist et al. 1992; Ruggerone et al. 2008). Therefore, it could be assumed that salmonids, and likely other species, may alter their normal behavior, including startle response and avoidance of the immediate project site, but occurrence within most of the 2,224-meter (continuous noise source) to 3,361-meter (impulsive noise source) disturbance areas would not change.

Thus, prey availability for wildlife predators within an undetermined portion of the construction impact zone for fish could potentially be reduced. These impacts would occur over each of 7 months of in-water construction during the 3-year construction period. The duration of fish avoidance of this area after pile driving stops is unknown, but a rapid return to normal recruitment, distribution, and behavior is anticipated. Any behavioral avoidance by fish of the disturbed area would still leave significantly large areas of fish and marine mammal foraging habitat in Hood Canal and the nearby vicinity. Some adverse effects on individual prey populations are possible with construction of the EHW-2, but effects on prey populations will not contribute to MMPA take.

### 9.1.2 Effects on Fish Habitats/Abundance

Construction of the EHW-2 would adversely affect some of the habitat conditions (NMFS 1999) for salmonids and forage fish in the project area. Positioning and anchoring the construction barges and driving piles will locally increase turbidity, disturb benthic habitats, disturb forage fish, and shade marine vegetation in the immediate project vicinity. Construction would bury benthic organisms with limited mobility under sediment. Increased turbidity would make it difficult for predators to locate prey. All of these actions would indirectly affect marine mammals by degrading foraging and refuge habitat quality for prey species and reducing their invertebrate and forage fish prey base. In addition to impacts to the biological productivity of benthic organisms, construction would reduce the extent and degrade the quality of marine vegetation, adversely affecting availability of marine fish prey populations for marine mammals. Construction impacts to benthic habitats reflect the size of the construction zone. Construction of the EHW-2 is expected to displace or disturb 25.7 acres of benthic habitat, including 0.92 acre of marine vegetation (primarily eelgrass beds and algae, but also a small portion of kelp beds). Some of these effects described above, such as barge placement and increased turbidity, would occur only during the in-water construction period and thus would be temporary.

Construction impacts to salmonid populations, which includes ESA-listed species, will be minimized by adhering to the in-water work period designated for northern Hood Canal waters, when less than 5 percent of all salmonids that occur in NBK at Bangor nearshore waters are expected to be present (SAIC 2006; Bhuthimethee et al. 2009). Some habitat degradation is expected during construction, but the impacts to salmonids and forage fish would be temporary and localized.

Long-term operation of the EHW-2 would adversely affect a number of habitat conditions for forage fish primarily in nearshore waters. Decreased habitat value for forage fish, salmonids, other finfish, and, to a lesser extent, shellfish, would result in localized minor long-term impacts to marine mammal prey availability. The increased surface area of overwater structures (6.3 acres) would reduce biological productivity overall through shading and reduction in the size of eelgrass beds and other marine vegetation (approximately 0.13 acre), and impact the prey base (benthic organisms, ground fish, and pelagic fish) in the intertidal, subtidal, and nearshore deeper water zones. In addition, the EHW-2 would inhibit movement of shoreline-dependent fishes such as juvenile salmonids and forage fishes. Increased lighting at the EHW-2 may affect prey availability, depending on the species, for marine mammals. Some fish may be attracted by artificial lighting, which may in turn attract predators, including marine mammals, and facilitate their feeding. Overall, a localized change to the prey base in terms of abundance and species composition for some marine mammals is expected. Section 11.7 describes the marine habitat mitigation action that the Navy will undertake as part of the proposed action. This habitat mitigation action, including mitigation for eelgrass, will compensate for the impacts of the proposed action to marine habitat and species.

Adverse impacts of the EHW-2 would be limited to the small area including and adjacent to the trestle and wharf (approximately 6.3 acres). In the context of the Hood Canal marine mammal populations overall, the affected area is too small to constitute an adverse impact. Thus, no additional MMPA take is expected with operation of the EHW-2. Moreover, the numbers of marine mammals affected by impacts to prey populations would be small; therefore, the impact would be insignificant in the context of marine mammal populations.

The project has the potential to affect the Southern Resident killer whale population, which does not occur in the project area, by indirectly affecting its prey base. The diet of Southern Resident killer whales includes a disproportionate number of adult Chinook (Ford et al. 1998; Ford et al. 2010; Hanson et al. 2010). Available information on the proportion of Hood Canal Chinook salmon in the diet of Southern Resident killer whales indicates that it is about 20.4 percent in May (however, this is based on a sample size of 9), but less than 5 percent in other months (June to September) for which data are available. Adult Hood Canal Chinook salmon returns are subject to many variables, among which the effects of the EHW-2 are likely to be minor. Mitigation efforts, including scheduling in-water construction for the period when juvenile Chinook salmon are least abundant, and using a bubble curtain or other noise attenuating device for impact pile driving, will minimize this potential adverse effect. Therefore, the project's effect on the Southern Resident killer whale prey base would be insignificant, and not likely to adversely affect the population.

## 9.2 Effect on Haul-out Sites

No effects are expected on existing haul-out sites. California sea lions, Steller sea lions, and harbor seals use various manmade structures on NBK at Bangor for hauling out, but cannot use the existing EHW, nor would they be able to use the new wharf and trestles as haul-out sites, as the decks of these structures will be approximately 13 feet above MHHW. The shoreline abutment will be a vertical structure 10 feet high and would not be accessible for hauling out. Armor rock placed at the base of the abutment could potentially be accessible to marine mammals. However, since the shoreline in the project area is not used for hauling out by any pinniped species under existing conditions, it is unlikely that pinnipeds would haul out in the vicinity of the EHW-2 in the future.

## 9.3 Likelihood of Habitat Restoration

Compensatory mitigation measures will be implemented to restore marine fish habitats, and by extension to restore marine mammal prey base. These measures are described in Section 11.7.

# 10 IMPACTS TO MARINE MAMMALS FROM LOSS OR MODIFICATION OF HABITAT

*The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.*

Construction and operation of the EHW-2 would affect marine mammal habitats indirectly through impacts to prey abundance and availability. The most important impacts to marine mammal fish species consumed by marine mammals would result from injury and behavioral disturbance to fish species during pile driving. The potential impact on Steller sea lions would be a localized, temporary loss of foraging opportunities (during in-water construction) and a potential exposure to behavioral harassment as they transit the project area. The affected area is negligible in contrast to the available foraging range for Steller sea lions in Hood Canal. The potential impact on California sea lions would be a very localized, temporary loss (during in-water construction) of foraging opportunities, and potential exposure to behavioral harassment as they transit the project area. The potential impact on harbor seals would be a very localized, temporary loss of foraging opportunities (during in-water construction) and potential exposure to behavioral harassment as they transit the project area. Fish may avoid an undetermined portion of the affected area, defined by the injury and behavioral disturbance thresholds in Table 9–1, during the in-water work season. Post-construction, the EHW-2 would adversely affect prey availability and abundance by creating a barrier to nearshore migration, shading the benthic habitat, and eliminating eelgrass beds. These adverse effects would be compensated for by mitigation actions described in Section 11. The numbers of marine mammals affected by impacts to prey populations would be small; therefore, the impact would be minor in the context of marine mammal populations.

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# 11 MEANS OF EFFECTING THE LEAST PRACTICABLE ADVERSE IMPACTS — MITIGATION MEASURES

*The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.*

The exposures outlined in Section 6 represent the maximum expected number of marine mammals that could be exposed to acoustic sources reaching Level B harassment levels. The Navy proposes to employ a number of mitigation measures, discussed below, in an effort to minimize the number of marine mammals potentially affected.

## 11.1 Mitigation for Pile Driving Activities

The modeling results for ZOIs discussed in Section 6 were used to develop mitigation measures for pile driving activities on NBK at Bangor. The ZOIs effectively represent the monitoring zone that will be established around each pile to prevent Level A harassment to marine mammals. While the ZOIs vary between the different diameter piles and types of installation methods, the Navy is proposing to establish mitigation zones for the maximum zone of influence for all pile driving conducted during construction of the EHW-2.

### 11.1.1 Shutdown and Buffer Zone (Impact and Vibratory Pile Driving/Removal)

As discussed in Section 6.4.2.2, results from acoustic monitoring during the TPP and the first year of EHW-2 construction indicate that the bubble curtain did not consistently achieve the expected 10 dB of noise attenuation. To account for this uncertainty, the Navy will monitor and implement an Injury Shutdown Zone larger than the modeled injury zone threshold distances, where in-water construction activities would be shut down to avoid injury to marine mammals (Table 6–8). The Injury Shutdown Zone is based on calculated distances to thresholds (based on in-situ measured source levels) rather than the original modeled distances discussed in Section 6.4.

- During impact pile driving the shutdown zone will include all areas where the underwater SPLs are anticipated to equal the Level A (injury) harassment criteria for marine mammals (180 dB isopleths for cetaceans; 190 dB isopleths for pinnipeds). For pinnipeds the shutdown distance will be 20 meters[11] from the pile and for cetaceans the shutdown distance will be 85 meters[12] from the pile.

[11] The modeled injury threshold distance for pinnipeds for one impact pile driver is approximately 5 meters, but the Navy has increased this distance up to 20 meters based on in-situ recorded sound pressure levels during the Test Pile Program and Year 1 EHW construction, which indicated the pinniped injury zone more consistently extended up to 12 meters from the pile (Table 6-8).

[12] The modeled injury threshold distance for cetaceans for one impact pile driver is approximately 22 meters, but the Navy has increased this distance up to 85 meters based on in-situ recorded sound pressure levels during the Test Pile Program, which indicated the cetacean injury zone more consistently extended up to 45 meters from the pile (Table 6-8).

- During vibratory pile driving/removal involving multiple pile driving rigs, the shutdown zone will include all areas where the underwater SPLs are anticipated to equal the Level A (injury) harassment criteria for marine mammals (180 dB isopleths for cetaceans; 190 dB isopleths for pinnipeds). For pinnipeds the shutdown distance will be 10 meters[13] from the pile and for cetaceans the shutdown distance will also be 10 meters[14] from the pile.
- All shutdown zones will initially be based on the distances from the source that were predicted for each threshold level. However, in-situ acoustic monitoring will be utilized to determine the actual distances to these threshold zones, and the size of the shutdown zones will be adjusted accordingly (increased or decreased) based on received sound pressure levels.
- During impact pile driving/removal the buffer zone will include all areas where the underwater or airborne SPLs are anticipated to equal or exceed the Level B (disturbance) harassment criteria for marine mammals during impact pile driving (160 dB isopleth). The modeled distance to the 160 dB isopleth for impulsive sound is 464 meters. Marine mammal observers stationed within the WRA cannot easily see animals beyond the PSB, which is at least 500 meters from the driven piles. It is not feasible for boats to move through the PSB structures during monitoring due to the intensive security checks required to enter the WRA. Therefore, visual monitoring to the furthest extent of the calculated disturbance zone for EHW-2 is largely obstructed by the PSB. Marine mammal monitors will monitor the area from the driven pile to the PSB at a minimum and will also record any additional observations of marine mammals beyond the fence.
- During vibratory pile driving, the Level B (disturbance) harassment criterion (120 dB isopleth) predicts an affected area of 41.4 square kilometers (16 square miles). The size of this area would make effective monitoring impractical. As a result, a buffer zone as described above will be monitored for pinnipeds and cetaceans during all vibratory pile driving/removal activities.
- The shutdown and buffer zones will be monitored throughout the time required to drive a pile. If a marine mammal enters the buffer zone, an exposure would be recorded and behaviors documented. However, the pile segment would be completed without cessation, unless the animal approaches or enters the shutdown zone, at which point, all pile driving activities will immediately be halted.
- Under certain construction circumstances, where initiating the shutdown and clearance procedures (which could include a delay of 15 minutes or more) would result in an imminent concern for human safety, the shutdown provision may be waived. The Navy is working with NMFS Headquarters to clarify situations or criteria in which such a scenario may occur.

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[13] The actual modeled injury threshold distance for pinnipeds for three vibratory pile drivers is approximately 2.3 meters, but the Navy has rounded this distance up to 10 meters to be consistent with the shutdown zone for in-water, non-pile-driving activities.
[14] The modeled injury threshold distance for cetaceans for three vibratory pile drivers is 10 meters.

#### 11.1.2 Shutdown Zone (In-water Construction Activities Not Involving a Pile Driving Hammer)

- During in-water construction activities not involving a pile driver, but having the potential to affect marine mammals, in order to prevent injury to these species from their physical interaction with construction equipment, a shutdown zone of 10 meters (33 feet) will be monitored to ensure that marine mammals are not present in this zone.
- These activities could include, but are not limited to: (1) the movement of the barge to the pile location, (2) the positioning of the pile on the substrate via a crane (i.e., "stabbing" the pile), (3) the removal of the pile from the water column/substrate via a crane (i.e., "deadpull"), or (4) the placement of sound attenuation devices around the piles.

#### 11.1.3 Visual Monitoring

A marine mammal monitoring plan will be finalized prior to commencement of pile driving activities; however, at a minimum it will include the following:

- Monitoring will be conducted by qualified, trained marine mammal observers (hereafter, "observer"). An observer is a biologist with prior training and experience in conducting at-sea marine mammal monitoring or surveys, and who has the ability to identify marine mammal species and describe relevant behaviors that may occur in proximity to in-water construction activities. A trained observer will be placed at the best vantage point(s) practicable (e.g., from a small boat, the pile driving barge, on shore, or any other suitable location) to monitor for marine mammals and implement shutdown/delay procedures when applicable by calling for the shutdown to the hammer operator.
- Prior to the start of pile driving/removal activity, the shutdown zones will be monitored for 15 minutes to ensure that they are clear of marine mammals. Pile driving will only commence once observers have declared the shutdown zone clear of marine mammals. The behavior of animals that remain in the buffer zone will be monitored and documented to the extent practicable.
- During impact and vibratory pile driving/removal, monitoring will be conducted before, during, and after pile driving activities. Monitoring will take place from 15 minutes prior to initiation through 30 minutes post-completion of pile driving activities. Pile driving activities include the time to install or remove a single pile, or series of piles, as long as the time elapsed between uses of the pile driver is no more than 30 minutes.
- During in-water construction activities that do not involve a pile driving hammer, as defined above in Section 11.1.2, monitoring will be conducted within the shutdown zone to preclude injury from their physical interactions with construction equipment. Monitoring will take place from 15 minutes prior to initiation until the action is complete.
- If a marine mammal approaches/enters the shutdown zone during the course of pile driving/removal operations, or other in-water construction activities not involving a pile hammer, the action will be halted and delayed until either the animal has voluntarily left and been visually confirmed beyond the shutdown zone or 15 minutes have passed without detection of the animal.

#### 11.1.4 Noise Attenuating Devices

Noise attenuating devices (e.g., bubble curtain) will be utilized during all impact pile driving operations.

#### 11.1.5 Soft Start for Impact Pile Driving Operations

The objective of a soft start is to provide a warning and/or give animals in close proximity to pile driving a chance to leave the area prior to an impact driver operating at full capacity, thereby exposing fewer animals to loud underwater and airborne sounds.

- A soft-start procedure will be used at the beginning of each day's in-water impact pile driving or if pile driving has ceased for more than 30 minutes.
- For impact pile driving, the following soft-start procedures will be conducted:
  - The contractor will start the bubble curtain prior to the initiation of impact pile driving.
  - The contractor will provide an initial set of strikes from the impact hammer at reduced energy, followed by a 30-second waiting period, then two subsequent sets. (The reduced energy of an individual hammer cannot be quantified because it varies for individual drivers. Also, the number of strikes will vary at reduced energy because raising the hammer at less than full power and then releasing it results in the hammer "bouncing" as it strikes the pile resulting in multiple "strikes.")

#### 11.1.6 Timing Restrictions

To minimize the number of fish exposed to underwater noise and other disturbance, in-water work will only be conducted during the in-water work window (from July 16 through February 15) for Puget Sound Marine Area 13 as outlined in WAC-220-110-271 and USACE (2010), when juvenile ESA-listed salmonids are least likely to be present. The initial months (July to September) of the timing window overlap with times when Steller sea lions are not expected to be present within the study area.

#### 11.1.7 Daylight Construction

Impact pile driving during the first half of the in-water work window (July 16 to September 23) will only occur between 2 hours after sunrise and 2 hours before sunset to protect breeding marbled murrelets. Vibratory pile driving and other construction activities occurring in the water between July 16 and September 23 could occur during daylight hours (sunrise to sunset). Between September 24 and February 15, construction activities occurring in the water would occur during daylight hours (sunrise to sunset[15]). Other construction will occur between 7:00 a.m. and 10:00 p.m. 6 days per week, but could occur 7 days per week.

### 11.2 Compensatory Habitat Mitigation

The Proposed Actions will result in the loss and shading of eelgrass habitat and other impacts on marine habitats. The Proposed Actions also will require a Section 10 permit under the Rivers and Harbors Act and a 404 permit from the U.S. Army Corps of Engineers (USACE). To receive permits the Proposed Actions must comply with *The Compensatory Mitigation for*

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[15] Sunrise and sunset will be determined based on the National Oceanic and Atmospheric Administration data, which can be found at http://www.srrb.noaa.gov/highlights/sunrise/sunrise.html.

*Losses of Aquatic Resources Final Rule* adopted on April 10, 2008 (hereafter Compensatory Mitigation Rule).

The Navy purchased habitat credits from the Hood Canal Coordinating Council In Lieu Fee Program to mitigate for unavoidable adverse impacts to aquatic resources. The purchase of credits will restore marine fish habitats, which will indirectly benefit marine mammals in the project area. The Hood Canal In Lieu Fee Program is a voluntary program sponsored by the Hood Canal Coordinating Council and approved by USACE and WDOE.

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# 12 MINIMIZATION OF ADVERSE EFFECTS ON SUBSISTENCE USE

*Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:*

*(i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;*

*(ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;*

*(iii) A description of what measures the applicant has taken an/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and*

*(iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.*

Subsistence use is the traditional exploitation of marine mammals by native peoples for their own consumption. Based on the discussions in Section 8, there are no adverse effects on the availability of species or stocks for subsistence use.

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# 13 MONITORING AND REPORTING MEASURES

*The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding.*

## 13.1 Monitoring Plan

The Marine Mammal Monitoring Plan (Appendix C) approved by NMFS under the IHA for the second in-water construction period (July 16, 2013, through February 15, 2014) will be implemented during the third in-water construction period.

## 13.2 Reporting

A draft comprehensive marine mammal monitoring report will be submitted to NMFS within 90 calendar days of the end of each in-water work period. The report will include marine mammal observations pre-activity, during-activity, and post-activity during pile driving days. A final comprehensive report will be prepared and submitted to NMFS within 30 calendar days following receipt of comments on the draft report from NMFS.

The reports shall include at a minimum:

- General data:
  - Date and time of activity
  - Water conditions (e.g., sea-state, tidal state)
  - Weather conditions (e.g., percent cover, percent glare, visibility)

- Specific pile driving data:
  - Description of the pile driving activities including the size and type of pile
  - The installation methods used for each pile and the duration each method was used per piles
  - Impact or vibratory hammer force used to drive/extract piles
  - Detailed description of the sound attenuation system, including the design specifications. Details of any issues associated with bubble curtain deployment or any functional checks conducted on the system should be recorded on a daily or per pile basis.
  - Depth of water in which the pile was driven
  - Depth into the substrate that the pile was driven

- Pre-activity observational survey-specific data:
  - Dates and time survey is initiated and terminated

- Description of any observable marine mammals and their behavior in the immediate area during monitoring
- If possible, the correlation to underwater sound levels occurring at the time of the observable behavior
- Times when pile driving or other in-water construction is delayed due to weather conditions, presence of marine mammals within shutdown zones, etc.
- Actions performed to minimize impacts to marine mammals

- During-activity observational survey-specific data:
  - Description of any observable marine mammal behavior within monitoring zones or in the immediate area surrounding the monitoring zones, including the following:
    - Distance from animal to pile driving sound source
    - Reason why/why not shutdown implemented
    - If a shutdown was implemented, behavioral reactions noted and if they occurred before or after implementation of the shutdown
    - If a shutdown is implemented, the distance from animal to sound source at the time of the shutdown
    - Distance to the animal from the source during soft start
  - If possible, the correlation to underwater or airborne sound levels occurring at the time of this observable behavior.
  - Actions performed to minimize impacts to marine mammals

- Post-activity observational survey-specific data:
  - Results, which include the detections of marine mammals, the species and numbers observed, sighting rates and distances, behavioral reactions within and outside of safety zones
  - Refined exposure estimate based on the number of marine mammals observed during the course of construction

# 14 RESEARCH

*Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.*

To minimize the likelihood that impacts will occur to the species, stocks, and subsistence use of marine mammals, all construction activities will be conducted in accordance with all federal, state, and local regulations and minimization measures proposed by the Navy will be implemented to protect marine mammals. The Navy will coordinate all activities with the relevant federal and state agencies. These include but are not limited to: the NMFS, USFWS, U.S. Coast Guard, Federal Energy Regulatory Commission, USACE, WDOE, and WDFW. The Navy will share field data and behavioral observations on all marine mammals that occur in the project area. Draft results of each monitoring effort will be provided to NMFS in summary reports within 60 days of the conclusion of monitoring. This information could be made available to regional, state, and federal resource agencies, scientists, professors, and other interested private parties upon written request to NMFS.

Additionally, the Navy provides a significant amount of funding and support for marine research. The Navy provided $26 million in Fiscal Year 2008 and $22 million in Fiscal Year 2009 to universities, research institutions, federal laboratories, private companies, and independent researchers around the world to study marine mammals. Over the past 5 years the Navy has funded over $100 million in marine mammal research, with several projects ongoing in Washington.

The Navy sponsors 70 percent of all U.S. research concerning the effects of human-generated sound on marine mammals and 50 percent of such research conducted worldwide. Major topics of Navy-supported research include the following:

- Gaining a better understanding of marine species distribution and important habitat areas,
- Developing methods to detect and monitor marine species before and during training,
- Understanding the effects of sound on marine mammals, and
- Developing tools to model and estimate potential effects of sound.

The Navy has sponsored several workshops to evaluate the current state of knowledge and potential for future acoustic monitoring of marine mammals. The workshops brought together acoustic experts and marine biologists from the Navy and other research organizations to present data and information on current acoustic monitoring research efforts and to evaluate the potential for incorporating similar technology and methods in Navy activities. The Navy supports research efforts on acoustic monitoring and will continue to investigate the feasibility of passive acoustics as a potential monitoring tool. Overall, the Navy will continue to research and contribute to university/external research to improve the state of the science regarding marine species biology and acoustic effects. These efforts include monitoring programs, data sharing with NMFS from research and development efforts, and future research as described previously.

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B.S. Mechanical Engineering, Washington State University
Years of Experience: 22

## Consultants

### Science Applications International Corporation (SAIC)

Bernice Tannenbaum, Marine Mammal Biologist
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M.S. Environmental Science, Oregon State University
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# 16 REFERENCES


Agness, A., and B.R. Tannenbaum. 2009. Naval Base Kitsap at Bangor marine mammal resource report. Prepared by Science Applications International Corporation, Bothell, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Allen. B.M., and R.P. Angliss. 2012. Alaska Marine Mammal Stock Assessments, 2011. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-234, 288 pp.

Allen, B.M., and R.P. Angliss. 2013. Alaska marine mammal stock assessments, 2012. NOAA Technical Memo NMFS-AFSC-245. U.S. Department of Commerce, NOAA/NMFS, Seattle, WA. March 2013. http://www.nmfs.noaa.gov/pr/sars/pdf/ak2012.pdf.

Angell, T., and K.C. Balcomb III. 1982. *Marine birds and mammals of Puget Sound*. University of Washington Press: Seattle, 145 pp.

Angliss, R.P., and R.B. Outlaw. 2005. Alaska Marine Mammal Stock Assessment, 2005. NOAA Technical Memorandum NMFS-AFSC-161.

ANSI. 1986. Methods for measurement of impulse noise (ANSI S12.7-1986). New York: Acoustical Society of America.

Antonelis, G.A., Jr., B.S. Stewart, and W.F. Perryman. 1990. Foraging characteristics of female northern fur seals (*Callorhinus ursinus*) and California sea lions (*Zalophus californianus*). *Canadian Journal of Zoology*. 68: 150–158.

Au, W.W.L., J.K.B. Ford, J.K. Horne, and K.A. Newman Allman. 2004. Echolocation signals of free ranging killer whales (*Orcinus orca*) and modeling of foraging for chinook salmon (*Oncorhynchus tshawytscha*). *The Journal of the Acoustical Society of America*. 115(2): 901–909.

Awbrey, F.T., J.C. Norris, A.B. Hubbard, and W.E. Evans. 1979. The bioacoustics of the Dall porpoise-driftnet interaction. Hubbs-Seaworld Research Institute Technical Report. 79-120: 1–41.

Bain, D.E., J.C. Smith, R. Williams, and D. Lusseau. 2006. Effects of vessels on behavior of southern resident killer whales (*Orcinus* spp.). NMFS Contract Report Nos. AB133F03SE0959 and AB133F04CN0040. Prepared by D. Bain (University of Washington Friday Harbor Labs, Friday Harbor, WA), J. Smith (Friday Harbor), R. Williams (Alert Bay, BC), and D. Lusseau (University of Aberdeen, UK).

Baird, R.W. 2001. Status of harbour seals, *Phoca vitulina*, in Canada. *Canadian Field-Naturalist*. 115(4): 663–675.

Baird, R.W., and L.M. Dill. 1995. Occurrence and behaviour of transient killer whales: Seasonal and pod-specific variability, foraging behaviour, and prey handling. *Canadian Journal of Zoology*. 73: 1300–1311.

Baird, R.W., and L.M. Dill. 1996. Ecological and social determinants of group size in transient killer whales. *Behavioral Ecology*. 7(4): 408–416.

Baird, R.W., and H. Whitehead. 2000. Social organization of mammal-eating killer whales: Group stability and dispersal patterns. *Canadian Journal of Zoology*. 78: 2096–2105.

Barlett, M.L., and G.R. Wilson. 2002. Characteristics of small boat signatures. *The Journal of the Acoustical Society of America.* 112(5): 2221.

Barlow, J. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington: 1. Ship surveys. *Fishery Bulletin.* 86(3): 417–432.

Barlow, J. 2010. Cetacean abundance in the California Current estimated from a 2008 ship-based line-transect survey. NOAA-TM-NMFS-SWFSC-456. National Marine Fisheries Service Southwest Fisheries Science Center, La Jolla, CA. March 2010. http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-456.pdf.

Barlow, J., and D. Hanan. 1995. An assessment of the status of harbor porpoise in central California. In *Report of the International Whaling Commission. Special Issue 16: Biology of the Phocoenids*. Bjørge, A. and G.P. Donovan. Cambridge: International Whaling Commission. 123−140.

Barrett-Lennard, L.G. 2000. Population structure and mating patterns of killer whales (*Orcinus orca*) as revealed by DNA analysis. Ph.D. Thesis, University of British Columbia, Vancouver, BC, Canada, 97 pp.

Barrett-Lennard, L., J. Ford, and K. Heise. 1996. The mixed blessing of echolocation: differences in sonar use by fish-eating and mammal-eating killer whales. *Animal Behaviour.* 51(3): 553−565.

Bejder, L., A.M.Y. Samuels, H.A.L. Whitehead, N. Gales, J. Mann, R. Connor, M. Heithaus, J. Watson-Capps, C. Flaherty, and M. Krutzen. 2006. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology.* 20(6): 1791−1798.

Bhuthimethee, M. 2008. Mary Bhuthimethee, Marine Scientist, Science Applications International Corporation, Bothell, WA. November 25, 2008. Personal communication with Bernice Tannenbaum, Wildlife Biologist, Science Applications International Corporation, Bothell, WA, re: Steller sea lions at NAVBASE Kitsap Bangor.

Bhuthimethee, M., C. Hunt, G. Ruggerone, J. Nuwer, and W. Hafner. 2009. NAVBASE Kitsap Bangor fish presence and habitat use, Phase III field survey report, 2007–2008. Prepared by Science Applications International Corporation, Bothell, WA, and Natural Resources Consultants, Inc. (Ruggerone), Seattle, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Bigg, M.A. 1981. Harbour seal *Phoca vitulina* Linnaeus, 1758 and *Phoca largha* Pallas, 1811. In *Handbook of marine mammals, Volume 2: Seals*, eds. Ridgway, S.H. and R. Harrison. San Diego: Academic Press. 1–27.

Bigg, M.A. 1985. Status of the Steller sea lion (*Eumetopias jubatus*) and California sea Lion (*Zalophus californianus*) in British Columbia. Vol. 77, *Canadian Special Publication of Fisheries and Aquatic Sciences*. Ottawa: Dept. of Fisheries and Oceans.

Bjørge, A., T. Bekkby, V. Bakkestuen, and E. Framstad. 2002. Interactions between harbor seals, *Phoca vitulina*, and fisheries in complex coastal waters explored by combined Geographic Information System (GIS) and energetics modeling. *ICES Journal of Marine Science*. 59: 29–42.

Black, N. A., A. Schulman-Janiger, R. L. Ternullo, and M. Guerrero-Ruiz. 1997. Killer whales of California and western Mexico: a catalog of photo-identified individuals. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-SWFSC-247, 174 pp.

Black, N. 2011. *Fish-eating (resident) killer whales sighted in Monterey Bay on February 10, 2011*. Monterey Bay Whale Watch. (Accessed February 22, 2011). http://www.montereybaywhalewatch.com/Features/PugetSoundKillerWhales1102.htm.

Blackwell, S.B., and C.R. Greene Jr. 2002. Acoustic measurements in Cook Inlet, Alaska, during August 2001. Greeneridge Report 271-2. Report from Greeneridge Sciences, Inc., Santa Barbara for National Marine Fisheries Service, Anchorage, AK. 43 pp.

Blackwell, S.B., J.W. Lawson, and M.T. Williams. 2004. Tolerance by ringed seals (*Phoca hispida*) to impact pipe-driving and construction sounds at an oil production island. *The Journal of the Acoustical Society of America*. 115(5): 2346–2357.

Boggs, S., Jr. 1995. Principles in Sedimentology and Stratigraphy, Second Edition. Prentice-Hall, Inc., Upper Saddle River, NJ.

Bonnell, M.L., M.O. Pierson, and G.D. Farrens. 1983. Pinnipeds and sea otters of central and northern California, 1980–1983: Status, abundance, and distribution. Volume III, Book 1. OCS Study MMS 84-0044. Los Angeles, CA: Minerals Management Service.

Boveng, P. 1988. Status of the Pacific harbor seal population on the U.S. west coast. Admin. Rep. LJ-88-06. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. 43 pp.

Bowen, W.D., and D.B. Siniff. 1999. Distribution, population biology, and feeding ecology of marine mammals. In *Biology of marine mammals*, ed. Reynolds, J.E. and S.A. Rommel. Washington: Smithsonian Institution Press. 423–484.

Bowen, W.D., D.J. Boness, and S.J. Iverson. 1999. Diving behaviour of lactating harbour seals and their pups during maternal foraging trips. *Canadian Journal of Zoology*. 77: 978–988.

Bredesen, E.L., A.P. Coombs, and A.W. Trites. 2006. Relationship between Steller sea lion diets and fish distributions in the eastern North Pacific. In *Sea Lions of the World*: Alaska Sea Grant College Program. 131–139.

Brown, R. F. 1988. Assessment of pinniped populations in Oregon. Processed Report 88-05, National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Seattle, WA.

Calambokidis, J. 2010. John Calambokidis, senior marine mammal biologist and co-founder of Cascadia Research, Olympia, WA. September 15, 2010. Personal communication with Chris Hunt, Marine Scientist, Science Applications International Corporation, Bothell, WA, re: the rare occurrence of large whales (e.g., gray/humpback whales) occurring south of the Hood Canal Bridge since its construction.

Calambokidis, J. 2012. John Calambokidis, senior marine mammal biologist and co-founder of Cascadia Research, Olympia, WA. February 16, 2012. Personal communication with Sharon Rainsberry, Fish Biologist, Naval Facilities Engineering Command, U.S. Navy, Bangor, WA, re: Information and number of humpback whales present in Hood Canal from January/February 2012 sightings and other documented sightings of humpback whales in Hood Canal.

Calambokidis, J. 2013. John Calambokidis, senior marine mammal biologist and co-founder of Cascadia Research, Olympia, WA. Series of emails, February 15–22, 2013. Personal communication with Andrea Balla-Holden, NAVFAC Northwest, re: gray whale occurrences in Hood Canal.

Calambokidis, J., E.A. Falcone, A. Douglas, L. Schlender, and J. Huggins. 2009. Photographic identification of humpback and blue whales off the U.S. West Coast: results and updated abundance estimates from 2008 field season. Final Report for Contract AB133F08SE2786 from Southwest Fisheries Science Center. 18 pp.

Calambokidis, J., E.A. Falcone, T.J. Quinn, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urban, D. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Flynn, A. Havron, J. Huggins, and N. Maloney. 2008. SPLASH: Structure of populations, levels of abundance and status of Humpback Whales in the North Pacific. Final report for Contract AB133F-03-RP-00078. 58 pp. Available from Cascadia Research (www.cascadiaresearch.org) and NMFS, Southwest Fisheries Science Center (http://swfsc.noaa.gov).

Calambokidis, J., J.R. Evenson, J.C. Cubbage, P.J. Gearin, and S.D. Osmek. 1992. *Harbor porpoise distribution and abundance off Oregon and Washington from aerial surveys in 1991*. Cascadia Research Collective, Olympia, WA, and National Marine Mammal Laboratory Alaska Fisheries Center National Marine Fisheries Service, Seattle, WA. Retrieved from website: http://www.cascadiaresearch.org/reports/Calambokidis Pp Dist Abund WA Aerial 1991.pdf.

Calambokidis, J., J.C. Cubbage, J.R. Evenson, S.D. Osmek, J.L. Laake, P.J. Gearin, B.J. Turnock, S.J. Jeffries, and R.F. Brown. 1993. Abundance estimates of harbor porpoise in Washington and Oregon waters. Final Report by Cascadia Research, Olympia, WA, to National Marine Mammal Laboratory, AFSC, NMFS, Seattle, WA. 55 pp.

Calambokidis, J., J.D. Darling., V. Deeck, P. Gearnin, M. Gosho, W. Megill, C.M. Tomback, D. Goley, C. Toropova, and B. Gisborne. 2002. Abundance, range and movements of a feeding aggregation of gray whales (*Eschrichtius robustus*) from California to southeastern Alaska in 1998. *Journal of Cetacean Research and Management*. 4(3): 267–276.

Calambokidis, J., S.M. Speich, J. Peard, G.H. Steiger, J.C. Cubbage, D.M. Fry, and L.J. Lowenstine. 1985. Biology of Puget Sound marine mammals and marine birds: population health and evidence of pollution effects. NOAA Technical Memorandum NOS OMA 18. NOAA National Ocean Service, Rockville, MD.

Calambokidis, J., S. Osmek, and J.L. Laake. 1997. Aerial surveys for marine mammals in Washington and British Columbia inside waters. Final Contract Report for Contract 52ABNF-6-00092, available from Cascadia Research Collective, Olympia, WA.

CALTRANS. 2001. Marine Mammal Impact Assessment for the San Francisco-Oakland Bay Bridge Pile Installation Demonstration Project. PIDP EA 012081.

CALTRANS. 2006. Marine mammals and acoustic monitoring for the marine foundations at piers E2 and T1. January–September 2006. San Francisco - Oakland Bay Bridge East Span Seismic Safety Project. Contract No. 04-SF-80 KP 12.2/KP 14.3, 04-ALA-80 KP 0.0/KP 2.1. Prepared by SRS Technologies and Illingworth and Rodkin, Inc. Prepared for California Department of Transportation.

CALTRANS. 2009. Technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on fish. California Department of Transportation. February 2009. Section 4.4.2.1, “Air Bubble Curtains.”

CALTRANS. 2010. Marine mammal monitoring for the self-anchored suspension temporary towers, June 2008–May 2009. Prepared by Prepared by Phil Thorson, Mantech SRS Technologies. Prepared for CALTRANS District 4, Sacramento, CA.

Campbell, G.S., R.C. Gisiner, D.A. Helweg, and L.L. Milette. 2002. Acoustic identification of female Steller sea lions (*Eumetopias jubatus*). *The Journal of the Acoustical Society of America*. 111 (6): 2920–2928.

Carlson, T.J., D.A. Woodruff, G.E. Johnson, N.P. Kohn, G.R. Plosky, M.A. Weiland, J.A. Southard, and S.L. Southard. 2005. Hydroacoustic measurements during pile driving at the Hood Canal Bridge, September through November 2004. Battelle Marine Sciences Laboratory, Sequim, WA.

Carretta, J.V., B.L. Taylor, and S.J. Chivers. 2001. Abundance and depth distribution of harbor porpoise (*Phocoena phocoena*) in northern California determined from a 1995 ship survey. *Fishery Bulletin.* 99(1): 29–39.

Carretta, J.V., K.A. Forney, M.M. Muto, J. Barlow, J. Baker, B. Hanson, and M.S. Lowry. 2007. U.S. Pacific marine mammal stock assessments: 2006. NOAA TM NMFS-SWFSC-398. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA.

Carretta, J.V., K.A. Forney, E. Oleson, K. Martien, M.M. Muto, M.S. Lowry, J. Barlow, J. Baker, B. Hanson, D. Lynch, L. Carswell, R.L.J. Brownell, Jr., J. Robbins, D.K. Mattila, K. Ralls, and M.C Hill. 2012. U.S. Pacific Marine Mammal Stock Assessments: 2011. NOAA-TM_NMFS-SWFSC-488. U.S. Department of Commerce.

Carretta, J.V., E. Oleson, D.W. Weller, A.R. Lang, K.A. Forney, J. Baker, B. Hanson, K. Martien, M.M. Muto, M.S. Lowry, J. Barlow, D. Lynch, L. Carswell, R.L.J. Brownell, Jr., D.K. Mattila, and M.C. Hill. 2013. U.S. Pacific Marine Mammal Stock Assessments: 2012. NOAA Technical Memorandum NMFS-SWFSC-504. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. January 2013. http://www.nmfs.noaa.gov/pr/sars/pdf/po2012.pdf.

Carretta, J.V., E. Oleson, D.W. Weller, A.R. Lang, K.A. Forney, J. Baker, B. Hanson, K. Martien, M.M. Muto, T. Orr, H. Huber, M.S. Lowry, J. Barlow, D. Lynch, L. Carswell, R.L. Brownell, Jr., and D.K. Mattila. 2013. U.S. Pacific Marine Mammal Stock Assessments (draft): 2013. NOAA Technical Memorandum NMFS-SWFSC-XXX. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. January 2013. http://www.nmfs.noaa.gov/pr/sars/pdf/po2013_draft.pdf.

CERC (Coastal Engineering Research Center). 1984. *Shore Protection Manual*, Fourth ed., U.S. Army Corps of Engineers, Washington, D.C.

Chivers, S.J., A.E. Dizon, P.J. Gearin, and K.M. Robertson. 2002. Small-scale population structure of eastern North Pacific harbour porpoises (*Phocoena phocoena*) indicated by molecular genetic analyses. *Journal of Cetacean Research and Management*. 4(2): 111−122.

COSEWIC. 2003. COSEWIC assessment and update status report on the Steller sea lion *Eumetopias jubatus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

Costa, D.P. 2007. A conceptual model of the variation in parental attendance in response to environmental fluctuation: foraging energetic of lactating sea lions and fur seals. *Aquatic Conservation: Marine and Freshwater Ecosystems.* 17 (S1): S44–S52.

Dahlheim, M.E., D.K. Ellifrit, and J.D. Swenson. 1997. *Killer whales of southeast Alaska: a catalogue of photo-identified individuals, 1997*. Seattle, WA: National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA.

Department of Fisheries and Oceans (DFO) Canada. 2009. Recovery potential assessment for West Coast Transient killer whales. DFO Canadian Science Advisory Secretariat Science Advisory Report 2009/039.

Everitt, R.D., P.J. Gearin, J.S. Skidmore, and R.L. DeLong. 1981. Prey items of harbor seals and California sea lions in Puget Sound, Washington. *Murrelet*. 62(3): 83−86.

Falcone, E., J. Calambokidis, G. Steiger, M. Malleson, and J. Ford. 2005. Humpback whales in the Puget Sound/Georgia Strait Region. Proceedings of the 2005 Puget Sound Georgia Basin Research Conference.

Feist, B.E. 1991. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. M.S. thesis, University of Washington, Seattle, WA.

Feist, B.E., J.J. Anderson, and R. Miyamoto. 1992. *Potential impacts of pile driving on juvenile pink (Oncorhynchus gorbuscha) and chum (O. keta) salmon behavior and distribution*. Seattle, WA: Fisheries Research Institute, School of Fisheries, and Applied Physics Laboratory, University of Washington.

Felleman, F.L., J.R. Heimlich-Boran, and R.W. Osborne. 1991. The feeding ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. In *Dolphin societies: Discoveries and puzzles*, eds. Pryor, K. and K.S. Norris. Berkeley: University of California Press. 113−147.

Ferrero, R.C. and C.W. Fowler. 1992. Survey designs for assessment of Harbor Porpoise and Harbor Seal populations in Oregon, Washington, and Alaska. AFSC Processed Report 92-03. National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA.

Ferrero, R.C. and W.A. Walker. 1999. Age, growth, and reproductive patterns of Dall's porpoise (*Phocoenoides dalli*) in the central North Pacific Ocean. *Marine Mammal Science*. 15: 273–313.

Finneran, J.J., R. Dear, D.A. Carder, and S.H. Ridgway. 2003. Auditory and behavioral responses of California sea lions (*Zalophus californianus*) to single underwater impulses from an arc-gap transducer. *The Journal of the Acoustical Society of America.* 114(3): 1667–1677.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and S.H. Ridgway, 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. *The Journal of the Acoustical Society of America*. 118: 2696–2705.

Finneran, J.J, C.E. Schlundt, B. Branstetter, and R.L. Dear. 2007. Assessing temporary threshold shift in a bottlenose dolphin (*Tursiops truncatus*) using multiple simultaneous auditory evoked potentials. *The Journal of the Acoustical Society of America*. 122: 1249–1264.

Fisheries Hydroacoustic Working Group. 2008. Memorandum of agreement in principle for interim criteria for injury to fish from pile driving. California Department of Transportation (CALTRANS) in coordination with the Federal Highway Administration (FHWA). http://www.wsdot.wa.gov/NR/rdonlyres/4019ED62-B403-489C-AF05-5F4713D663C9/0/InterimCriteriaAgreement.pdf.

Foote, A.D., R.W. Osborne, and A.R. Hoelzel. 2004. Environment: whale-call response to masking boat noise. *Nature.* 428(6986): 910.

Ford, J.K. 1987. A catalogue of underwater calls produced by killer whales (*Orcinus orca*) in British Columbia. *Canadian Data Report of Fisheries and Aquatic Sciences*, No. 633. 1–165.

Ford, J.K. 1991. Vocal traditions among resident killer whales (*Orcinus orca*) in coastal waters of British Columbia. *Canadian Journal of Zoology.* 69(6): 1454–1483.

Ford, J.K.B. and G. M. Ellis. 1999. Transients: Mammal-Hunting Killer Whales of British Columbia, Washington, and Southeastern Alaska. University of British Columbia Press, Vancouver, BC. 96 pp.

Ford, J.K.B., G.M. Ellis, and K.C. Balcomb. 2000. *Killer whales: the natural history and genealogy of* Orcinus orca *in British Columbia and Washington State.* 2nd ed. Vancouver: UBC Press.

Ford, J.K.B., G.M. Ellis, L.G. Barrett-Lennard, A.B. Morton, R.S. Palm, and K.C. Balcomb III. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. *Canadian Journal of Zoology.* 76: 1456–1471.

Ford, J.K.B., G.M. Ellis, and P.F. Olesiuk. 2005. Linking prey and population dynamics: Did food limitation cause recent declines of 'resident' killer whales (*Orcinus orca*) in British Columbia? Canadian Science Advisory Secretariat Research document 2005/042. Department of Fisheries and Oceans.

Ford, J.K., G.M. Ellis, P.F. Olesiuk, and K.C. Balcomb. 2010. Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? *Biology Letters*. 6(1): 139–142.

Forney, K.A. 1997. Patterns of variability and environmental models of relative abundance for California cetaceans. Ph.D. dissertation, Scripps Institution of Oceanography, University of California, San Diego.

Forney, K.A. 2007. Preliminary estimates of cetacean abundance along the U.S. west coast and within four National Marine Sanctuaries during 2005. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-406. 27 p.

Forney, K.A., and J. Barlow. 1998. Seasonal patterns in the abundance and distribution of California cetaceans, 1991-1992. *Marine Mammal Science*. 14(3): 460–489.

Frasier, T.R., S.M. Koroscil, B.N. White, and J.D. 2011. Assessment of population substructure in relation to summer feeding ground use in the eastern North Pacific gray whale. *Endangered Species Research*.14: 39–48.

Gaskin, D.E., S. Yamamoto, and A. Kawamura. 1993. Harbor Porpoise, *Phocoena phocoena* (L.), in the coastal waters of northern Japan. *Fishery Bulletin*. 91(3): 440-454.

Gearin, P., S.R. Melin, R.L. DeLong, H. Kajimura, and M.A. Johnson. 1994. Harbor porpoise interactions with a Chinook salmon net fishery in Washington State. In *Gillnets and Cetaceans*. W.F. Perrin, G.P. Donovan, and J. Barlow (eds.). *Report of the International Whaling Commission*. Special Issue 15. 427–438.

Gilbert, J.R., and N. Guldager. 1998. Status of harbor and gray seal populations in northern New England. Woods Hole, MA: National Marine Fisheries Service.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift, and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal*. 37: 16–34.

Green, G.A., J.J. Brueggeman, R.A. Grotefendt, C.E. Bowlby, M.L. Bonnell, and K.C. Balcomb III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989–1990. In *Oregon and Washington marine mammal and seabird surveys*. Ed. J.J. Brueggeman. 1-1–1-100. OCS Study MMS 91-0093. Los Angeles, California: Minerals Management Service.

Guénette, S., S.J.J. Heymans, V. Christensen, and A.W. Trites. 2006. Ecosystem models show combined effects of fishing, predation, competition, and ocean productivity on Steller sea lions (*Eumetopias jubatus*) in Alaska. *Canadian Journal of Fishes and Aquatic Sciences*. 63: 2495–2517.

Gulland, F.M.D., H. Pérez-Cortés, J. Urgan, R.L. Rojas-Bracho, and G. Ylitalo. 2005. Eastern North Pacific gray whale (*Eschrichtius robustus*) unusual mortality event, 1999–2000. NOAA Technical Memorandum, NMFS-AFSC-150. National Oceanic and Atmospheric

Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA.

Hafner, W., and B. Dolan. 2009. Naval Base Kitsap at Bangor Water Quality. Phase I survey report for 2007–2008. Prepared by Science Applications International Corporation, Bothell, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Hammermeister, T., and W. Hafner. 2009. Naval Base Kitsap sediment quality investigation: data report. Prepared by Science Applications International Corporation, Bothell, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Hanggi, E.B., and R.J. Schusterman. 1994. Underwater acoustic displays and individual variation in male harbour seals, *Phoca vitulina*. *Animal Behaviour*. 48: 1275−1283.

Hansen, M., M. Wahlberg, and P.T. Madsen. 2008. Low-frequency components in harbor porpoise (*Phocoena phocoena*) clicks: communication signal, by-products, or artifacts? *The Journal of the Acoustical Society of America.* 124(6): 4059−4068.

Hanson, B., R.W. Baird, J.K.B. Ford, J. Hempelmann-Halos, D.M. Van Doonik, J.R. Candy, C.K. Emmons, G.S. Schorr, B. Gisborne, K.L. Ayres, S.K. Wasser, K.C. Balcomb, K. Balcomb-Bartok, J.G. Sneva, and M.J. Ford. 2010. Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range. *Endangered Species Research.* 11: 69−82.

Harris. C.M. 1998. Handbook of acoustical measurements and noise control (3rd Edition). Huntington, NY: Acoustical Society of America.

Hart Crowser. 2013. Naval Base Kitsap-Bangor Explosives Handling Wharf 2: Year 1 Marine Mammal Monitoring Report (2012–2013), Bangor, Washington. Prepared by Hart Crowser. Prepared for NAVFAC, Silverdale, WA. April 2013.

Hastings, M.C., and A.N. Popper. 2005. Effects of Sound on Fish. Report prepared by Jones & Stokes for California Department of Transportation, Contract No. 43A0139, Task Order 1.

HDR Inc. 2012. Naval Base Kitsap at Bangor Test Pile Program, Bangor, Washington. Final Marine Mammal Monitoring Report. Prepared for Naval Facilities Engineering Northwest, Silverdale, WA. April 2012.

HDR. 2013. Naval Base Kitsap-Bangor Explosives Handling Wharf 2 Year 1 Marine Mammal Monitoring Report (2012-2013), Bangor, Washington. Prepared by HDR. Prepared for Naval Facilities Engineering Command, Silverdale, WA. April 2013.

Heath, C. B. 2002. California, Galapagos, and Japanese sea lions– *Zalophus californianus, Z. wollebaeki, and Z. japonicus.* In *Encyclopedia of Marine Mammals*, eds. Perrin, W.F., B. Würsig, and J.G.M. Thewissen. New York: Academic Press. 180−186.

Heimlich-Boran, J.R. 1988. Behavioral ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. *Canadian Journal of Zoology*. 66: 565−578.

Hemilä, S., S. Nummela, A. Berta, and T. Reuter. 2006. High-frequency hearing in phocid and otariid pinnipeds: An interpretation based on inertial and cochlear constraints (L). *Journal of the Acoustical Society of America*. 120(6): 3463−3466.

Hildebrand, J. 2004. Sources of anthropogenic sound in the marine environment. Marine Mammal Commission. http://www.mmc.gov/sound/internationalwrkshp/pdf/hildebrand.pdf.

Hoelzel, A.R., M.E. Dahlheim, and S.J. Stern. 1998. Low genetic variation among killer whales (*Orcinus orca*) in the Eastern North Pacific, and genetic differentiation between foraging specialists. *Journal of Heredity*. 89: 121–128.

Hoelzel, A.R., J. Hey, M.E. Dahlheim, C. Nicholson, V. Burkanov, and N. Black. 2007. Evolution of Population Structure in a Highly Social Top Predator, the Killer Whale. *Molecular Biology and Evolution.* 24(6): 1407–1415.

Hoelzel, A.R., A. Natoli, M.E. Dahlheim, C. Olavarria, R.W. Baird, and N.A. Black. 2002. Low worldwide genetic diversity in the killer whale (*Orcinus orca*): implications for demographic history. *Proceedings. Biological Sciences / The Royal Society.* 269(1499): 1467–1473.

Holt, M. 2008. Sound exposure and southern resident killer whales (*Orcinus orca*): A review of current knowledge and data gaps. NOAA Technical Memorandum NMFS-NWFSC-89.

Houck W.J., and T.A. Jefferson. 1999. Dall's porpoise - *Phocoenoides dalli* (True, 1885). In *Handbook of Marine Mammals, Volume 6: The Second Book of Dolphins and Porpoises*, eds. Ridgway, S.H. and S.R. Harrison. San Diego, CA: Academic Press. 443–472.

Houghton, J. 2012. Personal communication. Juliana Houghton, M.Sc. student, University of Washington, email to Sharon Rainsberry, NAVFAC NW fish biologist. July 26, 2012.

Houghton, J., R.W. Baird, C.K. Emmons, and M.B. Hanson. In progress. Predator occurrence changes as prey abundance increases: studies of mammal-eating killer whales in southern British Columbia and Washington state from 1987–2010.

Huber, H. R., S. J. Jeffries, R. F. Brown, R. L. DeLong, and G. VanBlaricom. 2001. Correcting aerial survey counts of harbor seals (*Phoca vitulina richardsi*) in Washington and Oregon. *Marine Mammal Science*. 17(2): 276–293.

Huber, H.R., B.R. Dickerson, S.J. Jeffries, and D.M. Lambourn. 2012. Genetic analysis of Washington State harbor seals (*Phoca vitulina richardii*) using microsatellites. *Canadian Journal of Zoology*. 90(12): 1361–1369. DOI: 10.1139/cjz-2012-0047.

Huber, H.R., S.J. Jeffries, D.M. Lambourn, and B.R. Dickerson. 2010. Population substructure of harbor seals (*Phoca vitulina richardsi*) in Washington State using mtDNA. *Canadian Journal of Zoology*. 88: 280–288.

ICF Jones and Stokes and Illingworth and Rodkin. 2009. Technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on fish. Prepared by ICF Jones and Stokes, Sacramento, CA, and Illingworth and Rodkin, Inc., Petaluma, CA. Prepared for California Department of Transportation, Sacramento, CA. February 2009.

Illingworth and Rodkin. 2001. Final data report: Noise and vibration measurements associated with the Pile Installation Demonstration Project for the San Francisco-Oakland Bay Bridge East Span. Submitted to the State of California, Department of Transportation, District 4, Toll Bridge Program, August 2001.

Illingworth and Rodkin. 2007. Compendium of Pile Driving Sound Data. Report. Prepared for the California Department of Transportation. September 27, 2007.

Illingworth and Rodkin. 2012a. Naval Base Kitsap at Bangor Test Pile Program. Acoustic Monitoring Report. Bangor, WA.

Illingworth and Rodkin. 2012b. Compendium of Pile Driving Sound Data. Report. Prepared for the California Department of Transportation. Updated October 2012.

Illingworth and Rodkin. 2013. Naval Base Kitsap at Bangor Trident Support Facilities Explosives Handling Wharf (EHW-2) Project. Acoustic Monitoring Report. Bangor, WA. Prepared for Naval Base Kitsap at Bangor, WA. May 15, 2013.

Integrated Concepts & Research Corporation. 2009. Marine mammal monitoring final report, 15 July 2008 through 14 July 2009. Construction and Scientific Marine Mammal Monitoring associated with the Port of Anchorage Marine Terminal Redevelopment Project. Prepared by, ICRC, Anchorage, AK. Prepared for the U.S. Department of Transportation Maritime Administration and the Port of Anchorage, Anchorage, AK. http://www.nmfs.noaa.gov/pr/pdfs/permits/poa_monitoring_report.pdf.

JASCO Research Ltd. 2005. Sound pressure and particle velocity measurements from marine pile driving at Eagle Harbor maintenance facility, Bainbridge Island WA. Prepared by JASCO Research Ltd., Victoria, BC. Prepared for Washington State Department of Transportation, Olympia, WA. http://www.wsdot.wa.gov/NR/rdonlyres/1F219171-FB7D-4754-AE7B-C23D7EAA28F0/0/EagleHarborMaintFacRpt.pdf.

Jefferson, T.A., S. Leatherwood, and M.A. Webber. 1993. FAO species identification guide. Marine mammals of the world. Rome, Italy: Food and Agriculture Organization of the United Nations.

Jeffries, S.J. 1985. Occurrence and distribution patterns of marine mammals in the Columbia River and adjacent coastal waters of northern Oregon and Washington. In *Marine Mammals and Adjacent Waters, 1980–1982*. Processed Report 85-04, National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Seattle, WA.

Jeffries, S. 2006. Steve Jeffries, Marine Mammal Specialist, Washington Department of Fish and Wildlife. December 14, 2006. Personal communication with Alison Agness, Science Applications International Corporation, re: occurrence of marine mammals in Hood Canal.

Jeffries, S. 2007. Steve Jeffries, Marine Mammal Specialist, Washington Department of Fish and Wildlife. June 25, 2007. Personal communication with Pamela Gunther, Senior Environmental Scientist, Science Applications International Corporation, Bothell, WA, re: California sea lions in the Pacific Northwest.

Jeffries, S.J., P.J. Gearin, H.R. Huber, D.L. Saul, and D.A. Pruett. 2000. Atlas of seal and sea lion haul-out sites in Washington. Washington State Department of Fish and Wildlife, Wildlife Science Division, Olympia, WA. 150 pp. http://wdfw.wa.gov/wlm/research/papers/seal_haulout/.

Jeffries, S., H. Huber, J. Calambokidis, and J. Laake. 2003. Trends and status of harbor seals in Washington State: 1978-1999. *The Journal of Wildlife Management*. 67(1): 208–219.

Kastak, D., and R.J. Schusterman. 1998. Low-frequency amphibious hearing in pinnipeds: methods, measurements, noise, and ecology. *The Journal Acoustical Society of America.* 103(4): 2216–2228.

Kastak, D., R.J. Schusterman, B.L. Southall and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. *The Journal of the Acoustic Society of America.* 106(2): 1142–1148.

Kastelein, R.A., P. Bunskoek, M. Hagedoorn, W.W.L. Au, and D. de Haan. 2002. Audiogram of a harbor porpoise (*Phocoena phocoena*) measured with narrow-band frequency-modulated signals. *The Journal of the Acoustical Society of America*. 112(1): 334–344.

Kastelein, R.A., R. van Schie, W.C. Verboom, and D. de Haan. 2005. Underwater hearing sensitivity of a male and a female Steller sea lion (*Eumetopias jubatus*). *The Journal of the Acoustical Society of America*. 118(3): 1820–1829.

Kastelein, R.A., W.C. Verboom, and J.M. Terhune. 2009. Underwater detection of tonal signals between 0.125 and 100 kHz by harbor seals (*Phoca vitulina*). *Journal of the Acoustical Society of America*. 125: 1222–1229.

Keple, A.R. 2002. Seasonal abundance and distribution of marine mammals in the southern Strait of Georgia, British Columbia. Master's thesis, University of British Columbia.

Ketten, D.R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. In *Sensory Systems of Aquatic Mammals*, eds. Kastelein, R.A., J.A. Thomas, and P.E. Nachtigall. The Netherlands: De Spil Publishers. 391–407.

Ketten, D.R. 1998. Marine mammal auditory systems: A summary of audiometric and anatomical data and its implications for underwater acoustic impacts. NOAA Technical Memorandum NMFS. NOAA-TM-NMFS-SWFSC-256.

Ketten, D.R. 2000. Cetacean ears. In *Hearing by Whales and Dolphins*, eds. Au, W.W.L., A.N. Popper, and R.R. Fay. New York: Springer-Verlag. 43–108.

Ketten, D.R. 2004. Marine mammal auditory systems: a summary of audiometric and anatomical data and implications for underwater acoustic impacts. *Polarforschung*. 72(2/3): 79–92.

Krahn, M.M., M.J. Ford, W.F. Perrin, P.R. Wade, R.P. Angliss, M.B. Hanson, B.L. Taylor, G.M. Ylitalo, M.E. Dahlheim, J.E. Stein, and R.S. Waples. 2002. Status review of Southern Resident killer whales *(Orcinus orca)* under the Endangered Species Act. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-54. 133 pp.

Krahn, M.M., M.J. Ford, W.F. Perrin, P.R. Wade, R.P. Angliss, M.B. Hanson, B.L. Taylor, G.M. Ylitalo, M.E. Dahlheim, J.E. Stein, and R.S. Waples. 2004. 2004 Status review of Southern Resident killer whales (*Orcinus orca*) under the Endangered Species Act. NOAA Technical Memo. NMFS-NWFSC-62. U.S. Department of Commerce. 73 pp.

Kriete, B. 2002. Bioenergetic changes from 1986 to 2001 in the southern resident killer whale population, *Orcinus orca*. Orca Relief Citizen's Alliance, Friday Harbor, WA.

Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B.C. In *Dolphin societies: Discoveries and puzzles*, eds. Pryor, K. and K.S. Norris. Los Angeles, CA: University of California Press. 149–159.

Laake, J. L., J. Calambokidis, S.D. Osmek, and D.J. Rugh. 1997. Probability of detecting harbor porpoise from aerial surveys: estimating g(0). *The Journal of Wildlife Management*. 61(1): 63–75.

Lance, M.M., and S. Jeffries. 2006. Estimating importance of rockfish, lingcod and other bottomfish in the diet of harbor seals in the San Juan Islands. Prepared by Washington Department of Fish and Wildlife, Olympia, WA. Prepared for U.C. Davis Wildlife Health Center, SeaDoc Society.

Lance, M.M., and S. Jeffries. 2007. Temporal and spatial variability of harbor seal diet in the San Juan Island archipelago. Prepared by Washington Department of Fish and Wildlife, Olympia, WA. Prepared for U.C. Davis Wildlife Health Center, SeaDoc Society.

Lang, A.R., B.L. Taylor, J. Calambokidis, V.L. Pease, A. Klimik, J. Scordino, K.M. Robertson, D. Litovka, V. Burkanov, P. Gearin, J.C. George, and B. Mate. 2011. Assessment of stock structure among gray whales utilizing feeding grounds in the Eastern North Pacific. Paper SC/M11/AWMP4 presented to the International Whaling Commission, Scientific Committee (AWMP Workshop, La Jolla, CA, March–April 2011). 22 pp.

Laughlin, J. 2005a. Effects of Pile Driving on Fish and Wildlife. Washington State Department of Transportation. Presentation to the Summer Meeting/Conference of the Transportation Research Board ADC40 (A1F04) Noise & Vibration Committee. Seattle, WA. July 20.

Laughlin, J. 2005b. Underwater Sound Levels Associated with Restoration of the Friday Harbor Ferry Terminal. Washington State Department of Transportation, Office of Air Quality and Noise, Seattle, WA.

Laughlin, J. 2010a. Vashon Ferry Terminal Test Pile Project– vibratory pile monitoring technical memorandum. Technical memorandum. Washington State Department of Transportation. Prepared by Jim Laughlin for John Callahan and Rick Huey. May 4, 2010. http://www.wsdot.wa.gov/NR/rdonlyres/5868F03F-E634-4695-97D8-B7F08C0A315B/0/VashonVibratoryPileReport.pdf.

Laughlin, J. 2010b. Keystone Ferry Terminal – vibratory pile monitoring technical memorandum. Washington State Department of Transportation. To John Callahan and Rick Huey. May 4, 2010. http://www.wsdot.wa.gov/NR/rdonlyres/B42B02E3-713A-44E1-A4A6-B9DDD0C9D28A/0/KeystoneVibratoryPileReport.pdf.

Laughlin, J. 2012. Compendium of background sound levels for ferry terminals in Puget Sound. WSF Underwater Background Monitoring Project. Washington State Department of Transportation. Seattle, WA. http://dot.wa.gov/NR/rdonlyres/7CD4A4B6-99CF-4670-BD88-E82F96F4627B/0/ComprehensiveWSFbkgrdSndLevel.pdf.

Le Boeuf, B.J. 2002. Status of pinnipeds on Santa Catalina Island. *Proceedings of the California Academy of Sciences*. 53(2): 11–21.

Lockheed Martin. 2010. Facility Design Criteria for P-990 Explosives Handling Wharf Number 2 (Covered) at Strategic Weapons Facility Pacific, Bangor, Washington. Contract N00030-06-C-0100. Initial Release 4 December 2009, Revision A 19 July 2010. DoD UCNI.

London, J.M. 2006. "Harbor Seals in Hood Canal: Predators and Prey." Ph.D. dissertation, University of Washington. Available from: http://www.marinemammal.org.

London, J.M., M.M. Lance, and S. Jeffries. 2002. Observations of harbor seal predation on Hood Canal salmonids from 1998 to 2000. Prepared by Washington Cooperative Fish and Wildlife Research Unit, University of Washington, School of Aquatic and Fisheries Sciences, Seattle, WA, and Washington State Department of Fish and Wildlife, Marine Mammal Investigations, Tacoma, WA. Prepared for Washington State Department of Fish and Wildlife, Olympia, WA http://wdfw.wa.gov/wlm/research/papers/harbor_seals/sealpredation.htm.

Longmuir, C., and T. Lively. 2001. Bubble curtain systems help protect the marine environment. *Pile Driver Magazine* (A publication of the Pile Driving Contractors Association). Summer 2001: 11-13, 16. http://www.piledrivers.org/files/uploads/D325D9C4-A533-4832-942A-DFD5B78EB325.pdf.

Loughlin, T. R. 1997. Using the phylogeographic method to identify Steller sea lion stocks. Pages 329–341 in *Molecular Genetics of Marine Mammals*, incorporating the proceedings of a workshop on the analysis of genetic data to address problems of stock identity as related to management of marine mammals, eds. Dizon, A.E., S.J. Chivers, and W.F. Perrin. *Society for Marine Mammalogy*, Spec. Rep. No. 3.

Loughlin, T.R. 2002. Steller's sea lion, *Eumetopias jubatus*. Pages 1181−1185 in *Encyclopedia of Marine Mammals*, eds. Perrin, W.F., B. Würsig, and J.G.M. Thewissen. San Diego, CA: Academic Press.

Loughlin, T.R., M.A. Perez, and R.L. Merrick. 1987. *Eumetopias jubatus*. *Mammalian Species*. 283: 1−7.

Lowry, M.S., B.S. Stewart, C.B. Heath, P.K. Yochem, and J.M. Francis. 1991. Seasonal and annual variability in the diet of California sea lions *Zalophus californianus* at San Nicolas Island, California, 1981−86. *Fishery Bulletin*. 89: 331−336.

Luxa, K. 2008. Food habits of harbor seals (*Phoca vitulina*) in two estuaries in northern Puget Sound, Washington. Master of Science, Western Washington University, Bellingham, WA.

Malme, C.I., P.R. Miles, C.W. Clark, P.L. Tyack, and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior. Phase II, January 1984 migration. Prepared by Bolt, Beranek, and Newman, Cambridge, MA. Prepared for United States Minerals Management Service, Alaska, OCS Office, Anchorage, AK.

Malme, C.I., B. Wursig, J.E. Bird, and P.L. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. In *Port and Ocean Engineering Under Arctic Conditions, Vol. II*, eds. Sackinger, W.M., M.O. Jefferies, J.L. Imm, and S.D. Treacy. Fairbanks, AK: University of Alaska. 55−73.

Maniscalco, J.M., K. Wynne, K.W. Pitcher, M.B. Hanson, S.R. Melin, and S. Atkinson. 2004. The occurrence of California sea lions (*Zalophus californianus*) in Alaska. *Aquatic Mammals*. 30(3): 427–433.

Mate, B.R. 1975. Annual migrations of the sea lions Eumetopias jubatus and Zalophus californianus along the Oregon coast. *Rapports et Proces-Verbaux des Reunions Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranee Monaco*. 169: 455–461.

Mate, B.R., B. Lagerquist, and L. Irvine. 2010. Feeding habitats, migration, and winter reproductive range movements derived from satellite-monitored radio tags on eastern North Pacific gray whales. Paper SC/62/BRG21 presented to the International Whaling Commission, Scientific Committee. 22 pp.

Matkin, C. and E. Saulitis. 1997. Killer whale *Orcinus orca*. Restoration Notebook (Publication of the Exxon Valdez Oil Spill Trustee Council) November: 1−12.

Matkin, C., G. Ellis, E. Saulitis, L. Barrett-Lennard, and D. Matkin. 1999. Killer Whales of Southern Alaska. North Gulf Oceanic Society. 96 pp.

Merrick, R. L., M. K. Chumbley, and G. V. Byrd. 1997. Diet diversity of Steller sea lions (*Eumetopias jubatus*) and their population decline in Alaska: a potential relationship. *Canadian Journal of Fisheries and Aquatic Sciences*. 54: 1342–1348.

Merrick, R. L., and T. R. Loughlin. 1997. Foraging behavior of adult female and young-of-the-year Steller sea lions in Alaskan waters. *Canadian Journal of Zoology*. 75: 776–786.

Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton, and W.J. Richardson. 1999. Whales. In *Marine Mammal and Acoustical Monitoring of Western Geophysical's Open-Water Seismic Program in the Alaskan Beaufort Sea, 1998*, eds. LGL and Greeneridge. LGL Report TA 2230-3. King City, Ontario, Canada: LGL Ecological Research Associates, Inc. 109 pp.

Mocklin, J. 2005. Appendix C: Potential impacts of cruise ships on the marine mammals of Glacier Bay. Glacier Bay National Park Science Advisory Board: Final report. Research and monitoring needs relevant to decisions regarding increasing seasonal use days for cruise ships in Glacier Bay. Appendices prepared by the Glacier Bay Vessel Management Science Advisory Board, September 2005.

Moore, S.E., W.L. Perryman, F. Gulland, P.R. Wade, L. Rojas-Bracho, and T. Rowles. 2001. Are gray whales hitting "K" hard? *Marine Mammal Science*. 17(4): 954–958.

Morejohn, G.V. 1979. The natural history of Dall's porpoise in the North Pacific Ocean. In *Behavior of Marine Animals, Vol. 3, Cetaceans*, eds. Winn, H.E. and B.L. Olla. New York: Plenum Press. 45–83.

Morris, J.T., V.I. Osychny, and P.J. Luey. 2008. Naval Base Kitsap Bangor – Supplemental Current Measurement Survey: August 2007 field data report. Final. Prepared by Science Applications International Corporation, Newport, RI. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Morton, A.B. 1990. A quantitative comparison of the behaviour of resident and transient forms of the killer whale off the central British Columbia coast. *Reports of the International Whaling Commission* (Special Issue 12): 245–248.

Morton, A.B., and H.K. Symonds. 2002. Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. *ICES Journal of Marine Science*. 59: 71–80.

Moulton, V.D., W.J. Richardson, R.E. Elliott, T.L. McDonald, C. Nations, and M.T. Williams. 2005. Effects of an offshore oil development on local abundance and distribution of ringed seals (*Phoca hispida*) of the Alaskan Beaufort Sea. *Marine Mammal Science*. 21(2): 217–242.

Mulsow, J., and C. Reichmuth. 2008. Aerial Hearing Sensitivity in a Steller Sea Lion. Extended abstract presented at the Acoustic Communication by Animals, Second International Conference. Corvallis, Oregon. August 12–15, 2008.

Mulsow, J., and C. Reichmuth. 2010. Psychophysical and electrophysiological aerial audiograms of a Steller sea lion (*Eumetopias jubatus*). *The Journal of the Acoustical Society of America.* 127(4): 2692–2701.

Mulsow, J., J.J. Finneran, and D.S. Houser. 2011a. California sea lion (*Zalphus californianus*) aerial hearing sensitivity measured using auditory steady-state response and psychophysical methods. *The Journal of the Acoustical Society of America*. 129(4): 2298–2306.

Mulsow, J., J.J. Finneran, and D.S. Houser. 2011b. Aerial audiograms of several California sea lion (*Zalphus californianus*) and Steller sea lions (*Eumetopias jubatus*) measured using single and multiple simultaneous auditory steady-state response methods. *The Journal of Experimental Biology*. 214: 1138–1147.

Navy. 2001. Shock trial of the WINSTON S. CHURCHILL (DDG 81): final environmental impact statement. Department of the Navy.

Navy. 2009. Results of acoustic monitoring of pile driving operations: Carlson Spit, Bangor Subbase, Washington. Prepared by Naval Surface Warfare Center – Carderock Division, Detachment Bremerton, Bremerton, WA. Prepared for Naval Facilities Engineering Command Northwest.

Navy 2010. Technical memorandum on Waterfront Noise Measurements conducted on 19–20 October 2010 at Naval Base Kitsap Bangor.

Navy. 2012. Marine mammal surveys at Naval Base Kitsap Bangor – sighting reports. NAVFAC NW Environmental. Naval Base Kitsap Bangor, Silverdale, WA.

Navy. 2013. Marine mammal surveys at Naval Base Kitsap Bangor – sighting reports. NAVFAC NW Environmental. Naval Base Kitsap Bangor, Silverdale, WA.

Navy. 2014a. Commander Task Force 3rd and 7th Fleet Navy Marine Species Density Database. NAVFAC Pacific Technical Report. Naval Facilities Engineering Command Pacific, Pearl Harbor, HI. http://nwtteis.com/DocumentsandReferences/NWTTDocuments/SupportingTechnicalDocuments.

Navy. 2014b, in prep. Naval Base Kitsap-Bangor Explosives Handling Wharf 2, Bangor Washington. Draft Year 2 Marine Mammal Monitoring Report. Prepared by Hart Crowser for NAVFAC, Silverdale, WA. Draft March 2014.

Newton, J.A., S.L. Albertson, K. Nakata, and C. Clishe. 1998. Washington State marine water quality in 1996 and 1997. Washington State Department of Ecology, Environmental Assessment Program, Publication No. 98-338. http://www.ecy.wa.gov/pubs/98338.pdf.

Newton, J.A., S.L. Albertson, K. Van Voorhis, C. Maloy, and E. Siegel. 2002. Washington State marine water quality, 1998 through 2000. Washington State Department of Ecology Environmental Assessment Program, Publication No. 02-03-056. http://www.ecy.wa.gov/pubs/0203056.pdf.

Ng, S.L., and S. Leung. 2003. Behavioral response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. *Marine Environmental Research.* 56(5): 555–567.

NMFS (National Marine Fisheries Service). 1991. Final Recovery plan for the humpback whale (*Megaptera novaengliae*). Prepared by Humpback Whale Recovery Team. Prepared for National Marine Fisheries Service, Silver Spring, MD. 120 pp.

NMFS. 1992. Final recovery plan for Steller sea lions *Eumetopias jubatus*. NMFS Office of Protected Resources, Silver Spring, MD. 92 pp.

NMFS. 1993. Final Rule: Designated Critical Habitat; Steller Sea Lion. 58 *Federal Register* 45269.

NMFS. 1997a. Final Rule: Threatened Fish and Wildlife; Change in Listing Status of Steller Sea Lions Under the Endangered Species Act. 62 *Federal Register* 24345.

NMFS. 1997b. Investigation of scientific information on the impacts of California sea lions and Pacific harbor seals on salmonids and on the coastal ecosystems of Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-28.

NMFS. 1999. The habitat approach: implementation of Section 7 of the Endangered Species Act for actions affecting the habitat of Pacific anadromous salmonids. Memorandum for NMFS/NWR Staff. Prepared by the National Marine Fisheries Service Northwest Region Habitat Conservation and Protected Resources Divisions. August 26, 1999. http://www.nwr.noaa.gov/Publications/Reference-Documents/upload/habitatapproach_081999-2.pdf.

NMFS. 2005. Endangered Fish and Wildlife; Notice of intent to prepare an environmental impact statement. 70 *Federal Register* 1871.

NMFS. 2006. Designation of Critical Habitat for Southern Resident Killer Whale. 71 *Federal Register* 69054.

NMFS. 2008a. Recovery Plan for the Steller Sea Lion (*Eumetopias jubatus*). Revision. National Marine Fisheries Service, Silver Spring, MD. 325 pp.

NMFS. 2008b. Draft Environmental Assessment: Reducing the impact on at-risk salmon and steelhead by California sea lions in the area downstream of Bonneville Dam on the Columbia River, Oregon and Washington. NOAA National Marine Fisheries Service, Northwest Region, Seattle, WA. pp. 127.

NMFS. 2008c. Recovery plan for southern resident killer whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Region, Seattle, WA. 247 pp.

NMFS. 2008d. Draft Environmental Impact Statement for proposed authorization of the Makah Whale Hunt. National Marine Fisheries Service Northwest Region. Seattle, WA. May 2008.

NMFS. 2009. Taking of marine mammals incidental to specified activities; construction of the East Span of the San Francisco-Oakland Bay Bridge. 74 *Federal Register* 41684.

NMFS. 2010. Endangered Species Act Section 7 Formal Consultation, Port Townsend ferry terminal dolphin replacement, Biological Opinion and Essential Fish Habitat Consultation. National Marine Fisheries Service Northwest Region, Seattle, WA. July 20, 2010.

NMFS. 2012a. Humpback Whale (*Megaptera novaeangliae*). http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/humpbackwhale.htm. Accessed on February 18, 2012.

NMFS. 2012b. Incidental Harassment Authorization. Explosives Handling Wharf (EHW-2) in the Hood Canal, Washington. Office of Protected Resources. National Marine Fisheries Service. Issued July 11, 2012.

NMFS. 2012c. Draft status review of the eastern distinct population segment of Steller sea lion (*Eumetopias jubatus*). Protected Resources Division, Alaska Region, National Marine Fisheries Service. Juneau, AK.

NOAA Fisheries. 2013a. NOAA removes the Eastern Steller Sea Lion from the Endangered Species Act list. News Release. October 23, 2013. http://alaskafisheries.noaa.gov/newsreleases/2013/easternssl102313.htm.

NOAA Fisheries. 2013b. Endangered and Threatened Species; Delisting of the Eastern Distinct Population Segment of Steller Sea Lion under the Endangered Species Act; Amendment to Special Protection Measures for Endangered Marine Mammals. *Federal Register* Vol. 78, Number 213, p. 66140-66199, November 4, 2013.

NOAA Fisheries. 2013c. Draft Guidance for assessing the effects of anthropogenic sound on marine mammals. Acoustic threshold levels for onset of permanent and temporary threshold shifts. National Ocean and Atmospheric Administration. Draft: 23 December 2013. http://www.nmfs.noaa.gov/pr/acoustics/draft_acoustic_guidance_2013.pdf.

Norberg, B. 2007a. Personal email communication between Brent Norberg (National Marine Mammal Laboratory Biologist) and Andrea Balla-Holden (URS Corporation Fisheries and Marine Mammal Biologist) on April 30, 2007.

Norberg, B. 2007b. Personal email communication between Brent Norberg (National Marine Mammal Laboratory Biologist) and Andrea Balla-Holden (URS Corporation Fisheries and Marine Mammal Biologist) on June 13, 2007.

Norris, K.S., and J.H. Prescott. 1961. Observations on Pacific cetaceans of Californian and Mexican waters. *University of California Publications in Zoology*. 63: 291–402.

Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. *Mammal Review*. 37(2): 81–115.

NRC. 2003. *Ocean noise and marine mammals*. Washington, DC: National Research Council Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals; The National Academies Press.

O'Keeffe, D.J., and G.A. Young. 1984. "*Handbook on the environmental effects of underwater explosions*." Naval Surface Weapons Center, Dahlgren and Silver Spring, NSWC TR 83-240, September 1984.

Olesiuk, P.F. 2008. Abundance of Steller sea lions (*Eumetopias jubatus*) in British Columbia. Research Document 2008/063. Canadian Science Advisory Secretariat, Ottawa.

Olesiuk, P.F., D. Burles, G. Horonowitsch, and T.G. Smith. 1993. Aerial censuses of pinnipeds in the Queen Charlotte Islands, 1 July–1 August, 1992. *Canadian Manuscript Report of Fisheries and Aquatic Sciences*. No. 2217.

Orca Network. 2010. Population information available at www.orcanetwork.org.

Orca Network. 2012. Orca Network sighting reports and archives accessed January and February 2012 at http://www.orcanetwork.org.

Orr, A.J., A.S. Banks, S. Mellman, H.R. Huber, R.L. DeLong, and R.F. Brown. 2004. Examination of the foraging habits of Pacific harbor seal (*Phoca vitulina richardsi*) to describe their use of the Umpqua River, Oregon, and their predation on salmonids. *Fishery Bulletin.* 102: 108−117.

Osborne, R., J. Calambokidis, and E.M. Dorsey. 1988. *A guide to marine mammals of Greater Puget Sound*. Anacortes, WA: Island Publishers.

Osmek, S., B. Hanson, J.L. Laake, S. Jeffries and R.L. DeLong. 1995. Harbor porpoise *Phocoena phocoena* population assessment studies for Oregon and Washington in 1994. Pages 141−172 in *Marine Mammal Assessment Program Status of Stocks and Impacts of Incidental Take*. National Marine Mammal Laboratory report submitted to the Office of Protected Resources, Silver Spring, MD.

Osmek, S.D., J. Calambokidis, and J.L. Laake. 1998. Abundance and distribution of porpoise and other marine mammals of the inside waters of Washington and British Columbia. In Proceedings of the Fourth Puget Sound Research Conference, Strickland, R., ed. *Puget Sound Water Quality Action Team, Olympia, WA*. 868−880; March 12−13, 1998, Seattle, WA.

Osmek, S.D., J. Calambokidis, J. Laake, P. Gearin, R. Delong, J. Scordino, S. Jeffries, and R. Brown. 1996. Assessment of the status of harbor porpoise (*Phocoena phocoena*) in Oregon and Washington Waters. December 1996. NOAA Technical Memorandum NMFS-AFSC-76.

Payne, K., and R. Payne. 1985. Large scale changes over 19 years in songs of humpback whales in Bermuda. *Zietschrift fur Tierpsychologie* 68: 89−114.

Payne, P.M., and L.A. Selzer. 1989. The distribution, abundance, and selected prey of the harbor seal, *Phoca vitulina concolor*, in southern New England. *Marine Mammal Science* 5(2): 173−192.

Phillips, C., B. Dolan, and W. Hafner. 2009. Naval Base Kitsap at Bangor water quality 2005 and 2006 field survey report. Prepared by Science Applications International Corporation, Bothell, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Peterson, S.H., M.M. Lance, S.J. Jeffries, and A. Acevedo-Gutierrez. 2012. Long distance movements and disjunct spatial use of harbor seals (*Phoca vitulina*) in the inland waters of the Pacific Northwest. *PLoS ONE* 7(6): e39046. doi:10.1371/journal.pone.0039046.

Pitcher, K. W., and D. G. Calkins. 1981. Reproductive biology of Steller sea lions in the Gulf of Alaska. *Journal of Mammalogy*. 62: 599–605.

Pitcher, K. W., P. F. Olesiuk, R. F. Brown, M. S. Lowry, S. J. Jeffries, J. L. Sease, W. L. Perryman, C. E. Stinchcomb, and L. F. Lowry. 2007. Status and trends in abundance and distribution of the eastern Steller sea lion (*Eumetopias jubatus*) population. *Fishery Bulletin*. 107(1): 102–115.

Prescott, R. 1982. Harbor seals: Mysterious lords of the winter beach. *Cape Cod Life*. 3(4): 24–29.

Read, A.J. 1990. Reproductive seasonality in harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. *Canadian Journal of Zoology*. 68: 284–288.

Read, A.J. 1999. Harbour porpoise *Phocoena phocoena* (Linnaeus, 1758). In *Handbook of Marine Mammals, Volume 6: The Second Book of Dolphins and Porpoises*, eds. Ridgway, S.H. and S.R. Harrison. San Diego, CA: Academic Press. 323–355.

Read, A.J., and A.A. Hohn. 1995. Life in the fast lane: The life history of harbor porpoises from the Gulf of Maine. *Marine Mammal Science.* 11(4): 423–440.

Reeder, D.M., and K.M. Kramer. 2005. Stress in free-ranging mammals: integrating physiology, ecology, and natural history. *Journal of Mammalogy.* 86(2): 225–235.

Reeves, R.R., B.S. Stewart, P.J. Clapham, and P.A. Folkens. 2008. *National Audubon Society Guide to marine mammals of the world*. New York: A.A. Knopf.

Reichmuth, C., M.M. Holt, J. Mulsow, J.M. Sills, and B.L. Southall. 2013. Comparative assessment of amphibious hearing in pinnipeds. *Journal of Comparative Physiology A.* 199: 491–507.

Rice, D.W., A.A. Wolman, and H.W. Braham. 1984. The gray whale, *Eschrichtius robustus*. *Marine Fisheries Review.* 46(4): 7–14.

Richardson, W.J., G.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. *Marine mammals and noise*. San Diego, CA: Academic Press. 576 pp.

Ridgway, S. H., D. A. Carder, R. R. Smith, T. Kamolnick, C. E. Schlundt, and W. R. Elsberry, 1997. Behavioral responses and temporary shift in masked hearing threshold of bottlenose dolphins, *Tursiops truncatus*, to 1-second tones of 141 to 201 dB re 1 μPa. Technical Report 1751, Revision 1. San Diego, California: Naval Sea Systems Command.

Riedman, M. 1990. *The Pinnipeds: seals, sea lions, and walruses*. Berkley, CA: University of California Press.

Ritter, F. 2002. Behavioural observations of rough-toothed dolphins (*Steno bredanensis*) off La Gomera, Canary Islands (1995–2000), with special reference to their interactions with humans. *Aquatic Mammals.* 28(1): 46–59.

Roffe, T. and B. Mate. 1984. Abundance and feeding habits of pinnipeds in the Rogue River, OR. *The Journal of Wildlife Management*. 48: 1262–1277.

Ruggerone, G.T., S.E. Goodman, and R. Miner. 2008. Behavioral response and survival of juvenile coho salmon to pile driving sounds. Prepared by Natural Resources Consultants, Inc., Seattle, WA, and Robert Miner Dynamic Testing, Inc. Prepared for Port of Seattle, Seattle, WA.

SAIC. 2006. Naval Base Kitsap-Bangor fish presence and habitat use. Combined phase I and II field survey report (Draft). Prepared by Science Applications International Corporation, Bothell, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Saulitis, E. L. 1993. The behavior and vocalizations of the “AT” group of killer whales (*Orcinus orca*) in Prince William Sound, Alaska. M.S. Thesis, University of Alaska Fairbanks, Fairbanks, AK. 193 pp.

Saulitis, E., C.O. Matkin, L.G. Barrett-Lennard, K. Heise, and G.M. Ellis. 2000. Foraging strategies of sympatric killer whale (*Orcinus orca*) populations in Prince William Sound, Alaska. *Marine Mammal Science.* 16: 94–109.

Scheffer, V.B., and J.W. Slipp. 1948. The whales and dolphins of Washington State with a key to the cetaceans of the west coast of North America. *American Midland Naturalist*. 39(2): 257−337.

Schlundt, E.D., R.L. Dear, L. Green, D.S. Houser, and J.J. Finneran. 2007. Simultaneously measured behavioral and electrophysiological hearing thresholds. *The Journal of the Acoustical Society of America*. 110 (5, pt. 2): 2722.

Schneider, D.C. and P.M. Payne, 1983. Factors affecting haul-out of harbor seals at a site in southeastern Massachusetts. *Journal of Mammalogy.* 64(3): 518−520.

Schusterman, R.J. 1974. Auditory sensitivity of a California sea lion to airborne sound. *The Journal of the Acoustical Society of America*. 56: 1248−1251.

Schusterman, R.J., and R.F. Balliet. 1969. Underwater barking by male sea lions (*Zalophus californianus*). *Nature.* 222(5199): 1179−1181.

Schusterman, R.J., R.F. Balliet, and J. Nixon. 1972. Underwater audiogram of the California sea lion by the conditioned vocalization technique. *Journal of the Experimental Analysis of Behavior*. 17: 339−350.

Schusterman, R.J., R.F. Balliet, and S. St. John. 1970. Vocal displays under water by the gray seal, the harbor seal, and the stellar [sic] sea lion. *Psychonomic Science.* 18(5): 303−305.

Schusterman, R.J., R. Gentry, and J. Schmook. 1966. Underwater vocalization by sea lions: Social and mirror stimuli. *Science.* 154(3748): 540−542.

Schusterman, R.J., R. Gentry, and J. Schmook. 1967. Underwater sound production by captive California sea lions. *Zoologica*. 52: 21−24.

Scordino, J. 2006. Steller sea lions (*Eumetopias jubatus*) of Oregon and Northern California: Seasonal haul-out abundance patterns, movements of marked juveniles, and effects of hot-iron branding on apparent survival of pups at Rogue Reef. Master of Science thesis, Oregon State University, Corvallis, OR. 92 pp.

Scordino, J. 2010. West coast pinniped program investigations on California sea lion and Pacific Harbor seal impacts on salmonids and other fishery resources. Pacific States Marine Fisheries Commission.

Shane, S.H., R.S. Wells, and B. Würsig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: A review. *Marine Mammal Science*. 2(1): 34–63.

Slater, M.C. 2009. Naval Base Kitsap, Bangor baseline underwater noise survey report. Prepared by Science Applications International Corporation, Bremerton, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene, C.R. Jr., Kastak, D., Ketten, D.K., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., and Tyack, P.L. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. *Special Issue of Aquatic Mammals*. 33(4): 412–522.

Suryan, R.M. and J.T. Harvey. 1998. Tracking harbor seals (*Phoca vitulina richardsi*) to determine dive behavior, foraging activity, and haul-out site use. *Marine Mammal Science*. 14(2): 361–372.

Szymanski, M.D., D.E. Bain, K. Kiehl, S. Pennington, S. Wong, and K.R. Henry. 1999. Killer whale (*Orcinus orca*) hearing: auditory brainstem response and behavioral audiograms. *The Journal of the Acoustical Society of America*. 106(2): 1134–1141.

Tannenbaum, B.R., M. Bhuthimethee, L. Delwiche, G. Vedera, and J.M. Wallin. 2009. Naval Base Kitsap at Bangor 2008 Marine Mammal Survey Report. Prepared by Science Applications International Corporation, Bothell, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Tannenbaum, B.R., W. Hafner, J. Wallin, L. Delwiche, and G. Vedera. 2011. Naval Base Kitsap at Bangor 2009–2010 Marine Mammal Survey Report. Prepared by Science Applications International Corporation, Bothell, WA. Prepared for NAVFAC NW, Silverdale, WA.

Temte, J. L. 1986. Photoperiod and the timing of pupping in the Pacific harbor seal (*Phoca vitulina richardsi*) with notes on reproduction in northern fur seals and Dall porpoises. Thesis, Oregon State University, Corvallis, USA.

Terhune, J.M., and W.C. Verboom. 1999. Right whales and ship noise. *Marine Mammal Science*. 15(1): 256–258.

Thompson, P.O., W.C. Cummings, and S.J. Ha. 1986. Sounds, source levels, and associated behavior of humpback whales, southeast Alaska. *The Journal of the Acoustical Society of America*. 80: 735–40.

Tyack, P.L., and C.W. Clark. 2000. Communication and acoustic behavior of dolphins and whales. In *Hearing by whales and dolphins*, eds. Au, W.W.L., A.N. Popper, and R.R. Fay. New York: Springer-Verlag. 156–224.

Unger, S. 1997. Identification of *Orcinus orca* by underwater acoustics in Dabob Bay. Presented at Oceans ’97 MTS/IEE. Marine Technology Society and The Institute of Electrical and Electronics Engineers. 333–338; October 6–9, 1997, Halifax, Nova Scotia.

Urick, Robert J. 1983. *Principles of underwater sound.* 3rd ed. New York: McGraw-Hill.

URS Consultants, Inc. 1994. Final remedial investigation report for the Comprehensive Long-Term Environmental Action Navy (CLEAN) Program, Northwest Area. Remedial investigation for Operable Unit 7, CTO-0058, SUBASE Bangor, Bremerton, WA. Prepared by URS Consultants, Inc., Seattle, WA. Prepared for Engineering Field Activity, Northwest, Western Division, Naval Facilities Engineering Command, Silverdale, WA. June 13, 1994.

USACE (U.S. Army Corps of Engineers). 2010. Approved work windows in all marine/estuarine areas excluding the mouth of the Columbia River (Baker Bay) by tidal reference area. Seattle District, United States Army Corps of Engineers, Seattle, WA. Posted March 19, 2010. http://www.nws.usace.army.mil/publicmenu/DOCUMENTS/REG/work_windows_-_all_marine_&_estuarine2.pdf.

Veirs, V. and S. Veirs. 2005. One year of background underwater sound levels in Haro Strait, Puget Sound. *The Journal of the Acoustical Society of America*. 117(4): 2577–2578.

Viada, S.T., R.M. Hammer, R. Racca, D. Hannay, M.J. Thompson, B.J. Balcom, and N.W. Phillips. 2008. Review of potential impacts to sea turtles from underwater explosive removal of offshore structures. *Environmental Impact Assessment Review*. 28(4): 267–285.

Walker, W.A., M.B. Hanson, R.W. Baird, and T.J. Guenther. 1998. Food habits of the harbor porpoise, *Phocoena phocoena*, and Dall’s porpoise, *Phocoenoides dalli*, in the inland waters of British Columbia and Washington. Pages 63–75 in Marine Mammal Protection Act and Endangered Species Act Implementation Program 1997. AFSC Processed Report 98-10.

Ward, W.D. 1997. Effects of high intensity sound. In *Encyclopedia of Acoustics, Volume III*, ed. M.J. Crocker. New York: John Wiley & Sons. 1497–1507.

Warner, M.J. 2007. Historical comparison of average dissolved oxygen in Hood Canal. Hood Canal Dissolved Oxygen Program. February 2007. http://www.hoodcanal.washington.edu/observations/historicalcomparison.jsp.

Warner, M.J., M. Kawase, and J.A. Newton. 2001. Recent studies of the overturning circulation in Hood Canal. In Proceedings of the 2001 Puget Sound Research Conference, Puget Sound Action Team, Olympia, WA. 9 pp. http://www.hoodcanal.washington.edu/documents/document.jsp?id=1561.

Wartzok, D., A.N. Popper, J. Gordon, and J. Merrill. 2003/04. Factors affecting the responses of marine mammals to acoustic disturbance. *Marine Technology Society Journal*. 37(4): 6–15.

Watkins, W.A. 1986. Whale reactions to human activities in Cape Cod waters. *Marine Mammal Science*. 2(4): 251–262.

WDFW (Washington Department of Fish and Wildlife). 2011. Gray Whale. 2011 Sensitive species annual report.

WDOE (Washington Department of Ecology). 1981. Instream Resources Protection Program, Kitsap Water Resource Inventory Area 15, including Proposed Administrative Rules. W.W.I.R.P.P. Series-No. 5. Washington Department of Ecology, Water Resources Policy Development Section, Olympia, WA.

Wiles, G. J. 2004. Washington State status report for the killer whale. Washington Department Fish and Wildlife, Olympia. 106 pp. http://wdfw.wa.gov/science/articles/orca/final_orca_status.pdf.

Williams, R., A.W. Trites, and D.E. Bain. 2002. Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. *Journal of Zoology.* 256(2): 255–270.

Willis, P.M., B.J. Crespi, L.M. Dill, R.W. Baird, and M.B. Hanson. 2004. Natural hybridization between Dall's porpoises (*Phocoenoides dalli*) and harbour porpoises (*Phocoena phocoena*). *Canadian Journal of Zoology*. 82: 828–834.

Wilson, S.C. 1978. Social organization and behavior of harbor seals, *Phoca vitulina concolor*, in Maine. Final report to the U.S. Marine Mammal Commission. Washington, D.C.: Smithsonian Institution Press.

Wilson, O.B.J., S.N. Wolf, and F. Ingenito. 1985. Measurements of acoustic ambient noise in shallow water due to breaking surf. *The Journal of the Acoustical Society of America.* 78(1): 190–195.

Wolski, L.F., R.C. Anderson, A.E. Bowles, and P.K. Yochem. 2003. Measuring hearing in the harbor seal (*Phoca vitulina*): Comparison of behavioral and auditory brainstem response techniques. *The Journal of the Acoustical Society of America*. 113(1): 629–637.

Wright. 2007. Personal communication re: tribal takes of marine mammals.

Wright, B.E., M.J. Tennis, and R.F. Brown. 2010. Movements of male California sea lions captured in the Columbia River. *Northwest Science.* 84(1): 60–72.

WSDOT (Washington State Department of Transportation). 2007a. Underwater sound levels associated with driving steel and concrete piles near the Mukilteo Ferry Terminal. Jim Laughlin, WSDOT Office of Air Quality and Noise, Seattle, WA. March 2007. http://www.wsdot.wa.gov/NR/rdonlyres/64500C4E-3472-4D03-84DF-9F2C787A28EC/0/MukilteoFerryTermTestPileRptWSDOT.pdf.

WSDOT. 2007b. Underwater sound levels associated with pile driving during the Anacortes Ferry Terminal Dolphin Replacement Project. Tim Sexton, Washington State Department of Transportation Office of Air Quality and Noise, Seattle, WA. April 2007. http://www.wsdot.wa.gov/NR/rdonlyres/5AD837F4-0570-4631-979B-AC304DCC5FA0/0/AnacortesFerryTerminal.pdf.

WSDOT. 2008. Eagle Harbor Hydroacoustic pressure monitoring technical memorandum. May 29, 2008. Memorandum from Jim Laughlin to Michael Morrow and Elie Ziegler. Washington State Department of Transportation. http://www.wsdot.wa.gov/NR/rdonlyres/BC5980A0-377C-4356-998AD13D87F4A8C7/0/EagleHarborMaintTechMemo.pdf.

WSDOT. 2009. National Marine Fisheries Service Pile Driving Calculator (Excel spreadsheet), version January 26, 2009. Washington State Department of Transportation, Olympia, WA. http://www.wsdot.wa.gov/NR/rdonlyres/1C4DD9F8-681F-49DC-ACAF-ABD307DAEAD2/0/BA_NMFSpileDrivCalc.xls.

WSDOT. 2010. Average noise reductions using different minimization strategies for WSDOT impact pile driving operations. Memorandum from Jim Laughlin to Sharon Rainsberry. Washington State Department of Transportation. July 20, 2010.

WSDOT. 2011. Edmonds Ferry Terminal – Vibratory Pile Monitoring Technical Memorandum. To John Callahan and Rick Huey from Jim Laughlin. WSDOT Office of Air Quality and Noise, Seattle, WA. October 20, 2011. http://www.wsdot.wa.gov/NR/rdonlyres/CCDE5B3C-07F2-4B3F-872D-9C817A463768/0/EdmondsVibratoryTechMemo.pdf.

WSDOT. 2012. Underwater vibratory sound levels from a steel and plastic on steel pile installation at the Anacortes Ferry Terminal. Jim Laughlin, Washington State Department of Transportation Office of Air Quality and Noise, Seattle, WA. March 2012. http://www.wsdot.wa.gov/NR/rdonlyres/82C5A3C7-883B-4213-89B3-C22727CF8AF1/0/AnacortesVibratoryNoiseRpt.pdf.

WSDOT. 2014. Biological Assessment Preparation for Transportation Projects - Advanced Training Manual, Chapter 7, "Noise Impact Assessment." Version 2014. Washington State Department of Transportation, Olympia, WA. February 2014. http://www.wsdot.wa.gov/Environment/Biology/BA/BAguidance.htm#Manual.

Würsig, B., S.K. Lynn, T.A. Jefferson, and K.D. Mullin. 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. *Aquatic Mammals.* 24(1): 41–50.

Yelverton, J.T., D.R. Richmond, E.R. Fletcher, and R.K. Jones. 1973. Safe distances from underwater explosions for mammals and birds. Lovelace Foundation, Albuquerque, DNA 3114T. http://stinet.dtic.mil/cgibin/GetTRDoc?AD=AD766952&Location=U2&doc=GetTRDoc.pdf.

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# APPENDIX A

# SUMMARY OF MARINE MAMMAL DENSITY ESTIMATES

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# APPENDIX A: SUMMARY OF MARINE MAMMAL DENSITY ESTIMATES

## 1.0 INTRODUCTION

To ensure compliance with United States (U.S.) environmental regulations including the Endangered Species Act, the Marine Mammal Protection Act, and the National Environmental Policy Act, the U.S. Navy evaluates potential environmental impacts from their activities. This quantitative impact analysis requires an estimate of the number of animals that might be affected. A key element of this estimation is knowledge of the abundance and concentration of the species in specific geographic areas where those activities will occur. The Navy's Marine Species Density Database (NMSDD) was developed and is used as a key element for modeling effects of in-water sound sources on marine species. The NMSDD contains the most scientifically supportable, species-specific density estimates (in animals/square kilometer) for marine mammals and sea turtles. Available sources of density information range from very robust ecological models and line-transect estimates to values based on only expert experience.

The following sections provide a summary of the density estimation methods that were developed for each species in Hood Canal as previously introduced in this Incidental Harassment Authorization.

### 1.1 Humpback Whale

A "minimum density estimate" of 0.000001 was assigned to the humpback whale. The value is assigned to a species that has historically occurred, and may occur again, but does not occur with any regularity in order to develop a density. A once-a-year sighting (e.g., humpback whale in Hood Canal) would receive a minimum density estimate value. This acknowledges that the species may be present but is unlikely the majority of the time.

### 1.2 Pinniped Density Methodology for the Pacific Northwest Inland Waters

The geographic areas used for the strata were based on Figure 1 from Jeffries et al. (2003). The inland waters consist of five regions: Strait of Juan de Fuca (Region 3), San Juan Islands (Region 4), Eastern Bays (Region 5), Puget Sound (Region 6), and Hood Canal (Region 7). The outer coast regions (1 and 2) are not part of the inland waters and as such were not part of this analysis.

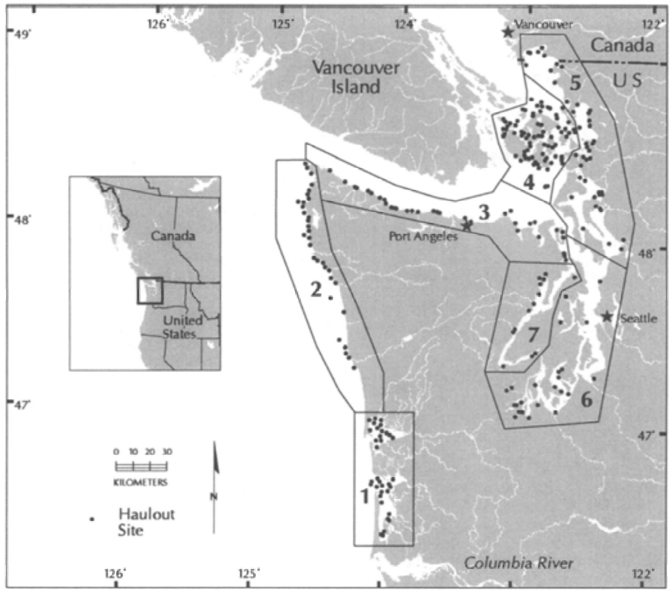


*Figure 1 from Jeffries et al. (2003). The Inland waters consist of areas 3, 4, 5, 6, and 7 only. These strata were used for harbor seals, California sea lions, and Steller sea lions.*

### *Harbor Seals*

The harbor seal population was distributed across the five regions using the last known haul-out count data in those corresponding regions (Year 1999 from Table 1 of Jeffries et al. (2003); provided as Table A–1 below). The haul-out correction factor (multiply by 1.53) was applied to account for animals in the water, but missed during the aerial haul-out survey counts (Huber et al. 2001). The resulting abundance is then divided by the area of the region. This abundance assumes that 100 percent of the population is in the water, 100 percent of the time. Since all three of these species haul out for many hours on any given day, a secondary correction factor to account for this behavior is appropriate. The assumption that all the animals of any given population would be present in the water at any given moment is not supported by surveys of haul-outs and would result in an overestimation of in-water densities. However, only a correction factor for harbor seals (multiply by 0.35) is available (Huber et al. 2001). Haul-out factors for California sea lions and Steller sea lions in this region are not yet available. This correction factor removes a small percentage of the population from the water to account for the haul-out behavior. The resulting in-water density is then used to estimate potential exposures from underwater sound sources.

**Table A–1. From Jeffries et al. 2003 (Year 1999) (Counts of animals hauled out of the water)**

| Year | Region | | | | | Total |
|---|---|---|---|---|---|---|
| | Strait of Juan de Fuca | San Juan Islands | Eastern Bays | Puget Sound | Hood Canal | |
| 1999 | 1,752 | 3,588 | 1,873 | 1,025 | 711 | 8,949 |

**Table A–2. Abundance of Animals by Region (Applies correction factor of 1.53 for animals in the water)**

| | Region | | | | | Total |
|---|---|---|---|---|---|---|
| | Strait of Juan de Fuca | San Juan Islands | Eastern Bays | Puget Sound | Hood Canal | |
| Abundance | 2,681 | 5,490 | 2,866 | 1,568 | 1,088 | 13,693 |

**Table A–3. Area by Region (in square kilometers) used in Density Calculations**

| | Region | | | | |
|---|---|---|---|---|---|
| | Strait of Juan de Fuca | San Juan Islands | Eastern Bays | Puget Sound | Hood Canal |
| Area (sq km) | 2243.8 | 1726.45 | 1299.08 | 1286.28 | 358.44 |

The number of animals in each of the regions (Table A–2) was divided by the area of that region (Table A–3) to come up with the overall density (Table A–4). This value assumes that 100 percent of the animals are in the water 100 percent of the time.

**Table A–4. Density by Region (in square kilometers) for Pacific Harbor Seals (Assumes 100% of the population is in the water 100 percent of the time)**

| | Region | | | | |
|---|---|---|---|---|---|
| | Strait of Juan deFuca | San Juan Islands | Eastern Bays | Puget Sound | Hood Canal |
| Density | 1.1948 | 3.1799 | 2.2062 | 1.219 | 3.0354 |

**Table A–5. Density by Region (in square kilometers) for Pacific Harbor Seals (Applies a correction factor of 0.35 to account for a percentage of the population from the water to account for animals hauled out at any given time)**

| | Region | | | | |
|---|---|---|---|---|---|
| | Strait of Juan deFuca | San Juan Islands | Eastern Bays | Puget Sound | Hood Canal |
| Density | 0.4182 | 1.1130 | 0.7722 | 0.4267 | 1.0624 |

### *Sea Lions*

For California sea lions and Steller sea lions, the initial strata layers were the same as harbor seals. However, areas 3 and 4 (Strait of Juan de Fuca and the San Juan Islands) were merged into one stratum and areas 5 and 6 (Eastern Bays and Puget Sound) were combined into another stratum, while area 7 (Hood Canal) was left as a separate stratum. This resulted in three overall regions, which were exactly the same for both species. This was based on their known haul-outs (both on the Canadian and U.S. side) and usage of the larger inland waters region. The area for those merged strata was then calculated. The number of animals known to use the haul-outs in each of the strata was divided by the area of that region to come up with the density.

*Seasonality*

Both species of sea lion are seasonal in this region. California sea lions are present all months except for July, and Steller sea lions are present all months except for June, July, August, and September (Table A–6). Therefore, during July for California sea lions, and June–September for Steller sea lions, their density is zero. Both species move seasonally to their breeding rookeries off the California and Oregon coasts, respectively. The densities presented represent the highest number that would be expected during the peak winter months (approximately December–February) when both species are present in the largest numbers in the inland waters. As such, projects or activities that would occur earlier than this peak season would overestimate their exposure numbers. Or stated another way, these densities would represent the maximum density based on the peak winter season months, and projects occurring prior to that time would likely expose fewer animals to project activities or sounds.

**Table A–6. Seasonal Occurrence for California and Steller Sea Lions in Hood Canal**

| | Present in Inland Waters/ Non-Breeding Season | Absent from Inland Waters/ Breeding Season |
|---|---|---|
| California sea lions | August–June | July (density = 0) |
| Steller sea lions | September–May | June, July, and August (density = 0) |

### *California Sea Lion*

**Table A–7. Abundance of California Sea Lion by Region (Based on haul-out counts)** (Navy 2012)

| | Region | | |
|---|---|---|---|
| | Strait of Juan de Fuca/ San Juan Islands | Eastern Bays/ Puget Sound | Hood Canal |
| Abundance | In prep | 330 | 100 |

**Table A–8. Area by Region (in square kilometers)**

| | Region | | |
|---|---|---|---|
| | Strait of Juan de Fuca/ San Juan Islands | Eastern Bays/ Puget Sound | Hood Canal |
| Area (sq km) | In prep | 2585.36 | 358.44 |

The abundance of animals in each region (Table A–7) was divided by the area of that region (Table A–8) to come up with the density (Table A–9) for California sea lions.

**Table A–9. Density by Region (in square kilometers) for the California Sea Lion**

| | Region | | |
|---|---|---|---|
| | **Strait of Juan de Fuca/ San Juan Islands** | **Eastern Bays/ Puget Sound** | **Hood Canal** |
| Density | In prep | 0.13 | 0.28 |

### *Steller Sea Lion*

**Table A–10. Abundance of Steller Sea Lion by Region (Navy 2012)**

| | Region | | |
|---|---|---|---|
| | **Strait of Juan de Fuca/ San Juan Islands** | **Eastern Bays/ Puget Sound** | **Hood Canal** |
| Abundance | In prep | 96 | 9 |

**Table A–11. Area by Region (in square kilometers)**

| | Region | | |
|---|---|---|---|
| | **Strait of Juan de Fuca/ San Juan Islands** | **Eastern Bays/ Puget Sound** | **Hood Canal** |
| Area (sq $km^2$) | In prep | 2585.36 | 358.44 |

We then divided the number of animals in each of the regions (Table A–10) by the area of that region (Table A–11) to come up with the density (Table A–12) for Steller sea lions.

**Table A–12. Density by Region (in square kilometers) for the Steller Sea Lion**

| | Region | | |
|---|---|---|---|
| | **Strait of Juan de Fuca/ San Juan Islands** | **Eastern Bays/ Puget Sound** | **Hood Canal** |
| Density | In prep | 0.037 | 0.025 |

### *Literature Cited:*

Jeffries et al. 2003. Jeffries, S.J., H. Huber, J. Calambokidis, and J. Laake. 2003. Trends and Status of Harbor Seals in Washington State: 1978–1999. *The Journal of Wildlife Management*, Vol. 67, No. 1 (Jan. 2003), pp. 207–218.

Huber et al. 2001. Huber, H.R., S.J. Jeffries, R.F. Brown, R.L. DeLong, and G. VanBlaricom. 2001. Correcting aerial survey counts of harbor seals (*Phoca vitulina richardsi*) in Washington and Oregon. *Mar. Mammal Sci*. 17(2): 276–293.

## 1.3 Transient Killer Whale

### *Summary of the Proposed Methodology for Estimating Density of Transient Killer Whales in the Inland Waters*

Data from Houghton et al. (*in prep*.) were used to estimate seasonal occurrence patterns of transient killer whales in the Inland Waters. Based on sighting data collected over a 7-year period (2004 to 2010), Houghton et al. (*in prep*.) presented the number of unique occurrences within Inland Waters on a monthly basis for five geographic strata (Table A–13). The Navy used their monthly occurrence data, in concert with their average group size estimate for the 2004 to 2010 period (5.16 animals) to estimate the average number of individuals occurring within the Inland Waters on a seasonal basis (Table A–14). Seasons were defined to be consistent with the NMSDD (e.g., summer = June to August, fall = September to November, etc.). The Navy then estimated seasonal density based on the area of each of the strata used by Houghton et al. (*in prep.*) (Table A–15).

Sighting data are inherently biased because effort is not accounted for. In addition, sightability is likely to vary by area, creating additional bias in the sighting data. However, seasonal distribution patterns appear to be relatively consistent (Houghton et al., *in prep*.); thus the 7-year sighting database can be used to identify average seasonal spatial patterns. Until more quantitative estimates are available from systematic survey data, these density estimates will be entered into the NMSDD and used for acoustic modeling purposes.

**Table A–13. Number of Occurrences 2004–2010 (7-year period) (Based on data in Houghton et al., *in prep*.)**

| Region | Summer | Fall | Winter | Spring | TOTAL |
|---|---|---|---|---|---|
| Puget Sound | 4 | 6 | 4 | 13 | 27 |
| Hood Canal | 1 | 0 | 2 | 3 | 6* |
| San Juan Islands | 22 | 16 | 3 | 14 | 55 |
| Gulf Islands/Georg. | 14 | 16 | 3 | 17 | 50 |
| Strait Juan de Fuca | 54 | 77 | 44 | 77 | 252 |

* This row of data is from the 6 animals that stayed over a 172-day period in 2005 and spanned multiple seasons.

**Table A–14. Number of Animals (Average occurrence over 7-year period multiplied by average group size)**

| Region | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Puget Sound | 2.948571 | 4.422857 | 2.948571 | 9.582857 |
| Hood Canal | 0.737143 | 0 | 1.474286 | 2.211429 |
| San Juan Islands | 16.21714 | 11.79429 | 2.211429 | 10.32 |
| Gulf Islands/Georg. | 10.32 | 11.79429 | 2.211429 | 12.53143 |
| Strait Juan de Fuca | 39.80571 | 56.76 | 32.43429 | 56.76 |

**Table A–15. Estimated Density for Study Areas**

| Region | Summer | Fall | Winter | Spring |
|---|---|---|---|---|
| Puget Sound | 0.001582 | 0.002373 | 0.001582 | 0.005141 |
| Hood Canal* | 0.001914 | 0 | 0.003828 | 0.005742 |
| San Juan Islands | 0.004208 | 0.00306 | 0.000574 | 0.002678 |
| Strait Juan de Fuca | 0.014583 | 0.020794 | 0.011882 | 0.020794 |

* The Hood Canal densities were derived from one anomalous occurrence of 6 animals over a 172-day period in 2005. Transients in Hood Canal could also have been assigned a minimum density estimate based on their infrequent occurrence. However, the density team opted to remain consistent with the methods presented in Houghton et al. (*in prep*.) for the entire inland waters.

***Literature Cited***

Houghton, J., R.W. Baird, C.K. Emmons, and M.B. Hanson (*in prep*.). Predator occurrence changes as prey abundance increases: studies of mammal-eating killer whales in southern British Columbia and Washington State from 1987–2010.

## 1.4 Dall's Porpoise

A "minimum density estimate" of 0.000001 was assigned to the Dall's porpoise. This value is assigned to a species that has historically occurred, and may occur again, but does not occur with any regularity in order to develop a density. A rare sighting (e.g., one-time sighting of a Dall's porpoise in 2008) would receive a minimum density estimate value. This acknowledges that the species may be present but is unlikely the majority of the time.

## 1.5 Harbor Porpoise

Based on guidance from other line transect surveys conducted for harbor porpoises using similar monitoring parameters (i.e., boat speed, number of observers, etc.) (Barlow 1988; Calambokidis et al. 1993; Carretta et al. 2001), the Navy determined the effective strip width for the surveys to be 1 kilometer, or a perpendicular distance of 500 meters from the transect to the left or right of the vessel. The effective strip width was set at the distance at which the detection probability for harbor porpoises was equivalent to one, which assumes that all individuals on a transect are detected. Only the sightings occurring within the effective strip width were used in the density calculation. Based on the data collected during the line transect surveys conducted as part of the Test Pile Program (TPP), a total of 38 individual harbor porpoises were sighted within the required perpendicular distance from the survey vessel. The total trackline length of all the surveys conducted during the TPP (September and October) was 471.2 kilometers (see Table B-1 of Appendix B of the TPP marine mammal report). By multiplying the trackline length of the surveys by the effective strip width, in this case 1 kilometer, the total area surveyed during the surveys was 471.2 square kilometers. Dividing the number of individual harbor porpoises sighted (38) by the area surveyed (471.2 square kilometers) results in a density of 0.0806 harbor porpoises per square kilometer. To account for availability bias [g(0)] or the animals which are unavailable to be detected because they are submerged, the Navy utilized a g(0) value of 0.54, derived from other similar line transect surveys (Barlow 1988; Calambokidis et al. 1993; Carretta et al. 2001). This resulted in a corrected density of 0.149 harbor porpoises per square kilometer.

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# APPENDIX B

# NOISE ANALYSIS APPROACH

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# APPENDIX B: NOISE ANALYSIS APPROACH

This appendix describes the methods for estimating underwater and airborne noise levels generated by pile driving and presents calculations of distances from pile driving sources to thresholds of potential impacts on marine mammals. The analysis was developed for National Environmental Policy Act (NEPA) review of the second Explosives Handling Wharf (EHW-2) project in 2011–2012, using the best available acoustic data for the project area. The following discussion supplements these data with measurements from more recent pile driving projects on Naval Base Kitsap (NBK) at Bangor, but the source values and analytical methods used in the original documentation for the project have been retained, as discussed in Section 6.

## 1.1 Fundamentals of Sound

Sound is a physical phenomenon consisting of minute vibrations that travel through a medium, such as air or water. Sound is generally characterized by several factors, including frequency and intensity. Frequency describes the sound’s pitch and is measured in units of hertz (Hz), or cycles-per-second, and in kilohertz (kHz), 1,000 cycles-per-second. High-pitched sounds are characterized by many cycles per second (hertz); low-pitched sounds are characterized by few hertz. Sound is also characterized based on volume or level, as measured by pressure. Due to the wide range of values for acoustic pressure, sound levels are defined using a logarithmic decibel (dB) scale referenced to a standard pressure. A doubling of pressure results in a 6 dB increase in sound level. Unless otherwise noted, all underwater sound levels are expressed in decibels relative to one micropascal (dB re 1 μPa).

Underwater sound is frequently characterized by three specific descriptors: (1) instantaneous peak sound pressure level (SPL) (dB peak), which describes the instantaneous maximum overpressure or underpressure observed during an event; (2) root-mean-square (RMS) (dB RMS) SPL, which is computed as the square root of the sum of the pressure squared, normalized over the event duration, and thus representative of an “average” SPL during an event[1]; and (3) sound exposure level, or SEL (dB SEL), indicating the amount, such as “dose” of acoustic energy, normalized to a one-second time interval, and computed as the cumulative sum of sound pressure squared normalized to a 1-second duration. When characterizing impulsive sound or noise, such as related to impact pile driving, all three descriptors are used to assess different biological effects to various marine species: the peak level indicates the largest absolute value of the instantaneous sound pressure over the frequency range from 20 Hz to 20,000 Hz seen in an impulse event; the RMS level represents the average level during the event; and the SEL level represents the energy observed during an impulse or over several impulses, normalized to a 1-second time period. For quasi steady-state noise such as operation of a boat or during vibratory pile driving, RMS levels are typically compared, although peak and SEL levels can also be computed, with SEL numerically equal to RMS level in this case. Specific RMS noise

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[1] Underwater sound measurement results obtained by Illingworth & Rodkin (2001) for the Pile Installation Demonstration Project in San Francisco Bay indicated that most impact pile driving impulses occurred over a 50- to 100-millisecond period. Most of the energy was contained in the first 30 to 50 milliseconds. Analyses of that underwater acoustic data for various pile strikes at various distances demonstrated that the acoustic signal measured using the standard “impulse exponential time-weighting” on the sound level meter (35-millisecond rise time) correlated to the RMS level measured over the duration of the pulse.

thresholds are used to describe specific impacts on marine mammal species, as described in Chapter 6.

The method commonly used to quantify airborne sounds consists of evaluating all frequencies of a sound according to a weighting system that reflects that human hearing is less sensitive at low frequencies and extremely high frequencies than at the mid-range frequencies. This is called A-weighting, and the decibel level measured is called the A-weighted sound level (dBA). A filtering method that reflects hearing of marine mammals has not yet been developed. Therefore, underwater sound levels are not weighted and measure the entire frequency range of interest. In the case of marine construction work, the frequency range of interest is 10 to 10,000 Hz although frequency ranges detected by many marine mammal species are much greater.

## 1.2 Description of Noise Sources

Underwater sound levels reflect multiple sources, including physical, biological, and anthropogenic noise. Physical noise includes waves at the surface, earthquakes, ice, and atmospheric noise. Biological noise includes sounds produced by marine mammals, fish, and invertebrates. Anthropogenic noise consists of vessels (small and large), dredging, aircraft overflights, and construction noise. Known noise levels and frequency ranges associated with anthropogenic sources similar to those that would be used for this project are summarized in Table B–1. Details of each of the sources are described in the following text.

**Table B–1. Representative Noise Levels of Anthropogenic Sources**

| Noise Source | Frequency Range (Hz) | Underwater Noise Level (dB re 1 μPa) | Reference |
|---|---|---|---|
| Small vessels | 250–1,000 | 151 dB RMS at 1 m | Richardson et al. 1995 |
| Tug docking gravel barge | 200–1,000 | 149 dB RMS at 100 m | Blackwell and Greene 2002 |
| Vibratory driving of 72-inch steel pipe pile | 10–1,000 | 180 dB RMS at 10 m | Illingworth and Rodkin 2007 |
| Impact driving of 36-inch steel pipe pile | 10–1,500 | 195 dB RMS at 10 m | WSDOT 2007a |
| Impact driving of 66-inch CISS piles | 100–1,500 | 210 dB peak at 10 m<br>185 dB SEL at 10 m<br>195 dB RMS at 10 m | WSDOT 2008 |
| Impact driving of 36-inch concrete piles | | 192 dB peak<br>174 dB SEL<br>176 dB RMS | WSDOT 2014 |

CISS = cast-in-steel-shell; dB re 1 μPa = decibels referenced at 1 micropascal; Hz = hertz; m = meter; RMS = root-mean-square; SEL = sound exposure level; WSDOT = Washington State Department of Transportation

In-water construction required for the EHW-2 project includes impact pile driving and vibratory pile driving. The sounds produced by these activities fall into one of two sound types: pulsed and non-pulsed (defined below). Impact pile driving produces pulsed sounds, while vibratory pile driving produces non-pulsed (or continuous) sounds. The distinction between these two general sound types is important because they have differing potential to cause physical effects, particularly with regard to hearing (e.g., Ward 1997 as cited in Southall et al. 2007).

Pulsed sounds (e.g., explosions, gunshots, sonic booms, seismic airgun pulses, and impact pile driving) are brief, broadband, atonal transients (ANSI 1986; Harris 1998) and occur either as isolated events or repeated in some succession (Southall et al. 2007). Pulsed sounds are all characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a decay period that may include a period of diminishing, oscillating maximal and minimal pressures (Southall et al. 2007). Pulsed sounds generally have a greater capacity to induce physical injury as compared with sounds that lack these features (Southall et al. 2007).

Non-pulse (intermittent or continuous sounds) can be tonal, broadband, or both (Southall et al. 2007). Some of these non-pulse sounds can be transient signals of short duration but without the essential properties of pulses (e.g., rapid rise time). Examples of non-pulse sounds include vessels, aircraft, machinery operations such as drilling or dredging, vibratory pile driving, and active sonar systems. The duration of such sounds, as received at a distance, can be greatly extended in highly reverberant environments (Southall et al. 2007).

## 1.3 Estimated Underwater Noise Levels

Construction of the EHW-2 will result in increased underwater noise levels in Hood Canal, due primarily to the installation of piles. Up to three vibratory driving rigs could be used concurrently, but only one impact hammer rig will operate at a time or in conjunction with multiple vibratory rigs. Some noise will be generated by construction support vessels, small boat traffic, and barge-mounted equipment such as cranes and generators, but this noise will typically not exceed existing underwater noise levels resulting from routine waterfront operations in the vicinity of the construction site, encompassing Delta Pier, Marginal Wharf, and the existing EHW facility. Several non-pile-driving construction activities will also occur at the project area. Among them are the installation of cast-in-place concrete pile caps, concrete wharf deck, operations support building, cranes, power utility booms, lightning protection towers, and camels. While no empirical data exist for these construction activities, they will occur on the tops of the piles or attached to the wharf's deck, and are expected to produce noise levels significantly lower than those estimated for pile installation using an impact/vibratory pile driver. It is possible that sound could be transmitted from these activities along the piles' length and enter the water. However, underwater acoustic impacts from these construction operations are expected to be minimal.

The greatest underwater noise will be created while driving piles using an impact hammer. An impact hammer will be used to "proof" every fourth to fifth driven pile to ensure it provides adequate load-bearing capacity. The majority of the pile driving, however, will use vibratory methods. In some cases where difficult geological conditions are encountered, it may be necessary to use an impact hammer to drive certain piles for part or all of their required depth. It is assumed that on most days, a single impact hammer would be used to proof up to five piles, with each pile requiring a maximum of 200 strikes. This likely scenario would require up to 1,000 impact strikes per day (1,000 daily strike scenario). A less likely but possible scenario assumes driving three piles full length (2,000 strikes per pile) and proofing an additional two piles at 200 strikes each with an impact hammer. This scenario would result in up to 6,400 impact strikes per day (6,400 daily strike scenario). Construction will typically occur 6 days per week, but could occur 7 days per week. Impact pile driving during the first half of the in-water work window (July 16 to September 23) will only occur between 2 hours after sunrise to 2 hours before sunset to protect breeding murrelets. Between September 24 and February 15, pile driving can occur during daylight hours. Up to 195 in-water pile driving days will be required in the third construction season. Several measures will be used to minimize the noise generated by pile driving. A soft-start approach, in which hammer energy levels are increased from low to high, will be used for impact pile driving to allow time for marine mammals to move away from the pile driving site before the highest noise levels are produced. A bubble curtain will be used to minimize underwater noise levels when the impact hammer is used, as described in Section 1.4.

All of the piles will be constructed of 24-inch, 36-inch, and 48-inch hollow steel. From the perspective of underwater noise generation, in general driving larger piles requires more energy, and thus pile driving larger piles is expected to produce higher underwater noise levels than smaller piles. Therefore, estimating source levels for impact pile driving for the EHW-2 involved a review of published data that met the following parameters:

1. Pile materials: steel pipe piles (30–72-inch diameter)
2. Pile driver type: vibratory and impact; and
3. Physical environment: shallow depth (<30 meters)

Available information most relevant to the EHW-2 pile driving project in terms of pile type and size, pile driver type, and water depth were identified (Table B–2). Where the data sources specify average maximum values, these are reported in Table B–2. Based on this review, the best conservative estimate of source level for impact hammer driving for the EHW-2 project was approximately 195 dB RMS re 1 μPa at 10 meters, in the absence of noise attenuation measures.

Table B–2 includes measurements of recent impact pile driving on NBK at Bangor, including 36-inch piles and 48-inch piles for the Test Pile Program (TPP) and EHW-2 first construction year, and 42-inch steel pipe piles for the Carderock pier project. These projects are similar to the third year EHW-2 work in terms of pile size, type, and location (substrate). The source levels for the Carderock pier project and the TPP project were estimated at 195 dB RMS and 192 dB RMS, respectively. No unattenuated data are available for the first-year EHW-2 project, for which an average maximum of 191 dB RMS was reported with a bubble curtain in place.

Available data for vibratory pile driving projects were reviewed (Table B–3). At the time that acoustic modeling was performed for the EHW-2 project, there was a paucity of data for vibratory driving; therefore, a conservative source level was used for the EHW-2 analysis based on data for 72-inch pipe: 180 dB RMS re 1 μPa at 10 meters. Additional data for 36-inch and 48-inch pipe piles were used from the TPP project on NBK at Bangor and other recent Washington State Department of Transportation (WSDOT) projects, all of which are less than 180 dB RMS.

### 1.4 Sound Attenuation with Bubble Curtains

A bubble curtain to mitigate noise levels will be employed to minimize the noise levels during impact pile driving operations. Unconfined bubble curtain attenuators (Type I) emit a series of bubbles around a pile to introduce a high-impedance boundary through which pile driving noise is attenuated. At the time the acoustic analysis for the EHW-2 project was performed, noise reduction results using an unconfined bubble curtain indicate widely varying results, with very little measurable attenuation in some cases (less than 6 dB) and high attenuation (greater than 15 dB) in other cases (Illingworth and Rodkin 2001; WSDOT 2010).

**Table B–2. Sound Pressure Levels from Pile Driving Studies Using Impact Hammers**

| Project | Location | Pile Type | Hammer Type | Water Depth | Distance | Measured Sound Levels (RMS) |
|---|---|---|---|---|---|---|
| Eagle Harbor Maintenance Facility[1] | Bainbridge Island, WA | Steel Pipe/ 30-inch | Diesel Hammer | 10 m | 10 m | 192 dB re 1 µPa |
| Friday Harbor Ferry Terminal[2] | Friday Harbor, WA | Steel Pipe/ 30-inch | Diesel Hammer | 10 m | 10 m | 196 dB re 1 µPa |
| Humboldt Bay Bridges[3] | CA | CISS Steel Pipe/ 36-inch | Diesel Impact Hammer | ~10 m | 10 m | 193 dB re 1 µPa |
| Mukilteo Test Piles[4] | WA | Steel Pipe/ 36-inch | Impact | 7.3 m | 10 m | 195 dB re 1 µPa |
| Anacortes Ferry[5] | WA | Steel Pipe/ 36-inch | Impact | 12.8 m | 10 m | 199 dB re 1 µPa |
| Test Pile Program, NBK at Bangor[6] | Hood Canal, WA | Steel Pipe/ 36-inch | Diesel | 13.7–26.8 m | 10 m | 196 dB re 1 µPa |
| EHW-2 First Year, NBK at Bangor[7] | Hood Canal, WA | Steel Pipe/ 36-inch | Impact | 0–30 m | 10 m | 191 dB re 1 µPa [8] |
| Carderock Pier, NBK at Bangor[9] | Hood Canal, WA | Steel Pipe/ 42-inch | Impact | 14.6–21.3 m | 10 m | 195 dB re 1 µPa |
| Test Pile Program, NBK at Bangor[6] | Hood Canal, WA | Steel Pipe/ 48-inch | Diesel | 26.2-28 m | 10 m | 194 dB re 1 µPa |
| EHW-2 First Year, NBK at Bangor[7] | Hood Canal, WA | Steel Pipe/ 48-inch | Impact | 13.7–26.8 m | 10 m | 194 dB re 1 µPa[8] |
| Russian River[3] | Russian River, CA | CISS Steel Pipe/ 48-inch | Diesel Impact | 2 m | 10 m<br>20 m<br>45 m<br>65 m | 195 dB re 1 µPa<br>190 dB re 1 µPa<br>185 dB re 1 µPa<br>175 dB re 1 µPa |
| Unknown[3,10] | CA | Steel CISS/ 60-inch | Impact | ~10 m | 10 m | 195 dB re 1 µPa |
| Richmond-San Rafael Bridge[3] | San Francisco Bay, CA | CIDH Steel Pipe/ 66-inch | Diesel Impact | 4 m | 4 m<br>10 m<br>20 m<br>30 m<br>40 m<br>60 m<br>80 m | 202 dB re 1 µPa<br>195 dB re 1 µPa<br>189 dB re 1 µPa<br>185 dB re 1 µPa<br>180 dB re 1 µPa<br>169 dB re 1 µPa<br>170 dB re 1 µPa |

**Sources:**

1. JASCO Research Ltd. 2005
2. Laughlin 2005b
3. Illingworth & Rodkin, Inc. 2007 and 2012b
4. WSDOT 2007a
5. WSDOT 2007b
6. Illingworth & Rodkin, Inc. 2012a
7. Illingworth & Rodkin 2013. During year 1 EHW-2 construction, only one 48-inch pile was driven.
8. Bubble curtain was in place for all measurements.
9. Navy 2009. Source level at 10 meters (m) estimated based on measurements at distances of 48 to 387 m.
10. Summary value possibly comprising multiple events rather than a single event.

CA = California; CISS = cast-in-steel-shell; dB = decibel; µPa = micropascal; m = meter; RMS = root-mean-square; WA = Washington

**Table B–3. Sound Pressure Levels from Pile Driving Studies Using Vibratory Drivers**

| Project | Location | Pile Type | Hammer Type | Water Depth | Distance | Measured Sound Levels (RMS) |
|---|---|---|---|---|---|---|
| Vashon Terminal[1] | WA | Steel Pipe/30-inch | Vibratory | ~6 m | 11 m | 165 dB re 1 µPa |
| Keystone Terminal[2] | WA | Steel Pipe/30-inch | Vibratory | ~5 m | 10 m | 164 dB re 1 µPa |
| Keystone Terminal[2] | WA | Steel Pipe/30-inch | Vibratory | ~8 m | 10 m | 165 dB re 1 µPa |
| Edmonds Ferry Terminal[3] | WA | Steel Pipe/36 inch | Vibratory | 5.8 m | 11 m | 162–163 dB re 1 µPa[6] |
| Anacortes Ferry Terminal[4] | WA | Steel Pipe/36-inch | Vibratory | 12.7 m | 11 m | 168–170 dB re 1 µPa[6] |
| Test Pile Program, NBK at Bangor[5] | Hood Canal, WA | Steel Pipe/36-inch | Vibratory | 13.7–26.8 m | 10 m | 154–169 dB re 1 µPa[6] |
| Unknown[7] | CA | Steel Pipe/36-inch | Vibratory Driver* | ~5 m | 10 m | 170 dB re 1 µPa |
| Unknown[7] | CA | Steel Pipe/36-inch | Vibratory Driver** | ~5 m | 10 m | 175 dB re 1 µPa |
| Test Pile Program, NBK at Bangor[5] | Hood Canal, WA | Steel Pipe/48-inch | Vibratory | 13.7–26.8 m | 10 m | 172 dB re 1 µPa[6] |
| Unknown[7] | CA | Steel Pipe/72-inch | Vibratory Driver | ~5 m | 10 m | 170 dB re 1 µPa |
| Unknown[7] | CA | Steel Pipe/72-inch | Vibratory Driver** | ~5 m | 10 m | 180 dB re 1 µPa |

**Sources:**

1. Laughlin 2010a; RMS noise levels reported in terms of the 30-second average continuous sound level and computed from the Fourier transform of pressure waveforms in 30-second time intervals. Average of measured values at 11 meters.
2. Laughlin 2010b; RMS noise levels reported in terms of the 30-second average continuous sound level and computed from the Fourier transform of pressure waveforms in 30-second time intervals.
3. WSDOT 2011b
4. WSDOT 2012
5. Illingworth & Rodkin 2012. RMS duration was 10 seconds and arithmetically averaged over the duration of the driving event.
6. Maximum of averages
7. Adapted from *Compendium of Pile Driving Data* report to the California Department of Transportation - Illingworth & Rodkin, Inc. 2007; *RMS impulse level used duration of (35 msec), typical. **RMS impulse level used duration of (35 msec), loudest.

CA = California; dB = decibel; µPa = micropascal; m = meter; msec = millisecond; RMS = root-mean-square; WA = Washington

Reductions of 85 percent (approximately 17 dB, computed as $20 \cdot \log_{10}$ the ratio of peak pressure reduced by 85 percent with the use of a bubble curtain) or more were reported with the proper use of a Type II (confined) bubble curtain (Longmuir and Lively 2001), although reductions of 5 to 15 dB are more typical (Laughlin 2005a). A confined bubble curtain places a shroud around the pile to hold air bubbles near the pile, ensuring they are not washed away by currents or tidal action. For impact analysis, an average SPL reduction of 10 dB was assumed. Estimated SPLs for impact pile driving noise without a noise attenuator are presented in the following analysis for reference only.

Due to the sharp, impulsive nature of impact pile driving, the frequency range over which detectable noise can be heard is broad; measurements have reported detectable noise up to 25.6 kHz (David 2006). However, the bulk of acoustic energy generated underwater due to pile driving ranges between 50 and 1,000 Hz (WSDOT 2013). This range was confirmed by recent pile driving acoustic reports in Puget Sound, which show the majority of observed energy to be below 1,000 Hz (Carlson et al. 2005; Laughlin 2005b).

## 1.5 Underwater Noise Modeling Technique

The degree to which underwater noise propagates away from a noise source is dependent on a variety of factors, most notably by the water depth and presence or absence of reflective or absorptive conditions including in-water structures and sediments. In a perfectly unobstructed (free-field) environment not limited by depth or water surface, noise follows the spherical spreading law, resulting in a 6 dB reduction in noise level for each doubling of distance from the source [20*log(range)]. Cylindrical spreading occurs in an environment wherein noise propagation is bounded by the water surface and sea bottom. In this case, a 3 dB reduction in noise level is observed for each doubling of distance from the source [10*log(range)]. The propagation environment along the Bangor waterfront on NBK is neither free-field nor cylindrical; as the receiver moves away from the shoreline, the water depth increases, resulting in an expected propagation environment that would lie between spherical and cylindrical spreading loss conditions. A practical sound propagation modeling technique is used to estimate the range from the pile driving activity to various expected SPLs in the water when no empirical in situ data are available (WSDOT 2013). The practical spreading loss method has been accepted by the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS). This model follows a geometric propagation loss based on the distance from the driven pile, resulting in a 4.5 dB reduction in level for each doubling of distance from the source. In this model, the SPL at some distance away from the source (e.g., driven pile) is governed by a measured source level, minus the transmission loss of the energy as it dissipates with distance. The transmission loss equation is given by:

$$Transmission\ Loss, TL = 15\log_{10}\left(\frac{R_1}{R_2}\right)$$

where $TL$ is the transmission loss in dB, $R_1$ is the distance of the modeled SPL from the driven pile, and $R_2$ is the distance from the driven pile of the initial measurement. This model follows recommended best practices by WSDOT (2013).

At the time the EHW-2 multiple, concurrent pile driving analysis was conducted, no empirical propagation loss studies along the Bangor waterfront on NBK were available; therefore, the practical spreading loss model was adopted to approximate the environment for noise propagation between the cylindrical and spherical methods.

Underwater noise is frequently characterized by three specific descriptors: (1) instantaneous peak SPL (dB peak), which describes the instantaneous maximum overpressure or underpressure observed during an event; (2) RMS (dB RMS) SPL, which is computed as the square root of the sum of the pressure squared normalized over the event duration, and is thus representative of an "average" SPL during an event; and (3) sound exposure level, or SEL (dB SEL), which indicates the amount, e.g., "dose" of acoustic energy normalized to a 1-second time interval, and is computed as the cumulative sum of sound pressure squared normalized to a 1-second duration. When characterizing impulsive noise, such as with impact pile driving, all three descriptors are used to assess different biological effects to a number of marine species. For quasi steady-state noise, such as operation of a boat or during vibratory pile driving, RMS levels are typically compared, although peak and SEL levels can also be computed. Due to the continuous nature of the noise, SEL values are often numerically equal to RMS levels in this case.

### 1.5.1 Impact Pile Driving

#### *Peak Levels*

Peak attenuation levels for 48-inch, hollow steel piles driven with a bubble curtain are provided in Table B–4 and shown in Figure B–1. Peak levels without a noise attenuator are also shown in the table for reference; all biological impact analyses assume the 10 dB reduction. Peak levels of 206 dB peak will be exceeded within a radius of 4 meters from each driven pile, and levels exceeding 180 dB peak will be exceeded within a radius of 215 meters when a properly operating confined bubble curtain or other noise attenuating device is used.

#### *RMS Levels*

RMS attenuation levels for impact-driven, 48-inch, hollow steel piles using a confined bubble curtain or noise attenuator are provided in Table B–5 and shown in Figure B–2. Using the practical propagation model, SPLs above 190 dB RMS re 1 μPa will be exceeded within a circle centered at the location of the driven pile out to a distance of 5 meters while driving 48-inch, hollow steel piles. Values for 180 dB RMS and 160 dB RMS are also provided in the table. RMS levels without a noise attenuator are provided for reference; all biological impact analyses assume the 10 dB reduction.

Average underwater baseline noise levels acquired near the NBK at Bangor Marginal Wharf facility, which is near the location of the EHW-2, were measured at a level of 114 dB RMS re 1 μPa (Slater 2009). Sound during impact pile driving will be detected above the average background noise levels at any location in Hood Canal with a direct acoustic path (i.e., "line of sight" from the driven pile to the receiver location). To the west of the EHW-2, Toandos Peninsula bounds the extent of sound travel within the construction area; thus, geography will not allow direct sound path propagation south of Brown Point, nor north of Termination Peninsula at the western terminus of the Hood Canal Bridge adjacent to Squamish Harbor. Locations beyond these points will receive substantially lower noise levels since there is no direct sound path, and thus no impacts will be observed.

#### *Sound Exposure Levels*

Impact SEL attenuation levels for 48-inch, hollow steel piles driven with an impact hammer and with a confined bubble curtain or other noise attenuating device are provided in Table B–6 and shown in Figure B–3. Two pile driving scenarios were modeled. Analysis included both the 1,000 and 6,400 daily strike scenarios. For this analysis, stationary, non-moving fish conditions were assumed, that is, fish that will not move away from the site during pile driving operations. Model results followed the technique used by NMFS (WSDOT 2009). Using the practical spreading model, a level of 187 dB SEL re 1 $\mu Pa^2$-sec will be exceeded within a circle centered at the location of the driven pile out to a distance of approximately 158 meters while driving 48-inch, hollow steel piles (1,000 daily strike scenario) using a bubble curtain attenuator, and up to 546 meters for the 6,400 daily strike scenario. Levels of 183 dB SEL re 1 $\mu Pa^2$-sec will be exceeded within a circle centered at the location of the driven pile out to a distance of approximately 293 meters in the 1,000 daily strike scenario, and 1,009 meters in the 6,400 daily strike scenario. It should be noted that the NMFS SEL model methodology includes a factor that

**Table B–4. Attenuation Levels vs. Distance Underwater for Pile Driving Peak Impact Noise**

| Distance (meters) From Driven Pile | With Noise Attenuator Practical Spreading Loss Model[1,2] (dB peak re 1 μPa) | Without Noise Attenuator Practical Spreading Loss Model[1] (dB peak re 1 μPa) |
|---|---|---|
| 2.1 | 210 | 220 |
| 3.9 | 206 | 216 |
| 7.3 | 202 | 212 |
| 10 | 200 | 210 |
| 20 | 195 | 205 |
| 30 | 193 | 203 |
| 61 | 188 | 198 |
| 91 | 186 | 196 |
| 122 | 184 | 194 |
| 152 | 182 | 192 |
| 183 | 181 | 191 |
| 216 | 180 | 190 |
| 305 | 178 | 188 |
| 488 | 175 | 185 |
| 975 | 170 | 180 |
| 1,951 | 166 | 176 |
| 4,877 | 160 | 170 |
| 11,659 | 154 | 164 |

dB = decibel; μPa = micropascal

1. Source level of 210 dB peak at 10 meters is assumed for 48-inch-diameter, hollow steel pile.
2. 10 dB reduction for confined bubble curtain or other noise attenuating device.

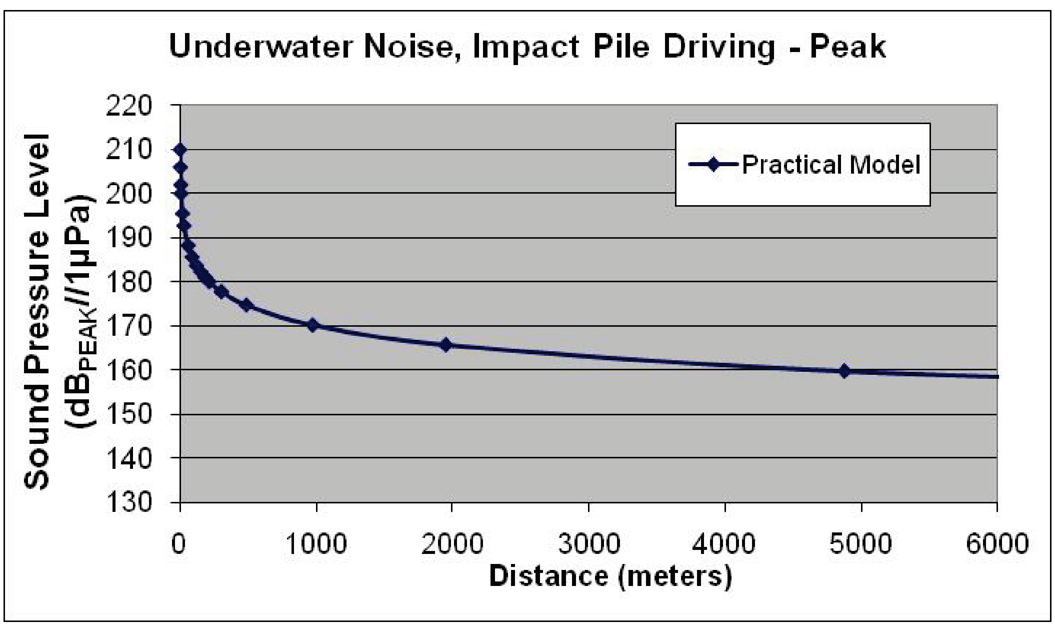


**Figure B–1. Peak Underwater Noise Assessment for Impact Pile Driving With Noise Attenuator**

**Table B–5. Attenuation Levels vs. Distance for Pile Driving RMS Impact Noise**

| Distance (meters) From Driven Pile | With Noise Attenuator Practical Spreading Loss Model[1,2] (dB RMS re 1 μPa) | Without Noise Attenuator Practical Spreading Loss Model[1] (dB RMS re 1 μPa) |
|---|---|---|
| 2.1 | 195 | 205 |
| 4.6 | 190 | 200 |
| 10 | 185 | 195 |
| 11 | 184 | 194 |
| 21 | 180 | 190 |
| 54 | 174 | 184 |
| 91 | 171 | 181 |
| 122 | 169 | 179 |
| 152 | 167 | 177 |
| 183 | 166 | 176 |
| 244 | 164 | 174 |
| 305 | 163 | 173 |
| 464 | 160 | 170 |
| 1,219 | 154 | 164 |
| 1,585 | 152 | 162 |
| 1,829 | 151 | 161 |
| 2,154 | 150 | 151 |

dB = decibel; μPa = micropascal; RMS = root-mean-square

1. Source level of 195 dB RMS at 10 meters is assumed for 48-inch-diameter, hollow steel pile.
2. 10 dB reduction for confined bubble curtain or other noise attenuator.

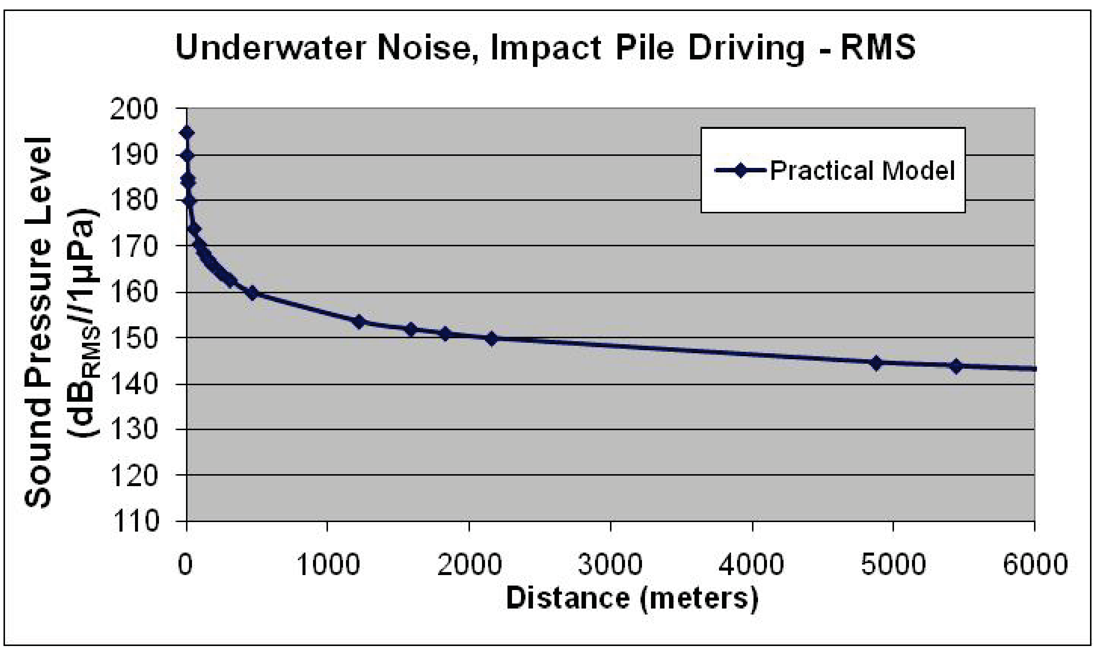


**Figure B–2. RMS Underwater Noise Assessment for Impact Pile Driving With Noise Attenuator**

**Table B–6. Attenuation Levels vs. Distance for Pile Driving SEL Impact Noise with Noise Attenuator, 1,000 and 6,400 Strikes per Day**

| Distance (meters) From Driven Pile | Practical Spreading Loss Model[1,2] 1,000 Strikes (dB SEL re 1 μPa$^2$-sec) | | Practical Spreading Loss Model[1,3] 6,400 Strikes (dB SEL re 1 μPa$^2$-sec) | |
|---|---|---|---|---|
| | With Attenuator | Without Attenuator | With Attenuator | Without Attenuator |
| 2.2 | 215 | 225 | 223 | 233 |
| 4.6 | 210 | 220 | 218 | 228 |
| 10 | 205 | 215 | 213 | 223 |
| 16 | 202 | 212 | 210 | 220 |
| 20 | 200 | 210 | 209 | 219 |
| 34 | 197 | 207 | 205 | 215 |
| 55 | 194 | 204 | 202 | 212 |
| 74 | 192 | 202 | 200 | 210 |
| 91 | 191 | 201 | 199 | 209 |
| 158 | 187 | 197 | 195 | 205 |
| 255 | 184 | 194 | 192 | 202 |
| 293 | 183 | 193 | 191 | 201 |
| 546 | 179[3] | 189 | 187[3] | 197 |
| 1,009 | 177[3] | 187 | 185[3] | 195 |
| 1,951 | 175[3] | 185 | 183[3] | 193 |
| 3,901 | 173[3] | 183 | 181[3] | 191 |
| 4,877 | 169[3] | 179[4] | 177[3] | 187[4] |
| 9,754 | 165[3] | 175[4] | 173[3] | 183[4] |

dB = decibel; μPa = micropascal; SEL = sound exposure level

1. Single-strike source level of 185 dB SEL at 10 meters is assumed for 48-inch-diameter, hollow steel pile.
2. 10 dB reduction for confined bubble curtain or noise attenuator.
3. Effective quiet range for SEL impact with noise attenuator is 464 meters.
4. Effective quiet range for SEL impact with noise attenuator is 2,154 meters.

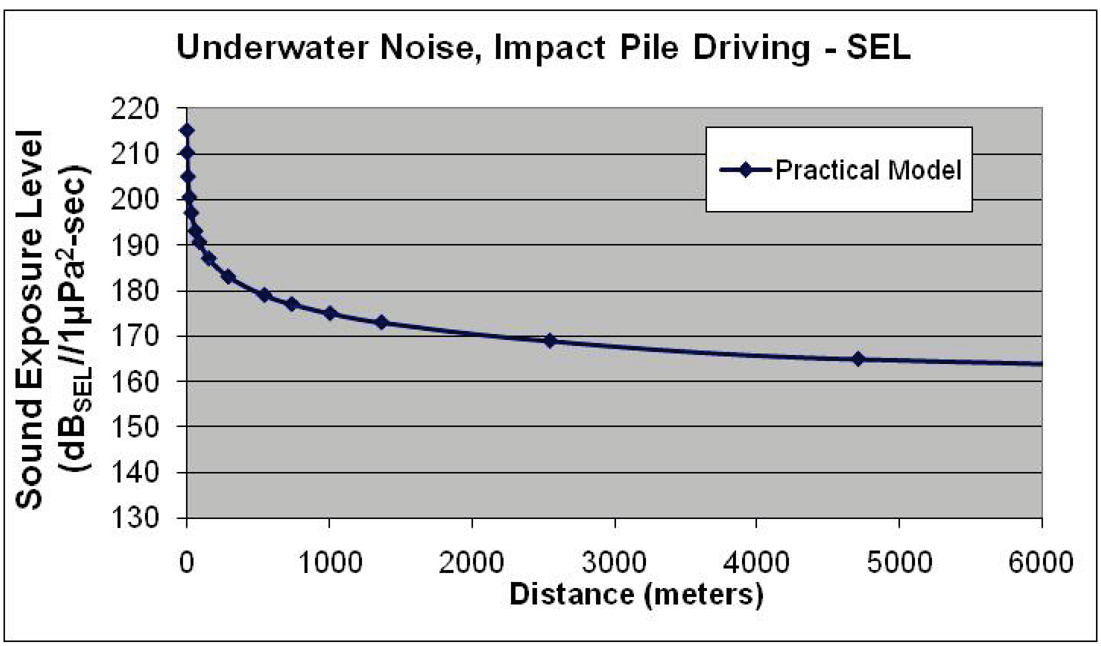


**Figure B–3. SEL Underwater Noise Assessment for Impact Pile Driving With Noise Attenuator, Likely Scenario, 1,000 Strikes**

adjusts the maximum affected area to exclude single strike values less than 150 dB SEL re 1 μPa$^2$-sec, which are assumed to not accumulate to cause injury (WSDOT 2009). This factor has the effect of fixing the maximum distance at which injury is expected to occur, regardless of the number of hammer strikes used in the model calculation. For these assumed conditions, both 187 and 183 dB SEL re 1 μPa$^2$-sec threshold values will be limited to 464 meters for 6,400 pile strikes.

### 1.5.2 Pile Driving, Multiple-Rig Operation

Underwater noise levels during multiple-rig pile driving will produce noise levels higher than those observed with a single rig operating due to the additive effects of multiple noise sources. Noise from multiple, simultaneous sources produces an increase in the overall noise field. A doubling in sound power results in an increase of 3 dB, which is the result of two sources incoherently adding acoustic pressures in the combined noise environment. The resultant SPL from *n*-number of multiple sources is computed with the following relationship using principles of decibel addition:

$$CombinedSPL = 10 \cdot \log_{10}\left(10^{\frac{SPL1}{10}} + 10^{\frac{SPL2}{10}} + ... + 10^{\frac{SPLn}{10}}\right)$$

For each multiple-source analysis, a two-dimensional grid of closely spaced points was created, and noise levels were computed from individual sources at each grid point, then incoherently summed together to estimate the combined noise field. This analysis provides a robust means to estimate the additive effects of noise levels with multiple pile drivers simultaneously operating. Peak and RMS values were computed for each multiple-rig scenario analyzed. Impact SEL calculations for multiple-rig scenarios were not repeated, since only one impact pile driver will be operated at any time. Continuous vibratory energy contributions were not included in SEL calculations for comparison to SEL thresholds for impact driving. This is because the SEL metric is intended to characterize total energy in transient noise events and is not intended for long-term, continuous noise types; the existing SEL thresholds are intended for transient noise events. Peak levels were determined by summing peak levels from impact pile driving with peak levels from vibratory driving. Peak vibratory levels were assumed to be 3 dB higher than continuous RMS levels following the assumption that the typical vibratory waveform is sinusoidal (WSDOT 2013); thus, peak pressures will be higher than RMS values by √2 (approximately 1.41 times higher pressure), which matches typical values of 183 dB peak reported in the literature (Illingworth and Rodkin 2007). Infrequent transient peaks of higher SPLs during vibratory driving could be possible if a pile contacts a hard object such as a rock in the substrate during vibratory driving, but this case was not modeled due to the transient, occasional nature of this occurrence.

For the case of continuous underwater noise, the effects of impulsive impact noise from an impact driver were added to continuous vibratory pile driving noise to provide the most conservative combined estimate of the equivalent continuous RMS sound field. This process involved converting the time-varying impact noise to an equivalent continuous RMS noise level, and then adding it to the continuous RMS noise level created by the vibratory driver. A time-weighting factor was computed to account for the ratio of the time duration the noise persisted compared to the time it was silent. Using this methodology, the equivalent continuous noise level from the impact driving is computed as the SPL of a steady sound source containing the same energy as the impact driver. Calculations for this assumed that the impact noise persisted for 100 milliseconds, which is representative of the longest duration impact waveforms reported for impact driving (ICF Jones and Stokes and Illingworth and Rodkin 2009). Furthermore, it was assumed that the pile driving rate was one hammer impact per second. The equivalent continuous noise factor was then computed as the ratio of "on" time vs. "total" time, or 10*log10(on/total), or 10*log10(100msec/1sec), resulting in a 10 dB factor which was subtracted from the RMS impact levels to form the equivalent continuous contribution by the impact hammer.

Two multiple-rig scenarios were analyzed: (1) three vibratory rigs operating concurrently, and (2) three vibratory rigs and one impact rig operating concurrently. Up to three vibratory rigs could be operating simultaneously, with each rig producing noise levels of up to 180 dB RMS re 1 μPa at 10 meters (Illingworth and Rodkin 2007). An impact pile driver will produce peak levels of 200 dB peak and 185 dB RMS re 1 μPa at 10 meters with a noise attenuator assumed to reduce radiated levels by 10 dB. Highest levels will be produced immediately adjacent to each pile being driven, and will taper off as the receiver moves away from the work area.

***Three Vibratory Pile Driving Rigs***

A majority of the pile driving will be done using vibratory methods. A vibratory pile driver operates by continuously shaking the pile at a fixed frequency, basically vibrating it into the ground. The vibrating action of the pile loosens or "liquefies" the bottom substrate in the vicinity of the pile, and, as a result, the pile moves downward due to the weight of the pile and the vibratory driver (WSDOT 2013). Due to the nature of the project, up to three vibratory pile driving rigs could be used simultaneously, which will create more underwater noise than a single vibratory driver.

With three vibrating pile rigs operating, SPLs of 150 dB RMS will occur at a distance of 2,082 meters from the work area, and levels of 120 dB RMS will occur at distances of up to 206,959 meters. Practically, the maximum affected range above 120 dB RMS will be approximately 13,800 meters from the driven pile, which is bounded by the furthest line-of-sight distance from the EHW-2 location to the northern shore of Squamish Harbor. Further propagation is limited by land masses.

Within 10 meters of each pile being driven, the noise from other piles being driven hundreds of feet away will not noticeably contribute to the noise in the vicinity of the initial pile. Thus, within 10 meters from a pile, maximum noise levels for a multiple-rig operating scenario will be approximately the same as that for a single rig operating. However, farther away from each pile, the noise contributions from adjacent pile drivers will become more significant, resulting in a more complex attenuation environment and higher observed noise levels than with a single rig operating. The noise field in the vicinity of the pile driving area (nominally within 300 meters of the work area) will not attenuate in a simple circular pattern due to the interaction and addition of the multiple rigs contributing to the overall noise field. At substantial distances, the field will behave in a more circular manner, however, as the relative distance from the rigs becomes large compared to the distance between the rigs. Table B–7 summarizes estimated distances to specific functional hearing group thresholds from the EHW-2 project site during three-rig vibratory driving.

**Table B–7. Estimated Distances to Underwater Noise Thresholds, Three Vibratory Drivers, Continuous RMS Noise**

| Functional Hearing Group | Underwater Threshold | Distance to Threshold (meters) |
|---|---|---|
| **Cetaceans (whales, dolphins, porpoises)** | | |
| Injury | 180 dB RMS | 10 |
| Behavior | 120 dB RMS | 13,800[1] |
| **Pinnipeds (seals, sea lions, walrus)** | | |
| Injury | 190 dB RMS | 2.1 |
| Behavior | 120 dB RMS | 13,800[1] |
| **Fish all sizes** | | |
| Behavior | 150 dB RMS | 2,082 |

1. Limited by propagation due to land mass.

***One Impact and Three Vibratory Pile Driving Rigs***

With one impact rig and three vibrating pile rigs operating, SPLs exceeding 150 dB RMS will occur at distances within 3,361 meters from the EHW-2 location (Table B–8). Peak levels exceeding 180 dB peak will occur within 224 meters of the pile driving activity. Use of a noise attenuator, such as a bubble curtain, was assumed to provide a 10 dB reduction in peak and impulsive RMS noise. Levels of 120 dB RMS will practically occur at distances of up to 13,800 meters (8.6 miles) from the driven pile, which is bounded by the furthest line-of-sight distance from the EHW-2 location to the northern shore of Squamish Harbor. Further propagation is limited by land mass.

There will be no increase in overall underwater noise along the Bangor waterfront on NBK from operation of the EHW-2 because there will be no expected increase in vessel traffic or other operational activities. However, operational noise will be introduced at the site of the EHW-2, which is adjacent to the existing EHW. Routine maintenance of the EHW-2 will include inspection and repair of piles, which will infrequently increase underwater noise levels due to occasional repair activity.

## 1.6 Estimated Airborne Noise Levels

The intensity of airborne pile driving sounds is influenced by many of the same factors that affect underwater sound including the size and type of piles, the type of pile driver, and the physical environment in which the activity takes place. Published pile driving noise levels were evaluated for potential use in the EHW-2 analysis. These included 97 dB RMS re 20 µPa at 160 meters (unweighted, Blackwell et al. 2004) for an impact hammer, and 97 dB RMS re 20 µPa at 12 meters (unweighted, McLaughlin 2010) for a vibratory driver. For comparison, more recent studies that met the following parameters were considered:

1. Pile material: steel pipe piles (30–66-inch diameter)
2. Pile driver type: vibratory and impact; and
3. Physical environment: shallow depth (<30 meters).

**Table B–8. Estimated Distances to Underwater Noise Thresholds, One Impact and Three Vibratory Pile Drivers, Peak, RMS, and SEL**

| Functional Hearing Group | Underwater Threshold | With Noise Attenuator Distance to Threshold (meters) | Without Noise Attenuator Distance to Threshold (meters) |
|---|---|---|---|
| **Cetaceans (whales, dolphins, porpoises)** | | | |
| Injury | 180 dB RMS | 10 (continuous)<br>22 (impulsive) | 22 (continuous)<br>105 (impulsive) |
| Behavior | 160 dB RMS (impulsive) | 724 | 2,295 |
| Behavior | 120 dB RMS (continuous) | 13,800[1] | 13,800[1] |
| **Pinnipeds (seals, sea lions, walrus)** | | | |
| Injury | 190 dB RMS | 2.1 (continuous)<br>4.9 (impulsive) | 4.8 (continuous)<br>22 (impulsive) |
| Behavior | 160 dB RMS (impulsive) | 724 | 2,295 |
| Behavior | 120 dB RMS (continuous) | 13,800[1] | 13,800[1] |
| **Fish ≥ 2 grams (based on 6,400 impact pile strikes)** | | | |
| Injury | 187 dB SEL | 464[2] | 2,154[3] |
| **Fish < 2 grams (based on 6,400 impact pile strikes)** | | | |
| Injury | 183 dB SEL | 464[4] | 2,154[5] |
| **Fish all sizes** | | | |
| Injury | 206 dB peak | 4 | 19 |
| Behavior | 150 dB RMS | 2,224 (continuous)<br>3,361 (impulsive) | 3,361 (continuous)<br>10,690 (impulsive) |

dB = decibel; RMS = root-mean-square; SEL = sound exposure level

1. Limited by propagation due to land mass.
2. Distances shown are limited by effective quiet; calculated distance is 546 meters.
3. Distances shown are limited by effective quiet; calculated distance is 2,551 meters.
4. Distances shown are limited by effective quiet; calculated distance is 1,009 meters.
5. Distances shown are limited by effective quiet; calculated distance is 4,713 meters.

Table B–9 details representative pile driving activities that have occurred in recent years. Given their similarity to the Navy's construction project, they represent reasonable SPLs that could be anticipated for EHW-2 construction.

Other construction activities or equipment, such as cranes, heavy trucks, excavators, and jackhammers used for land clearing, delivery of materials, and debris removal, will also cause noise; however, this noise level will be much lower compared to noise produced by the impact hammer (Table B–10). In the absence of pile driving noise, maximum construction noise will be 95 dBA re 20 µPa at a distance of 15 meters from the activity, computed as the summation of noise of three loudest pieces of construction equipment (scraper, backhoe, and jackhammer) operating simultaneously (WSDOT 2014).

## Table B–9. Airborne Sound Pressure Levels from Similar In-situ Monitored Construction Activities

| Project and Location | Pile Size and Type | Installation Method | Water Depth | Measured Sound Pressure Levels |
|---|---|---|---|---|
| Northstar Island, AK[1] | 42-inch steel pipe pile | Impact | ~40 feet | 97 dB RMS re 20 μPa at 525 feet (160 m) |
| Keystone Ferry Terminal, WA[2] | 30-inch steel pipe pile | Vibratory | ~30 feet | 98 dB RMS re 20 μPa at 36 feet (11 m) |
| Test Pile Program[3] | 36-inch | Impact[4,5] | NA | 109 dB (107 dBA) Lmax at 50 feet (15 m)<br>Drop off at 15 Log (distance) from 50 to 1,000 feet (15 to 305 m) |
| Test Pile Program[3] | 36-inch | Vibratory[6] | NA | 93 dB (87 dBA) Leq at 50 feet (15 m)<br>102 dB (97 dBA) Lmax at 50 feet<br>Drop off at 16 Log (distance) from 50 to 1,000 feet (15 to 305 m) |
| Test Pile Program[3] | 48-inch | Impact[4,5] | NA | 107 dB (105 dBA) at 50 feet (15 m)<br>Drop off at 15 Log (distance) from 50 to 1,000 feet (15 to 305 m) |
| Test Pile Program[3] | 48-inch | Vibratory[6] | NA | 94 dB (87 dBA) Leq at 50 feet (15 m)<br>104 dB (98 dBA) Lmax at 50 feet (15 m)<br>Drop off at 16 Log (distance) from 50 to 1,000 feet (15 to 305 m) |

**Sources:**

1. Blackwell et al. 2004
2. Laughlin 2010b
3. Illingworth & Rodkin 2012. Values for 24-inch-diameter piles are not included for TPP because only one 24-inch-diameter pile was measured and the driving period was very short (i.e., less than 30 seconds).
4. Table 30 of the TPP Acoustic Monitoring Report. These are the average of the maximum levels for all pile driving events measured. The maximum levels were 2 to 3 dB higher. Only Lmax levels reported for impact pile driving. Note that the Leq measured for impact pile driving reported in Table 29 included time when there was no pile driving, because the events were so short and the minimum measurements period was 1 minute. Typically, the Leq for impact pile driving is 8 to 10 dB (or dBA) lower than the Lmax level.
5. Note that this RMS for impact pile driving is based on a maximum level from a continuous measurement of sound pressure levels averaged over 1/8th of a second (125 milliseconds). The Leq during a pile-driving event is typically 7 to 10 dB or dBA lower).
6. Table 29 of the TPP Acoustic Monitoring Report. These are the average of the maximum levels for all pile-driving events measured. The maximum levels were 3 to 7 dB higher. Note that the sound levels from vibratory pile driving propagate at a rate of 15 times the Log10 of the distance. This lower rate reflects the complexity of the source and the near-field measurements.

dB = decibel; dBA = A-weighted decibel; Leq = equivalent level; Lmax = maximum level; μPa = micropascal, RMS = root-mean-square

**Table B–10. Maximum Noise Levels at 15 Meters for Common Construction Equipment**

| Equipment Type | Maximum Noise Level (dBA) |
|---|---|
| Scraper | 90 |
| Backhoe | 90 |
| Jackhammer | 89 |
| Crane | 81 |
| Pumps | 81 |
| Generator | 81 |
| Front loader | 79 |
| Air Compressor | 78 |

**Source:** WSDOT 2013

dBA = A-weighted decibel; µPa = micropascal; SPL = sound pressure level

Note: Maximum SPLs in dBA re 20 µPa (A-weighted).

Sensitive receptors along Hood Canal adjacent to the project site will be affected by construction noise. Airborne noise due to impact pile driving will be the most noticeable to such sensitive receptors. Noise impacts due to other construction activities will be minimal. Construction will typically occur 6 days per week, but could occur 7 days per week. Pile driving during the first half of the in-water work window (July 16 to September 23) will only occur between 2 hours after sunrise to 2 hours before sunset to protect breeding murrelets. Between September 24 and February 15, pile driving can occur during daylight hours. Non-pile-driving construction activities could last until 10:00 p.m. in accordance with the Washington Administrative Code (WAC) noise guidelines. The number of pile driving days will be between 211 and 411, including the time to drive the abutment piles.

Construction noise behaves as a point-source, and thus propagates in a spherical manner, with a 6 dB decrease in SPL per doubling of distance (WSDOT 2013). Two specific noise conditions exist at the EHW-2 project site, namely propagation over water to the west side of Hood Canal, and over heavily vegetated terrain on the east side of Hood Canal. In the first condition, WSDOT (2013) considers propagation over water as a “hard-site” condition; thus, no additional noise reduction factors apply. However, in the second condition two noise reduction factors apply for the topography of the EHW-2 project site. The first of these is a 7.5 dB loss factor per doubling of distance in “soft-site” conditions, wherein normal, unpacked earth is the predominant soil condition. The second factor is a reduction of 10 dB for interposing dense vegetation, e.g., trees and brush, between the noise source and potential receptors.

### 1.6.1 Impact Pile Driving

Table B–11 tabulates expected unweighted, received RMS noise levels strike scenario for three terrain conditions:

- Noise over soft-site terrain conditions, using a 7.5 dB loss factor per doubling of distance;
- Noise over soft-site terrain conditions, using a 7.5 dB loss factor as described above, with a 10 dB reduction in maximum noise level due to the presence of dense vegetation; and
- Noise over water, using a 6 dB loss factor per doubling of distance.

Figure B–4 shows the same information in a graphical format.

**Table B–11. Attenuation Levels vs. Distance for Pile Driving Impact Airborne Noise, Unweighted RMS**

| Distance (meters) From Driven Pile | Over Water[1] | Soft Site, No Vegetation[2] | Soft Site, With Vegetation[3] |
|---|---|---|---|
| 8.5 | 122 | 124 | 114 |
| 9.8 | 121 | 122 | 112 |
| 15.2 | 117 | 117 | 107 |
| 30.2 | 111 | 110 | 100 |
| 76 | 103 | 100 | 90 |
| 113 | 100 | 96 | 86 |
| 190 | 95 | 90 | 80 |
| 358 | 90 | 83 | 73 |

dBA = A-weighted decibel; μPa = micropascal; SPL = sound pressure level

Note: Maximum SPLs in dB RMS re 20 μPa (unweighted).

1. 6 dB loss per doubling of distance due to hard-site conditions.
2. 7.5 dB loss per doubling of distance due to soft-site conditions.
3. 7.5 dB loss per doubling of distance due to soft-site conditions, plus 10 dB fixed loss due to the presence of vegetation.

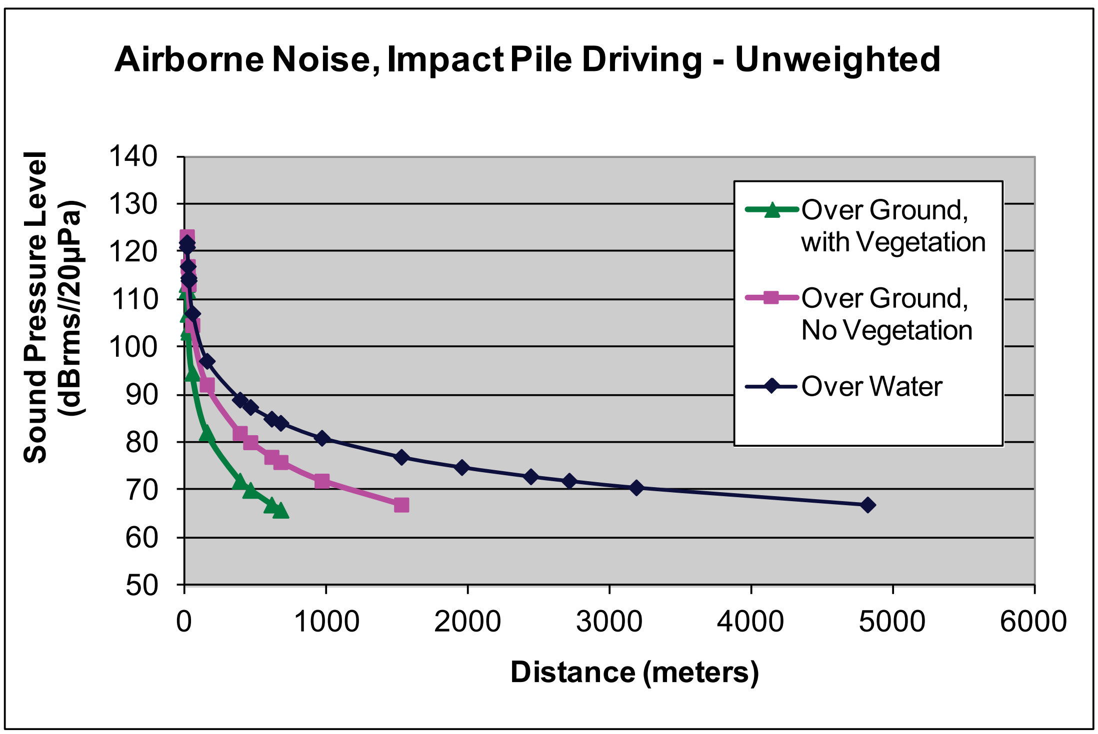


**Figure B–4. Airborne Noise Assessment for Impact Pile Driving Showing Expected Noise Levels Over Terrain and Water, Unweighted Sound Pressure Levels**

### 1.6.2 Vibratory Pile Driving

A vibratory pile driver will be the preferred method to drive pilings. An impact hammer will be used if a vibratory pile driver was unable to install pilings to the required depth. No more than one impact pile driver will operate at one time. Up to three vibratory pile driving rigs could be used simultaneously, which will create more airborne noise than a single vibratory driver. Estimated noise conditions are presented for both single-rig and multiple-rig construction. Multiple-rig construction estimates are presented for concurrent operation of three vibratory drivers, and one impact hammer with three vibratory pile drivers.

Several measures will be used to minimize the noise generated by pile driving. A soft-start approach, in which hammer energy levels are increased from low to high, will be used for both pile driving methods to allow time for birds and mammals to move away from the pile driving site before the highest noise levels are produced.

### 1.6.3 Pile Driving, Multiple-Rig Operation

Noise from multiple, simultaneous sources produces an increase in the overall noise field. A doubling in sound power results in an increase of 3 dB in the environment, which is the result of two sources incoherently adding acoustic pressures in the combined noise environment. The resultant SPL from *n*-number of multiple sources is computed with the following relationship using principles of decibel addition:

$$CombinedSPL = 10 \cdot \log_{10}\left(10^{\frac{SPL1}{10}} + 10^{\frac{SPL2}{10}} + ... + 10^{\frac{SPLn}{10}}\right)$$

For each multiple-source analysis, a two-dimensional grid of closely spaced points was created, and noise levels were computed from individual sources at each grid point, then incoherently summed together to estimate the combined noise field. A-weighted and unweighted values were computed for each multiple-rig scenario analyzed. RMS calculations were made for both equivalent continuous sound and impulsive sound. An equivalent continuous SPL was computed for the impact driver by spreading the impulsive RMS energy over the same time duration as a vibratory driver. With an assumed impact rate of one pile strike per second, and an impulsive duration of 125 msec (one-eighth of a second, equivalent to a sound meter "fast" averaging time for peak measurements), an equivalent continuous SPL was computed. This result was summed with continuous RMS noise levels from the vibratory drivers to establish the combined equivalent continuous noise level. For the impulsive RMS metric of concurrently operating pile drivers, vibratory RMS levels were added directly to the impulsive RMS sound levels of the impact driver. The maximum impulsive noise was computed as the sum of continuous vibratory energy and the impulsive RMS energy over the duration of the impact strike. Since this is only computed over the duration of each pile strike, the impulsive RMS SPL for multiple rigs operating will always be higher than continuous, equivalent RMS SPLs.

For this analysis, it was assumed that all rigs were operating simultaneously, and the noise was incoherently summed to produce the expected noise field. Highest levels will be produced immediately adjacent to each pile being driven, and will taper off as the receiver moved away from the work area. Within close proximity of the EHW-2 construction area, the resultant noise field is complex and non-circular due to the geometry of the pile driver rigs. As the receiver moves away from the construction area, the resultant noise field will become somewhat circular.

Two multiple-rig scenarios were analyzed: (1) three vibratory rigs operating concurrently and (2) three vibratory rigs and one impact rig operating concurrently. Highest levels will be produced immediately adjacent to each pile being driven and will taper off as the receiver moves away from the work area.

### *Three Vibratory Pile Driving Rigs*

Airborne noise levels during multiple-rig impact and vibratory pile driving will produce noise levels higher than those observed with a single rig operating. Three vibratory rigs will each produce noise levels of up to 95 dBA re 20 µPa at 15 meters, and unweighted noise levels of 97 dB RMS re 20 µPa at 12 meters. Within 15 meters of each pile being driven, the noise from other piles being driven hundreds of feet away will not noticeably contribute to the noise in the vicinity of the initial pile. Thus, within 15 meters from a pile, maximum noise levels for a multiple-rig operating scenario will be approximately the same as that for a single rig operating. Farther away from each pile, the noise contributions from adjacent pile drivers will become more significant, resulting in a more complex attenuation environment and higher observed noise levels than with a single rig operating. With three vibratory rigs operating, unweighted levels of 100 dB RMS will occur at a distance of 8.5 meters or less from each driven pile, and a level of 90 dB RMS will occur within 27.7 meters of each rig. Table B–12 summarizes estimated distances to specific functional hearing group thresholds from the EHW-2 project site during three-rig vibratory driving.

**Table B–12. Estimated Distances to Airborne Noise Thresholds, Three Vibratory Drivers, Continuous RMS Noise**

| Functional Hearing Group | Airborne Threshold | Distance to Threshold (meters)[1] |
|---|---|---|
| **Pinnipeds (seals, sea lions, walrus)** | | |
| Behavior, harbor seals | 90 dB RMS, unweighted | 27.7 |
| Behavior, other species | 100 dB RMS, unweighted | 8.5 |

dB = decibel; RMS = root-mean-square

1. Distance thresholds show worst-case condition, over water.

### *One Impact and Three Vibratory Pile Driving Rigs*

Maximum noise levels will occur during use of an impact hammer in combination with multiple vibratory rigs. With one impact rig and three vibratory rigs operating, unweighted levels of 100 dB RMS will occur at a distance of 114 meters or less from the impact driven pile, and within 12 meters of each vibratory driven pile. Unweighted levels exceeding 90 dB RMS will occur within 361 meters of the impact driven pile, and levels greater than 100 dB RMS will occur within 114 meters of the impact pile. Table B–13 summarizes estimated distances to specific functional hearing group thresholds from the EHW-2 project site during concurrent impact and three-rig vibratory driving.

**Table B–13. Estimated Distances to Airborne Noise Thresholds, One Impact and Three Vibratory Drivers**

| Functional Hearing Group | Airborne Threshold | Distance to Threshold (meters)[1] |
|---|---|---|
| **Pinnipeds (seals, sea lions, walrus)** | | |
| Behavior, harbor seals | 90 dB RMS, unweighted | 127 (continuous)<br>361 (impulse) |
| Behavior, other species | 100 dB RMS, unweighted | 40 (continuous)<br>114 (impulse) |

dB = decibel; RMS = root-mean-square

1. Distance thresholds show worst-case condition, over water.

Operations will result in increased localized noise at the EHW-2 project site. However, overall noise along the Bangor waterfront on NBK is anticipated to remain similar to existing conditions, since vessel traffic will remain the same. Once construction of the EHW-2 is completed, noise occurring at the existing EHW and other waterfront facilities will occur at the existing EHW facility and the EHW-2. Maintenance of the EHW-2 will include routine inspections, repair, and replacement of facility components (not piles) as required. These activities will not generate noise appreciably different from normal operational noise along the Bangor industrial waterfront on NBK.

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# APPENDIX C

# MARINE MAMMAL MONITORING PLAN

# Marine Mammal Monitoring Plan
# Year 2

## TRIDENT SUPPORT FACILITIES
## EXPLOSIVES HANDLING WHARF (EHW-2)

## NAVAL BASE KITSAP at BANGOR
## SILVERDALE, WA

**May 2013**

## DEPARTMENT OF THE NAVY

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## 1.0 INTRODUCTION

The purpose of this monitoring plan is to provide a protocol for marine mammal monitoring during the proposed construction of the second Explosives Handling Wharf (EHW-2) at the Naval Base Kitsap (NBK) at Bangor, WA waterfront. This plan was developed to support the respective Biological Assessment (BA) and Incidental Harassment Authorization (IHA) documents for ESA and MMPA permitting. Those documents provide a more in-depth discussion on the modeling assumptions and calculations for the project and are incorporated here by reference.

Marine mammal monitoring will be conducted before, during, and after pile driving activities, within the areas that are estimated to be encompassed by the airborne and underwater injury or behavioral disturbance thresholds.

## 2.0 ACTION AREA

*The action area includes "all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action" (50 CFR § 402.02). Specifically, the action area is defined as the geographic extent of physical, biological, and chemical effects of the action above baseline conditions. The action area boundary takes into account how the action's physical, chemical, and biotic effects (stressors) move across the landscape, through direct and indirect pathways, over time, to identify the spatial and temporal scale of the action area (WSDOT 2011).*

Construction of the EHW-2 will generate both airborne and underwater sound from impact and vibratory pile driving. To determine which noise effect extended the farthest, sound propagation was modeled and compared to ambient levels.

The ambient noise levels at NBK at Bangor were previously measured over a one month period in the summer of 2007 (July 10 – Aug 14) (Slater 2009). The underwater sound measurements were conducted at several locations in the vicinity of the project area. The location closest to the project area, designated as Marginal Wharf in the report, recorded data from two hydrophones deployed 300-500 feet north of the Marginal Wharf. Recordings were made 5 minutes per hour throughout the entire study period (Slater 2009). Average underwater broadband ambient noise levels near the project site were 114 dB RMS re: 1 microPascal (dB re 1µPa) between 100 hertz (Hz) and 20 kilohertz (kHz). Airborne noise levels at the NBK at Bangor waterfront in the daytime ranged between 60 and 104 dBA (decibels in the A-weighted scale) and averaged 64 dBA; night levels ranged between 64 and 96 dBA, averaging 64 dBA, consistent with other urbanized environments where equipment is operating.

Baseline underwater and airborne noise measurements were also conducted during the Test Pile Program (TPP) at NBK at Bangor from August – October 2011. Underwater ambient levels recorded during the TPP were consistent with those previously reported in Slater (2009). Recordings made in the middle of the Hood Canal approximately 2,200-2,300 meters from the pile averaged 114 dB RMS re: 1 microPascal between 50 Hz and 20 kHz. Ambient airborne data was collected at locations farther from the wharves than during prior data collection efforts, in order to reduce the potential for acoustic contributions from waterfront activities being incorporated into the ambient environment. Measurements were generally made between 125 – 550 meters from the pile, along the shoreline between EHW-1 and Marginal Wharf. Airborne ambient levels averaged 55 dBA Leq re: 20 microPa between 25 Hz and 20 KHz.

Using the practical spreading loss model for transmission ($15*\log_{10}[R_1/R_2]$, where $R_1$ is the distance of the modeled sound pressure level from the driven pile, and $R_2$ is the distance from the driven pile of the initial measurement), it was determined that underwater sound from vibratory pile driving was the stressor identified to have the furthest geographic distribution to be distinguishable above ambient conditions. Sound generated from vibratory pile driving would intersect land masses (e.g., Toandos Peninsula) prior to attenuating to measured background levels. As such, the geographic boundary of the Action Area was defined by the line-of-sight intersection of land and water and is shown on Figure 1.

To determine the potential areas in which marine mammal monitoring may be required for monitoring, the Navy modeled the sound propagation out to defined threshold criteria from sound pressure levels anticipated for impact and vibratory pile driving during EHW-2 construction. Figures 2 and 3 depict the anticipated extent of underwater and airborne zones of influence based on the various marine mammal threshold criteria.

# 3.0 METHODS

## 3.1. OBSERVER QUALIFICATIONS

Monitoring will be conducted by qualified, trained marine mammal observers (hereafter, “observer”). An observer is a biologist with prior training and experience in conducting at-sea marine mammal monitoring or surveys, and who has the ability to identify marine mammal species and describe relevant behaviors that may occur in proximity to in-water construction activities. A trained observer will be placed at the best vantage point(s) practicable (e.g., from a small boat, the pile driving barge, on shore, or any other suitable location) to monitor for marine mammals and implement shutdown/delay procedures when applicable by calling for the shutdown to the hammer operator. The observers will have no other construction related tasks while conducting monitoring.

A dedicated monitoring coordinator will be on-site during all construction days. The monitoring coordinator will oversee the environmental monitoring staff including both marine mammal and marbled murrelet observers. The monitoring coordinator will serve as the liaison between the environmental monitoring staff and the construction contractor to assist in the distribution of information.

**Figure 1. EHW-2 Action Area**

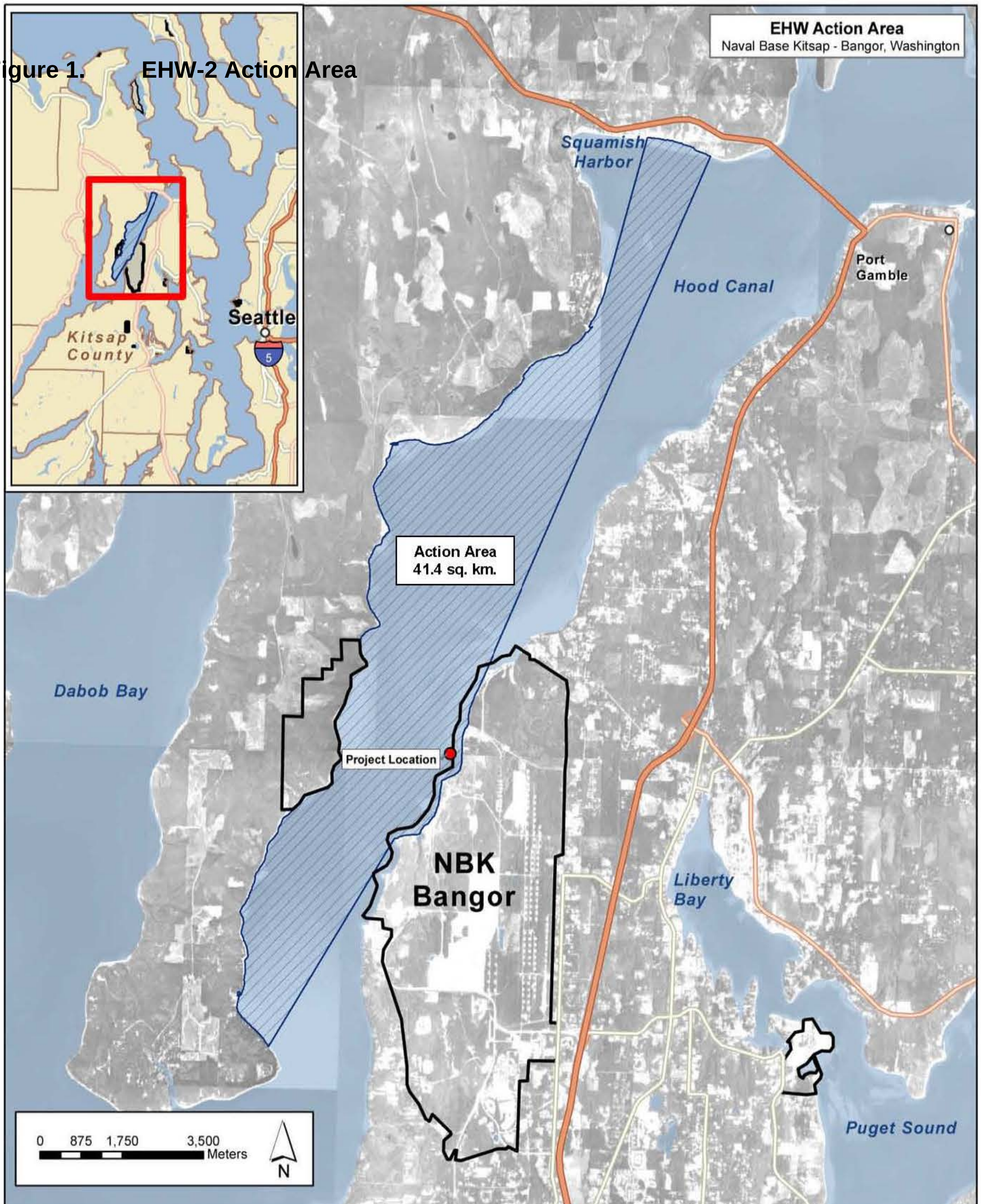


Figure 1. EHW-2 Action Area

The distances to and the area encompassed by the underwater noise thresholds for cetacean and pinnipeds for concurrent impact and vibratory pile driving are shown in Figure 2.

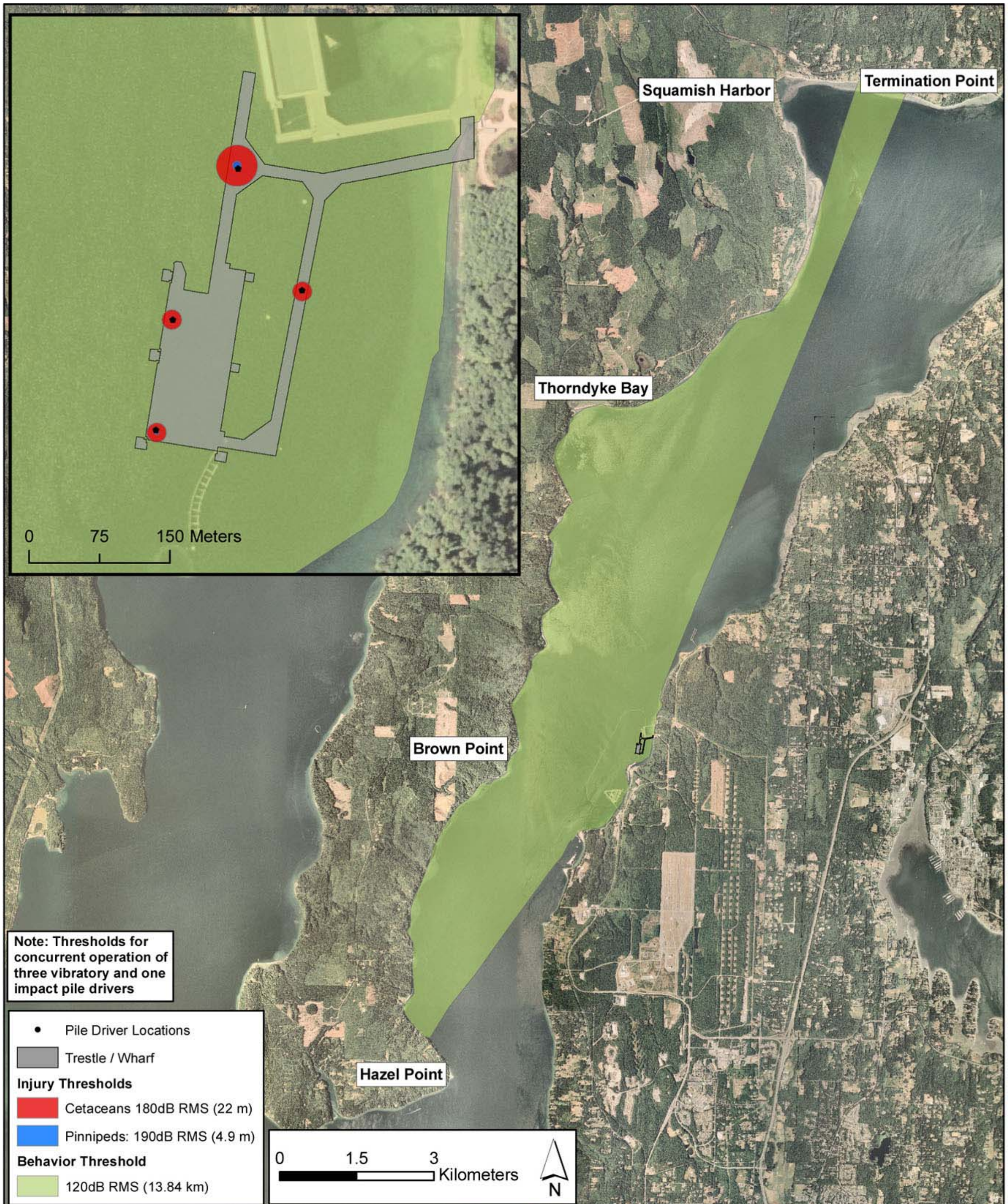


**Figure 2. Distance to NMFS Underwater Noise Thresholds for Marine Mammals**

Figure 3 indicates the airborne noise thresholds for harbor seals and other pinnipeds, for concurrent impact and vibratory pile driving.

Figure 3. Distance to NMFS Airborne Noise Thresholds for Marine Mammals

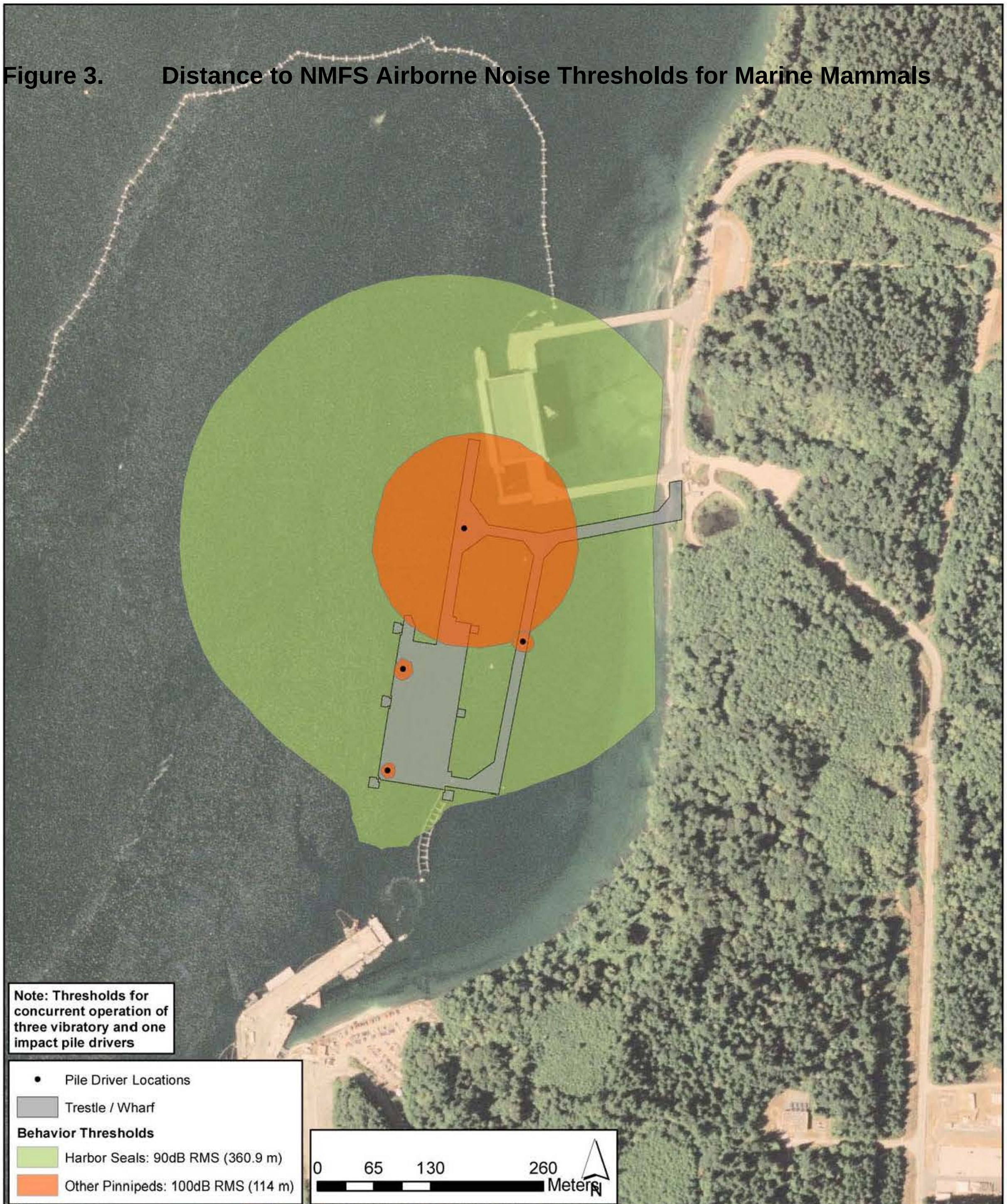


Figure 3. Distance to NMFS Airborne Noise Thresholds for Marine Mammals

## 3.2. DATA COLLECTION

Observers will use a NMFS-approved Marine Mammal Sighting Form (Appendix A) which will be completed by each observer for each survey day.

- Date and time that pile driving begins or ends;
- Construction activities occurring during each sighting;
- Weather parameters (e.g. percent cover, percent glare, visibility);
- Water conditions (e.g. Tidal state [incoming (flood), slack (neither direction), or outgoing (ebb)], and sea state). The Beaufort Sea State Scale (Appendix B) will be used to determine sea-state.
- Species, numbers, and if possible, sex and age class of marine mammals;
- Marine mammal behavior patterns observed, including bearing from observer and direction of travel. Note concurrent pile driving activity;
- Specific focus should be paid to recording behavioral reactions just prior to or during soft-start (impact pile driving) and shutdown procedures;
- Distance from pile driving activities to marine mammals and distance from the marine mammal to the observation point;
- Record of whether an observation required the implementation of shutdown procedures and the duration each shutdown.
- Locations of all marine mammal observations;
- Other human activity in the area. Record the hull numbers of fishing vessels if possible.

## 3.3. EQUIPMENT

The following equipment will be required to conduct marine mammal monitoring:

- Survey boats (with flying bridge for elevated observations) will include: covered cabin areas to keep electrical equipment dry, a fixed marine radio for the Captain to communicate on Ch. 16 and other marine channels independent of observers communicating on a dedicated channel, depth finder, measuring tape, navigational plotting equipment, and both fixed and hand-held GPS Units. Vessels will comply with all Coast Guard regulations and be able to pass a Coast Guard safety inspection;
- Hearing protection for biologists and boat operators within the airborne impact injury zone;
- Portable marine radios and headsets for the observers to communicate with the monitoring coordinator, construction contractor, and other observers;
- Cellular phones, without a camera (one per boat/observing location), and the contact information for the other observers, monitoring coordinator, and NMFS point of contact;
- Green flags (one per boat/observing location) as back-up for radio communication;
- Red flags (one per boat/observing location) as back-up for radio communication;
- Nautical charts;
- Daily tide tables for the project area within the Hood Canal;
- Watch or Chronometer;
- Binoculars with built-in rangefinder or reticles – (quality 7 x 50 or better);
- Monitoring plan, IHA permit, and/or other relevant permit requirement specifications in sealed clear plastic cover;
- Notebook with pre-standardized monitoring Marine Mammal Observation Record forms on waterproof paper (e.g. Rite-in-the Rain);

- Marine mammal identification guides on waterproof paper
- Clipboard
- Pen / Pencil

## 3.4. SHUTDOWN AND BUFFER ZONES

The acoustic modeling results presented within the EHW-2 Environmental Impact Statement and the request for an Incidental Harassment Authorization were used to develop the shutdown zones for pile installation activities. While the acoustic zones of influence vary between the different diameter piles and installation methods, the Navy established shutdown zones based on the maximum zone of influence for pile installation activities (see analysis in compliance documents for details). The shutdown zones were created to delineate areas in which marine mammals may be exposed to injurious underwater sound levels due to pile driving. Marine mammal monitoring will also occur for additional areas beyond the shutdown zone where sound pressure levels may cause harassment. Monitoring of these zones and the implementation of other minimization measures, such as the use of sound attenuation devices, will reduce the impacts of underwater sound from pile driving to these species.

Shutdown and Buffer Zone (*Impact and Vibratory pile driving/removal*):

- During impact pile driving the shutdown zone shall include all areas where the underwater SPLs are anticipated to equal the Level A (injury) harassment criteria for marine mammals (180 dB isopleths for cetaceans; 190 dB isopleths for pinnipeds). For pinnipeds the shutdown distance will be 20 meters[1] from the pile and for cetaceans the shutdown distance will be 85 meters[2] from the pile.
- During vibratory pile driving/removal involving multiple pile driving rigs, the shutdown zone shall include all areas where the underwater SPLs are anticipated to equal the Level A (injury) harassment criteria for marine mammals (180 dB isopleths for cetaceans; 190 dB isopleths for pinnipeds). For pinnipeds the shutdown distance will be 10 meters[3] from the pile and for cetaceans the shutdown distance will also be 10 meters[4] from the pile.
- All shutdown zones are based on the distances from the source which were predicted for each threshold level.
- During impact pile driving the buffer zone shall include all areas where the underwater or airborne SPLs are anticipated to equal or exceed the Level B (disturbance) harassment criteria for marine mammals during impact pile driving (160 dB isopleth). The average measured distance to the 160 dB threshold for impact pile driving is 505 meters. The monitored buffer zone is approximately equal to the behavioral disturbance zone during

[1] The modeled injury threshold distance for pinnipeds for one impact pile driver is approximately 5 meters, but the Navy has increased this distance up to 20 meters based on in-situ recorded sound pressure levels during the TPP which indicated the pinniped injury zone more consistently extended up to 20 meters from the pile.
[2] The modeled injury threshold distance for cetaceans for one impact pile driver is approximately 22 meters, but the Navy has increased this distance up to 85 meters based on in-situ recorded sound pressure levels during the TPP which indicated the cetacean injury zone more consistently extended up to 85 meters from the pile.
[3] The actual modeled injury threshold distance for pinnipeds for three vibratory pile drivers is approximately 2.3 meters, but the Navy has rounded this distance up to 10 meters to be consistent with the shutdown zone for in-water non-pile driving activities.
[4] The modeled injury threshold distance for cetaceans for three vibratory pile drivers is 10 meters.

impact pile driving, with the exception that monitoring outside the WRA fence line is impractical and therefore is not proposed. For pinnipeds and cetaceans the buffer zone would be approximately 464 meters and would be encompassed by the area inside the WRA fence line in the immediate vicinity of the EHW-2 footprint.

- During vibratory pile driving, the Level B (disturbance) harassment criterion (120 dB isopleth) predicts an affected area of 41.4 sq km (16 sq mi). The size of this area would make effective monitoring impractical. As a result, a buffer zone of 464 meters, equivalent to the size of the predicted 160 dB isopleth, will be monitored for pinnipeds and cetaceans during all vibratory pile driving/removal activities. This distance would serve as a guideline for the placement of marine mammal observing platforms and would be considered the minimum area covered; however, marine mammal observers would record all marine mammal sightings which are visually feasible, including those beyond the 464 meter "buffer zone". All sightings would be recorded and potential takes would be noted. The definitive determination of any "take", however, would be determined after post-processing of the year one acoustic data to compare the sighting distance to the actual extent of any harassment zones.
- The shutdown and buffer zones will be monitored throughout the time required to drive or remove a pile. If a marine mammal enters the buffer zone, an exposure would be recorded and behaviors documented. However, the pile segment would be completed without cessation, unless the animal approaches or enters the shutdown zone around any of the pile driving rigs. If a marine mammal approaches or enters the shutdown zone around any rig, all pile driving/removal activities associated with that rig will immediately be halted. Pile driving may proceed at other rigs as long as marine mammals have not been sighted within the shutdown zones associated with those rigs.
- Under certain construction circumstances where initiating the shutdown and clearance procedures (which could include a delay of 15 min or more) would result in an imminent concern for human safety, the shutdown provision may be waived at the discretion of the construction foreman. A pile may be deemed "dangerous" if the implementation of the shutdown procedures would: 1) constitute a significant hazard to the personnel installing/removing the pile, 2) result in a great risk of causing damage to an existing structure (either EHW-1 or newly constructed portions of EHW-2), or 3) create a risk of the pile slipping from the cradle during shutdown procedures due to the angle of installation/removal (i.e. during batter pile installation/removal). The construction foreman would be required to coordinate with the monitoring coordinator at the start of each construction day to identify in advance piles which may meet these criteria. The Navy would be notified daily of any piles for which shutdown procedures were waived and a written justification would be provided by the construction foreman documenting the necessity for waiving shutdown procedures. .

Shutdown Zone (*In-water construction activities not involving a pile driving hammer*):

- During in-water construction activities not involving a pile driver, but having the potential to affect marine mammals, in order to prevent injury to these species from their physical interaction with construction equipment, a shutdown zone of 10 meters (33 feet) will be monitored to ensure that marine mammals are not present in this zone.

- These activities could include, but are not limited to: (1) the movement of the barge to the pile location, (2) the positioning of the pile on the substrate via a crane (i.e., "stabbing" the pile), (3) the removal of the pile from the water column/substrate via a crane (i.e. "deadpull"), or (4) the placement of sound attenuation devices around the piles.
- Marine mammal monitoring will only occur for the period 15 minutes prior to the activity through the duration required to complete the in-water work.

## 3.5. OBSERVER MONITORING LOCATIONS

In order to effectively monitor the shutdown zones, marine mammal observers will be positioned at the best practicable vantage point(s), taking into consideration security, safety, and space limitations at the NBK waterfront, in order to properly monitor these zones. Observers may be stationed in small vessels or on the pile driving barge(s) at locations that will provide adequate visual coverage for the marine mammal shutdown and buffer zones. During pile driving of the abutment or some of the shallow trestle piles, due to the proximity to the shoreline and the difficulties in maneuvering a vessel in shallow water, an observer may alternatively be positioned on shore, but from an elevated platform to monitor the shutdown zone(s).

Security restrictions and operations inside the Waterfront Restricted Area (WRA) as defined by the area inside the Port Security Barrier (PSB) fence line, may also preclude the placement of boats/personnel at certain times and locations. For instance, security concerns regarding the number of vessels within the WRA have resulted in the Navy limiting the number of monitoring vessels for marine mammal and marbled murrelet monitoring plans, in addition to the construction related vessels (i.e. barges, tugs, etc.). Additionally, security requires that all vessels maintain a minimum standoff distance of 25 feet from the PSB fence at all times. During operations that occur at the EHW-1 facility and Marginal Wharf, monitoring personnel may also be precluded from being stationed on/near these structures.

One observer will be placed at a suitable location around each active pile driving rig in order to observe the respective shutdown zones for vibratory and impact pile driving. as described in detail in Section 3.4, Shutdown and Buffer Zones. These observers' monitoring would be primarily dedicated to observing the shutdown zones, however, they would record all marine mammal sightings beyond these distances provided it did not interfere with their effectiveness at carrying out the shutdown procedures. Additionally, a vessel-based monitoring platform will be located approximately 100-400 meters from the pile to monitor the buffer zone(s) for vibratory and impact pile driving/removal activities, as described in detail in Section 3.4, Shutdown and Buffer Zones. The observer associated with this platform would also record all visible marine mammal sightings beyond the buffer zone both within and outside of the WRA.

Potential observation locations are depicted in Figure 4. The exact positioning of the observer platforms/monitoring boats will vary as different pile driver types and pile locations become active within the footprint of the proposed EHW-2 facility. Each monitoring location/platform will have a minimum of 1 dedicated marine mammal observer (not including boat operators). At the start of the EHW-2 project when the maximum number of pile driving rigs (four) are expected to be on-site, there will be a minimum number of five marine mammals observers (one monitoring the shutdown zone at each of the four active rigs, and one monitoring the buffer zone within the WRA). As construction progresses and pile driving rigs are removed from operation, monitoring personnel associated with those locations will no longer be required and will be eliminated from the monitoring effort.

## 3.6. MONITORING TECHNIQUES

The Navy will collect sighting data and behaviors of marine mammal species observed in the shutdown zone and the immediate vicinity within the WRA during the period of construction. All observers will be experienced biologists trained in marine mammal identification and behaviors, as described in Section 3.1, Observer Qualifications. NMFS requires that the observers have no other construction-related tasks while conducting monitoring.

The efficacy of visual detection depends on several factors including the observer's ability to detect the animal, the environmental conditions (visibility and sea state), and monitoring platforms. Monitoring of the shutdown zones will take place from 15 minutes prior to initiation through 30 minutes post-completion of all pile driving and removal activities. Monitoring of the shutdown zones for other in-water construction activities as defined in Section 3.4 will take place from 15 minutes prior to initiation until the activity has been completed.

**Figure 4. Representative Marine Mammal Monitoring Locations within the Underwater Noise Thresholds for Impact and Vibratory Pile Driving**

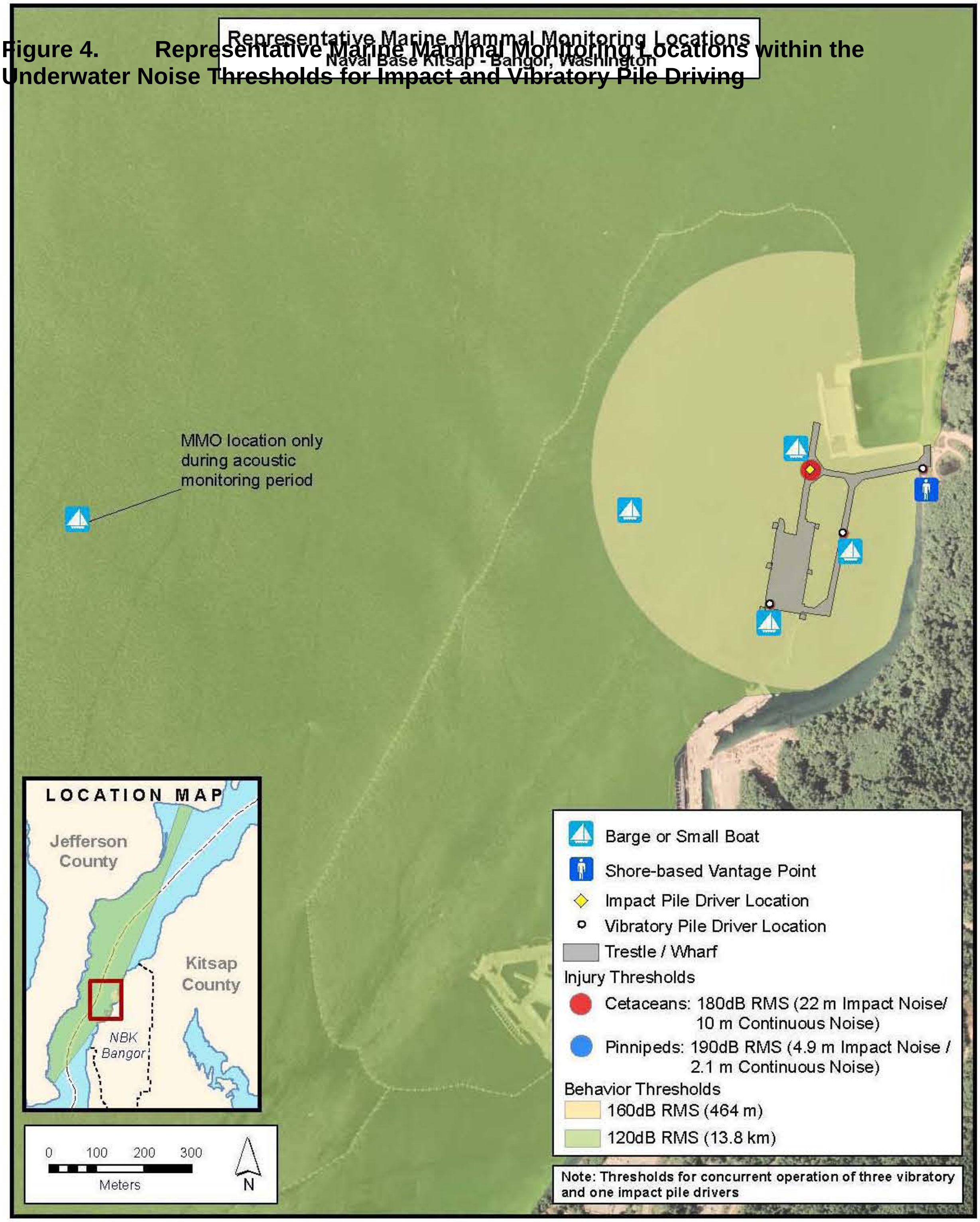


Figure 4. Representative Marine Mammal Monitoring Locations within the Underwater Noise Thresholds for Impact and Vibratory Pile Driving

### *3.6.1. Visual Survey Protocol – Pre-Activity Monitoring*

Prior to the start of pile driving/removal or other in-water construction activities, the shutdown zone(s) will be monitored for 15 minutes to ensure that there are no marine mammals present. If concurrent marbled murrelet monitoring reveals that marbled murrelets are present within the shutdown zone for that species, pile driving will not start and surveys will continue until the marbled murrelets leave the shutdown zone voluntarily per the Marbled Murrelet Monitoring Plan. The following survey methodology will be implemented prior to commencing pile installation/removal or other in-water construction activities:

- Observers will survey the shutdown and buffer zone. They will ensure that no marine mammals are seen within the shutdown zone before pile-driving/removal or other in-water construction activities begin.
- If marine mammal(s) are present within or approaching the shutdown zone prior to pile driving/removal or other in-water construction activities,, the survey will continue and the start of these activities will be delayed until the animal(s) leave the shutdown zone voluntarily and have been visually confirmed beyond the shutdown zone, or 15 minutes has elapsed without re-detection of the animal.
- If marine mammal(s) are not detected within the shutdown zone (i.e. the zone is deemed clear of marine mammals), the observers will raise a green flag and radio the monitoring coordinator/construction contractor that pile driving/removal or other in-water construction activities can commence.
- If marine mammal(s) are present within the buffer zone, pile driving/removal or other in-water construction activities would not need to be delayed, but observers would monitor and document, to the extent practical, the behavior of marine mammals that remain in the buffer zone.
- Marine Mammal Observation Record forms (Appendix A) will be used to document observations.
- Any survey boats engaged in marine mammal monitoring will maintain speeds equal to or less than 10 knots.
- Observers will be trained and experienced marine mammal observers in order to accurately verify species sighted.
- Observers will use binoculars and the naked eye to search continuously for marine mammals.
- In case of fog or reduced visibility, the observers must be able to see the shutdown zones or pile driving/removal will not be initiated until visibility in these zones improves to acceptable levels.
- During impact pile driving, the marbled murrelet monitoring protocols will be run concurrently with the above described monitoring efforts.

### *3.6.2. Visual Survey Protocol – During Activity Monitoring*

The shutdown and buffer zones will be monitored throughout the time required to install or remove a pile (including the soft start procedures[5]), or complete other in-water construction as

[5] The sequence of the soft-start procedures includes a minor deviation from those typically requested by the NMFS which utilize a longer waiting period (one minute vs. 30 seconds). The Navy requested to change the waiting period

defined in Section 3.4. If concurrent marbled murrelet monitoring reveals that marbled murrelets are present or have entered the shutdown zone for that species, impact pile driving will not start and surveys will continue until the marbled murrelets leave the shutdown zone voluntarily per the Marbled Murrelet Monitoring Plan. The following survey methodology will be implemented during pile driving/removal and other in-water construction activities:

- If a marine mammal is observed within or entering the buffer zone during pile driving/removal an exposure would be recorded and behaviors documented. However, that pile segment would be completed without cessation, unless the animal approaches or enters the shutdown (injury) zone, at which point all pile installation/removal activities associated with that rig and other in-water construction activities will be halted. The observers shall immediately radio to alert the monitoring coordinator/construction contractor and raise a red flag. This action will require an immediate "all-stop" on pile operations. Shutdown at one pile driving location may not necessarily trigger shutdowns at other locations where pile driving is occurring concurrently.
- However, under certain construction circumstances where initiating the shutdown and clearance procedures (which could include a delay of 15 min or more) would result in an imminent concern for human safety the shutdown provision may be waived (see Section 3.4 for additional details).
- Once a shutdown has been initiated, pile installation/removal activities at that rig and other in-water construction activities will be delayed until the animal has voluntarily left the shutdown zone and has been visually confirmed beyond the shutdown zone, or 15 minutes have passed without re-detection of the animal.
- During the in-water construction delay, surveys will continue to be conducted and pile driving and other in-water construction activities will not resume until the shutdown zone has been deemed clear of all marine mammals.
- Once marine mammals are no longer detected within the shutdown zone (i.e. the zone is deemed clear of marine mammals), the observers will raise a green flag and radio the monitoring coordinator/construction contractor that activities can re-commence;
- If marine mammals are detected outside the shutdown zone, the observers will continue to monitor these individuals and record their behavior, but pile driving and other in-water construction may proceed. Any marine mammals detected outside the shutdown zone after pile driving or other in-water construction activities are initiated shall likewise continue to be monitored and their behaviors recorded.
- Marine Mammal Observation Record forms (Appendix A) will be used to document observations.
- Any survey boats engaged in marine mammal monitoring will maintain speeds equal to or less than 10 knots.
- Observers will be trained and experienced marine mammal observers in order to accurately verify species sighted.

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because observational data during the Test Pile Program and EHW-1 repairs indicated a one minute wait period may be too long. Longer breaks between the sounds may be interpreted by the animals as a transient sound, and may not serve the intended purpose to provide an indication that louder sounds are about to begin. The Navy consulted with NMFS regarding using a shorter waiting period (i.e. 30 seconds) and the Service found the Navy's reasoning to be valid and accepted the requested modification.

- Observers will use binoculars and the naked eye to search continuously for marine mammals.
- In case of fog or reduced visibility, the observers must be able to see the shutdown zones or pile driving/removal and in-water construction activities will not be initiated until visibility in these zones improves to acceptable levels.
- During impact pile driving the marbled murrelet monitoring protocols will be run concurrently with the above described monitoring efforts.

### *3.6.3. Visual Survey Protocol – Post-Activity Monitoring*

Monitoring of the shutdown and buffer zones will continue for 30 minutes following completion of pile installation activities. A post-monitoring period is not required for other in-water construction. These surveys will record marine mammal observations, and will focus on observing and reporting unusual or abnormal behavior of marine mammals. Marine Mammal Observation Record forms (Appendix A) will be used to document observations. In general, the same protocols described in section 3.6.2 would apply. During these surveys, if any injured, sick, or dead marine mammals are observed procedures outlined in Section 4.0 should be following regarding notifying the appropriate authorities.

## 4.0 INTERAGENCY NOTIFICATION

In the event that the Navy needs to modify terms of this monitoring plan, the NMFS representative will be promptly contacted for discussion of the requested modification. In addition, if the Navy finds an injured, sick, or dead marine mammal, the Navy will notify NMFS immediately. All of these marine mammal sightings will be called into the NMFS Stranding Hotline (1-800-853-1964**)** unless the marine mammal's condition is a direct result of the project, in which case additional notification should be made to Brent Norberg (NMFS NW) at (206) 526-6550 and Ben Laws (NMFS HQ) (301) 427-8425. The Navy will provide NMFS with the species or description of the animal(s), the condition of the animal (including carcass condition if the animal is dead), location, the date and time of first discovery, observed behaviors (if alive), and photo or video (if available).

Care should be taken in handling dead specimens to preserve biological materials in the best possible state for later analysis of cause of death, if that occurs. In preservation of biological materials from a dead animal, the finder (i.e. marine mammal observer) has the responsibility to ensure that evidence associated with the specimen is not unnecessarily disturbed.

## 5.0 MONITORING REPORTS

A comprehensive annual marine mammal monitoring report documenting marine mammal observations will be submitted to NMFS at the end of the second in-water work season:

The draft comprehensive marine mammal monitoring report will be submitted to NMFS within 90 calendar days of the end of each in-water work period. The report will include marine mammal observations pre-activity, during-activity, and post-activity during pile driving days. A final comprehensive report will be prepared and submitted to NMFS within 30 calendar days following resolution of comments on the draft report from NMFS.

The reports shall include at a minimum:

- General data:
    - Date and time of activity
    - Water conditions (e.g., sea-state, tidal state)
    - Weather conditions (e.g., percent cover, percent glare, visibility)
- Specific pile driving data:
    - Description of the pile driving activity being conducted (pile locations, pile driving naming system, pile size and type), and times (onset and completion) when pile driving occurs.
    - The construction contractor and/or marine mammal monitoring staff will coordinate to ensure that pile driving times and strike counts are accurately recorded. The duration of soft start procedures (impact only) should be noted as separate from the full power driving duration.
    - Description of in-water construction activity not involving pile driving (location, type of activity, onset and completion times)
    - Detailed description of the sound attenuation system, including design specifications. Details of any issues associated with bubble curtain deployment or any functional checks conducted on the system should be recorded on a daily or per pile basis.
    - 
- Pre-activity observational survey-specific data:
    - Dates and time survey is initiated and terminated
    - Description of any observable marine mammals and their behavior in the immediate area during monitoring
    - Times when pile driving or other in-water construction is delayed due to presence of marine mammals within shutdown zones.
- During -activity observational survey-specific data:
    - Description of any observable marine mammal behavior within monitoring zones or in the immediate area surrounding the monitoring zones, including the following:
        - Distance from animal to pile driving sound source.
        - Reason why/why not shutdown implemented.
        - If a shutdown was implemented, behavioral reactions noted and if they occurred before or after implementation of the shutdown.
        - If a shutdown is implemented, the distance from animal to sound source at the time of the shutdown.
        - Behavioral reactions noted during soft starts and if they occurred before or after implementation of the soft start.
        - Distance to the animal from the sound source during soft start.
- Post-activity observational survey-specific data:

- Results, which include the detections and behavioral reactions of marine mammals, the species and numbers observed, sighting rates and distances,
- Refined exposure estimate based on the number of marine mammals observed. This may be reported as a rate of take (number of marine mammals per hour or per day), or using some other appropriate metric.

## 6.0 REFERENCES

Slater, M.C. 2009. Naval Base Kitsap, Bangor baseline underwater noise survey report. Prepared by Science Applications International Corporation, Bremerton, WA. Prepared for BAE Systems Applied Technologies, Inc., Rockville, MD.

Washington Department of Transportation (WSDOT). 2011. Biological assessment preparation for transportation projects Advanced training manual, version 02-2011. Washington State Department of Transportation, Olympia, WA.

# APPENDIX A

# MARINE MAMMAL OBSERVATION RECORD FORM

## APPENDIX A
## MARINE MAMMAL OBSERVATION RECORD FORM

Project Name: ______________________________  Monitoring Location____________________________ (Pier Location, Vessel based, Land Location, other)  Page __________ of _________

Date: ________________________________  Vessel Name: _______________________________  Time Effort Initiated:__________

Time Effort Completed:_________

**Sighting Data**

| Event Code | Sighting Number (1 or 1.1 if resight) | Time/Duration watching sighting (Start/End time if continuous) | WP # (every time a sighting is made) | Observer | Sighting cue | Species | Dist/ Dir to Animal (from Observer) | Dist to Pile (btwn animal & pile) | # of Animals Group Size (min/max/best) # of Calves | Relative Motion/and Behavior Code (see code sheet) | Const Type During Sighting | Miti gation used during sighting ? | Miti gation Type? | Visibility | % Glare | Weath Cond | Sea State and Wave Ht | Swell Dir | Behavior Change/ Response to Activity/Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | : : <br> : : | | | | | m or km ° | m or km | / / <br> ___ calves | opening closing parallel none Behavior Code: ___ | PRE POST SSV SSI V I PC DP ST NONE | Y <br> N | DE <br> SD | B P M G E | | | Light Mod Heavy | N or S <br> W or E | |
| | | : : <br> : : | | | | | m or km ° | m or km | / / <br> ___ calves | opening closing parallel none Behavior Code: ___ | PRE POST SSV SSI V I PC DP ST NONE | Y <br> N | DE <br> SD | B P M G E | | | Ligh tMod Heavy | N or S <br> W or E | |
| | | : : <br> : : | | | | | m or km ° | m or km | / / <br> ___ calves | opening closing parallel none Behavior Code: ___ | PRE POST SSV SSI V I PC DP ST NONE | Y <br> N | DE <br> SD | B P M G E | | | Light Mod Heavy | N or S <br> W or E | |
| | | : : <br> : : | | | | | m or km ° | m or km | / / <br> ___ calves | opening closing parallel none Behavior Code: ___ | PRE POST SSV SSI V I PC DP ST NONE | Y <br> N | DE <br> SD | B P M G E | | | Light Mod Heavy | N or S <br> W or E | |
| | | : : <br> : : | | | | | m or km ° | m or km | / / <br> ___ calves | opening closing parallel none Behavior Code: ___ | PRE POST SSV SSI V I PC DP ST NONE | Y <br> N | DE <br> SD | B P M G E | | | Light Mod Heavy | N or S <br> W or E | |
| | | : : <br> : : | | | | | m or km ° | m or km | / / <br> ___ calves | opening closing parallel none Behavior Code: ___ | PRE POST SSV SSI V I PC DP ST NONE | Y <br> N | DE <br> SD | B P M G E | | | Light Mod Heavy | N or S <br> W or E | |
| | | : : <br> : : | | | | | m or km ° | m or km | / / <br> ___ calves | opening closing parallel none Behavior Code: ___ | PRE POST SSV SSI V I PC DP ST NONE | Y <br> N | DE <br> SD | B P M G E | | | Light Mod Heavy | N or S <br> W or E | |

Sighting #=chronological number of sightings, If resight of same animal, then 1.1, 1.2, etc. WP (Waypoint)=GPS recording of lat/long, time/date stamp. Critical for vessel observers.

*Sighting Form last revised June 27, 2012. POC-DoN, NAVFAC NW, Balla-Holden*

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# Sighting Codes
# (Sighting Cue & Behavior Codes)

### Behavior codes

| Code | Behavior | Definition |
|---|---|---|
| BR | Breaching | Leaps clear of water |
| CD | Change Direction | Suddenly changes direction of travel |
| CH | Chuff | Makes loud, forceful exhalation of air at surface |
| DI | Dive | Forward dives below surface |
| DE | Dead | Shows decomposition or is confirmed as dead by investigation |
| DS | Disorientation | An individual displaying multiple behaviors that have no clear direction or purpose |
| FI | Fight | Agonistic interactions between two or more individuals |
| FO | Foraging | Confirmed by food seen in mouth |
| MI | Milling | Moving slowly at surface, changing direction often, not moving in any particular direction |
| PL | Play | Behavior that does not seem to be directed towards a particular goal; may involve one, two or more individuals |
| PO | Porpoising | Moving rapidly with body breaking surface of water |
| SL | Slap | Vigorously slaps surface of water with body, flippers, tail etc. |
| SP | Spyhopping | Rises vertically in the water to "look" above the water |
| SW | Swimming | General progress in a direction. Note general direction of travel when last seen [Example: "SW (N)" for swimming north] |
| TR | Traveling | Traveling in an obvious direction. Note direction of travel when last seen [Example: "TR (N)" for traveling north] |
| UN | Unknown | Behavior of animal undetermined, does not fit into another behavior |
| **Pinniped only** | | |
| EW | Enter Water (from haul out ) | Enters water from a haul-out for no obvious reason |
| FL | Flush (from haul out ) | Enters water in response to disturbance |
| HO | Haul out (from water) | Hauls out on land |
| RE | Resting | Resting onshore or on surface of water |
| LO | Look | Is upright in water "looking" in several directions or at a single focus |
| SI | Sink | Sinks out of sight below surface without obvious effort (usually from an upright position) |
| VO | Vocalizing | Animal emits barks, squeals, etc. |
| **Cetacean only** | | |
| LG | Logging | Resting on surface of water with no obvious signs of movement |

### Marine Mammal Species

| Code | Marine Mammal Species |
|---|---|
| CASL | California Sea Lion |
| HSEA | Harbor Seal |
| STSL | Steller Sea Lion |

| | |
|---|---|
| HPOR | Harbor Porpoise |
| DPOR | Dall's Porpoise |
| ORCA | Killer Whale |
| HUMP | Humpback Whale |
| UNLW | Unknown Large Whale |
| OTHR | Other |
| UNKW | Unknown |

**Event**

| Code | Activity Type |
|---|---|
| E ON | Effort On |
| E OFF | Effort Off |
| PRE | Pre Watch |
| POST | Post Watch |
| SSI | Soft start-impact |
| WC | Weather Condition/Change |
| S | Sighting |
| M-DE | Mitigation Delay |
| M-SD | Mitigation Shutdown |

**Construction Type**

| Code | Activity Type |
|---|---|
| SSI | Soft Start (Impact) |
| V | Vibratory Pile Driving (installation and extraction) |
| I | Impact Pile Driving |
| PC | Pneumatic Chipping |
| DP | Dead pull |
| ST | Stabbing |
| NONE | No Pile Driving |
| OTH | Other |

**Mitigation Codes**

| Code | Activity Type |
|---|---|

| | |
|---|---|
| DE | Delay onset of Pile Driving |
| SD | Shut down Pile Driving |

**Visibility**

| Code | Distance Visible |
|---|---|
| B | Bad (<0.5km) |
| P | Poor (0.5 – 1.5km) |
| M | Moderate (1.5 – 10km) |
| G | Good (10 - 15km) |
| E | Excellent (>15km) |

**Glare**

Percent glare should be the total glare of observers' area of responsibility. Determine if observer coverage is covering 90 degrees or 180 degrees and document daily. Then assess total glare for that area. This will provide needed information on what percentage of the field of view was poor due to glare.

**Weather Conditions**

| Code | Weather Condition |
|---|---|
| S | Sunny |
| PC | Partly Cloudy |
| L | Light Rain |
| R | Steady Rain |
| F | Fog |
| OC | Overcast |

**Sea State and Wave Height**

Use Beaufort Sea State Scale for Sea State Code. This refers to the surface layer and whether it is glassy in appearance or full of white caps. In the open ocean, it also takes into account the wave height or swell, but in inland waters the wave height (swells) may never reach the levels that correspond to the correct surface white cap number. Therefore, include wave height for clarity.

| Code | Wave Height |
|---|---|
| Light | 0 – 3 ft |
| Moderate | 4 – 6 ft |
| Heavy | >6 ft |

**Swell Direction**

Swell direction should be where the swell is coming from (S for coming from the south). If possible, record direction relative to fixed location (pier). Choose this location at beginning of monitoring project.

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# APPENDIX B

## BEAUFORT SEA STATE SCALE

# APPENDIX B
# BEAUFORT SEA STATE SCALE

**US Navy and Beaufort Sea State Codes** (http://ioc.unesco.org and http://www.wrh.noaa.gov/pqr/info/beaufort.php)

| Beaufort SS | Wind speed (knots) | Wind description | Wave height (ft) Beaufort | Sea State – Beaufort | Notes specific to on-water seabird observations | Photos indicating Beaufort Sea State |
|---|---|---|---|---|---|---|
| 0 | <1 | Calm | 0 | Calm; like a mirror | Excellent conditions, no wind, small or very smooth swell. You have the impression you could see anything. |  |
| 1 | 1-3 | Light air | ¼ < ½ | Ripples with appearance of scales; no foam crests | Very good conditions, surface could be glassy (Beaufort 0), but with some lumpy swell or reflection from forests, glare, etc. |  |

| Beaufort SS | Wind speed (knots) | Wind description | Wave height (ft) Beaufort | Sea State – Beaufort | Notes specific to on-water seabird observations | Photos indicating Beaufort Sea State |
|---|---|---|---|---|---|---|
| 2 | 4-6 | Light breeze | ½ – 1 (max 1) | Small wavelets; crests with glassy appearance, not breaking | Good conditions, no whitecaps; texture/lighting contrast of water make murrelets hard to see. Surface could also be glassy or have small ripples, but with a short, lumpy swell, thick fog, etc. |  |
| 3 | 7-10 | Gentle breeze | 2 – 3 (max 3) | Large wavelets; crests begin to break; scattered whitecaps | Fair conditions, scattered whitecaps, detection of murrelets definitely compromised; a hit-or-miss chance of seeing them owing to water choppiness and high contrast. This could also occur at lesser wind with a very short wavelength, choppy swell. |  |

| Beaufort SS | Wind speed (knots) | Wind description | Wave height (ft) Beaufort | Sea State – Beaufort | Notes specific to on-water seabird observations | Photos indicating Beaufort Sea State |
|---|---|---|---|---|---|---|
| 4 | 11-16 | Moderate breeze | 3 ½ – 5 (max 5) | Small waves becoming longer, numerous whitecaps | Whitecaps abundant, sea chop bouncing the boat around, etc. |  |
| 5 | 17-20 | Fresh breeze | 6 – 8 (max 8) | Moderate waves, taking longer form; many whitecaps; some spray | |  |

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# APPENDIX C

# CHAIN OF CUSTODY RECORD FORM

<table>
<tr><th colspan="5">Chain of Custody Record</th></tr>
<tr><td>Date and Time of Collection:</td><td colspan="2">Duty Station:</td><td colspan="2">Collection By:</td></tr>
<tr><td colspan="2">Source of Specimen (Person and/or Location)<br>Found At:</td><td colspan="3">Project Name:</td></tr>
<tr><td>Item No:</td><td colspan="4">Description of Specimen (include Species and Tag Number):</td></tr>
<tr><td rowspan="2">Item No:</td><td>From: (Print Name, Agency)</td><td>Release Signature:</td><td>Release Date:</td><td rowspan="2">Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other:</td></tr>
<tr><td>To: (Print Name, Agency)</td><td>Receipt Signature:</td><td>Receipt Date:</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |
| Item No: | From: (Print Name, Agency) | Release Signature: | Release Date: | Delivered via:<br>FEDEX<br>U.S. Mail<br>In Person<br>Other: |
| | To: (Print Name, Agency) | Receipt Signature: | Receipt Date: | |